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Retrospective Cohort Study

Learning curve of kidney transplantation in a high-volume center: A Cohort study of 1466 consecutive recipients

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ABSTRACT

Background: The purpose of this study was to evaluate surgical outcomes of kidney transplantation (KTX) based on surgeon volume and surgeon experience, and to develop the learning curve model for KTX using the cumulative sum (CUSUM) analysis.

Methods: A retrospective review of 1466 consecutive recipients who underwent KTX between 2010 and 2017 was conducted. In total, 51 surgeons, including certified transplant surgeons, transplant fellows and surgical residents were involved in these procedures using a standardized protocol. Outcomes were compared based on surgeon volume (low [1–30] versus high [31 ≥] volume) and surgeon's type (consultant surgeons, fellows or residents).

Results: Operative time (129 versus 135 min, $P < 0.001$) and warm ischemia time (20.9 versus 24.2 min, $P < 0.001$) were significantly shorter in the high-volume group, however postoperative outcomes were equal in both groups. The CUSUM analysis revealed that approximately 30 procedures were necessary to improve surgical skills. In addition, no effect of surgeon's type including consultant surgeons, fellows and residents on postoperative outcomes was found.

Conclusions: Surgical training in KTX using a standardize protocol can be accomplished with a steep learning curve without compromising perioperative outcomes under the careful selection of surgeons and procedures.

1. Introduction

Kidney transplantation (KTX) is a complex surgical procedure which requires properly trained surgeons. However, there can be an area of tension between educating the trainees during the surgical procedure and providing patients with the optimal quality of patient care. This process raises important issues on how to monitor surgeons' learning curve and guarantee the quality of surgical procedures.

The cumulative sum (CUSUM) analysis was developed to evaluate the learning curve for surgical procedures [1,2], and has been adopted in many fields of surgery [3–5]. In several publications the impact of a learning curve and surgical training in KTX has been examined [6–8], concluding that the outcomes of selected trainees was acceptable under the supervision of experienced surgeons. However, no study has investigated the impact of a learning curve in KTX using the CUSUM analysis for surgical skills, or identified the number of procedures for trainee surgeons must reach in order to adequately and safely perform KTX.

Our institution is a high-volume center in living kidney donation and KTX in Western Europe [9], completing more than 1500 living donor nephrectomies and over 4000 KTX so far. The aim of this study was to evaluate the learning curve model for KTX using the CUSUM analysis in a high-volume center. Furthermore, we explored the necessary number of procedures to improve surgical technique.

2. Materials and methods

2.1. Patients and study design

We conducted a retrospective review of a prospectively collected database of 1466 consecutive recipients who underwent KTX at our institution between June 2010 and December 2017. All procedures were performed by 51 consultant surgeons, transplant fellows or surgical residents during this period. The approval of the Ethics Committee at our institution was obtained, and the study was conducted in accordance with the tenets of the Declaration of Helsinki. The work has

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Table 1
Recipient characteristics and outcomes of 1466 consecutive patients based on surgeons' volumes.

	Total	Group 1 (1–10)	Group 2 (11–20)	Group 3 (21–30)	Group 4 (31–40)	Group 5 (41–60)	Group 6 (61–80)	Group 7 (81–100)	Group 8 (101 ≥)	P value
No. of KTX	1466	304	109	84	78	152	131	132	476	
Age (years)	55.1 (14.3)	56.5 (13.3)	55.3 (13.6)	54.3 (14.3)	56.0 (13.9)	56.5 (12.9)	53.2 (15.6)	53.6 (14.6)	54.8 (14.9)	0.55
Gender										
Male	929 (63%)	186 (61%)	57 (52%)	55 (65%)	52 (67%)	104 (68%)	95 (73%)	87 (66%)	293 (62%)	0.044
Female	537 (37%)	118 (39%)	52 (48%)	29 (35%)	26 (33%)	48 (32%)	36 (27%)	45 (34%)	183 (38%)	
BMI (kg/m2)	26.6 (4.9)	26.5 (4.8)	26.4 (5.0)	26.7 (4.4)	27.3 (4.4)	26.6 (4.8)	26.8 (5.2)	26.7 (5.0)	26.5 (5.0)	0.72
Donor type										
Living	962 (66%)	157 (52%)	84 (77%)	54 (64%)	56 (72%)	117 (77%)	93 (71%)	91 (69%)	310 (65%)	< 0.001
Deceased	504 (34%)	147 (48%)	25 (23%)	30 (36%)	22 (28%)	35 (23%)	38 (29%)	41 (31%)	166 (35%)	
Number of KTX										
1st	1223 (83%)	262 (86%)	95 (87%)	70 (83%)	68 (87%)	126 (83%)	111 (85%)	103 (78%)	388 (81%)	0.11
2nd	185 (13%)	36 (12%)	11 (10%)	11 (13%)	9 (12%)	23 (15%)	17 (13%)	18 (14%)	60 (13%)	
3rd or more	58 (4%)	6 (2%)	3 (3%)	3 (4%)	1 (1%)	3 (2%)	3 (2%)	11 (8%)	28 (6%)	
Operative time (min)	131 (41)	138 (35)	126 (31)	137 (56)	131 (36)	131 (38)	133 (40)	135 (43)	126 (44)	< 0.001
Blood loss (mL)	349 (432)	361 (381)	314 (370)	410 (600)	331 (365)	291 (324)	331 (499)	429 (482)	344 (444)	0.02
WIT (min)	22.0 (7.4)	25.3 (6.6)	22.2 (7.0)	22.5 (8.0)	20.8 (6.9)	20.7 (7.3)	20.9 (5.9)	20.9 (7.5)	20.9 (7.8)	< 0.001
Complication	200 (13.6%)	44 (14.5%)	19 (17.4%)	7 (8.3%)	9 (11.5%)	23 (15.1%)	19 (14.5%)	18 (13.6%)	61 (12.8%)	0.70
Urological	155 (10.6%)	36 (11.8%)	16 (14.7%)	6 (7.1%)	7 (9.0%)	19 (12.5%)	16 (12.2%)	12 (9.1%)	43 (9.0%)	0.52
Vascular	16 (1.1%)	4 (1.3%)	1 (0.9%)	1 (1.2%)	1 (1.3%)	1 (0.7%)	1 (0.8%)	3 (2.3%)	4 (0.8%)	0.94
Bleeding	37 (2.5%)	8 (2.6%)	3 (2.8%)	1 (1.2%)	1 (1.3%)	3 (2.0%)	2 (1.5%)	4 (3.0%)	15 (3.2%)	0.88
LOS (days)	14.2 (10.2)	15.1 (12.4)	14.4 (7.7)	13.8 (7.5)	14.9 (10.1)	14.4 (9.5)	15.1 (13.6)	13.3 (7.1)	13.6 (9.5)	0.13

Data were presented as mean (standard deviation) and numbers (percentages).
KTX kidney transplantation, *BMI* body mass index, *WIT* warm ischemia time, *LOS* length of stay.

been reported in line with the STROCSS criteria [10]. The present study was registered at the University Hospital Medical Information Network (UMIN), registration number UMIN000040213.

2.2. Clinical data

For all enrolled recipients, the following demographic and clinical data were collected: age, gender, body mass index (BMI), the type of surgeon (surgical resident, transplant fellow, or consultant surgeon), the type of donor (living or deceased), number of KTX per patient (first, second, and third or more), operative time, blood loss, warm ischemia time (WIT), postoperative complication, and postoperative length of stay (LOS). Data on postoperative complications included urological complications, vascular complications, and postoperative bleeding. Urological complications were defined as ureter stenosis, ureter necrosis, or urine leakage which required percutaneous nephrostomy placement within 1 year after KTX. Vascular complications included stenosis or thrombosis of the artery and/or vein. Postoperative bleeding was defined as any event which required reoperation.

2.3. Surgical technique

The details of our surgical techniques have been described in other publications [11,12]. Kidneys are implanted into the iliac fossa. The renal vein is first anastomosed to the external iliac vein with end-to-side continuous suturing using Prolene 5–0. The renal artery is then anastomosed to the external iliac artery with end-to-side continuous sutures with Prolene 5–0. Lastly, the anastomosis between the donor ureter and recipient bladder is performed with an extravesical anastomosis using an external splint.

2.4. Surgical training system

Surgical residents, transplant fellows and consultant surgeons were involved in KTX. Surgical residents are defined as trainees in a surgical specialty for a total of 6 years. They were involved in KTX in their final years of training using a standardized protocol, and all residents received surgical supervision by consultant surgeons. Transplant fellows who finished all residency pursued additional transplant training for 2 years, and could perform KTX independently. Consultant surgeons who finished their fellowship were fully qualified to perform KTX independently. Fellows and consultant surgeons had assistance by residents, fellows or consultant surgeons on demand. Normally starters don't perform third or more KTX in patients with atherosclerotic vessels.

2.5. Statistical analysis

Firstly, surgeons at our institution were categorized into eight groups based on the volume of surgeries performed (groups: group 1 (1–10), group 2 (11–20), group 3 (21–30), group 4 (31–40), group 5 (41–60), group 6 (61–80), group 7 (81–100), and group 8 (101 ≥)); recipient demographics and perioperative outcomes were then reviewed. Secondly, the CUSUM analysis was adopted to identify the number of surgeries necessary to reach optimal performance by focusing on WIT. In the CUSUM analysis, the cumulative sums of differences from the total cohort's mean in each surgeon were calculated and combined as the mean cumulative sum. Afterwards, outcomes were also compared between low (1–30) and high (31 ≥) volume group based on the CUSUM analysis. Finally, the outcomes between residents, fellows, and consultant surgeons were compared. In cases where there were significant confounding factors in preoperative variables, a propensity score matching (PSM) was performed using a logistic regression model with one-to-one ratio matching based on propensity scores, as previously described [13,14]. Data was presented as mean and standard deviation for continuous variables. Categorical data was presented as proportions. Differences between groups were assessed using the Mann-Whitney *U* test for continuous variables, and Fisher's exact test or chi-square test for categorical variables. JMP version 11 software (SAS Institute, Cary, NC) was used for all statistical analyses. A P–value < 0.05 was considered statistically significant.

3. Results

3.1. Study cohort

The overall results of recipient characteristics and outcomes were summarized in Table 1. Out of 1466 KTX, 962 (66%) were living donors

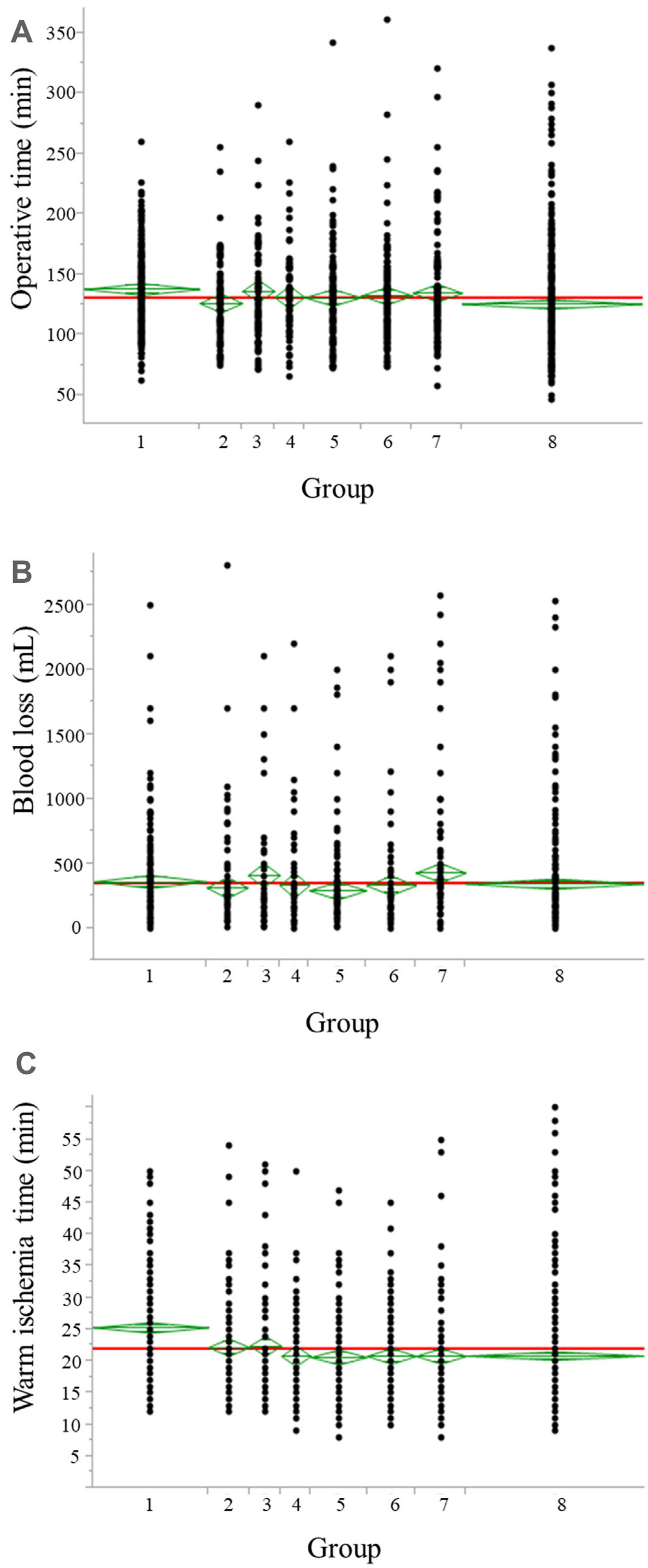

Fig. 1. Learning curve of operative time, blood loss, and warm ischemia time in kidney transplantation between 8 groups: Group 1 (1–10), Group 2 (11–20), Group 3 (21–30), Group 4 (31–40), Group 5 (41–60), Group 6 (61–80), Group 7 (81–100), and Group 8 (101≥). A. Operative time, B. Blood loss, C. Warm ischemia time.

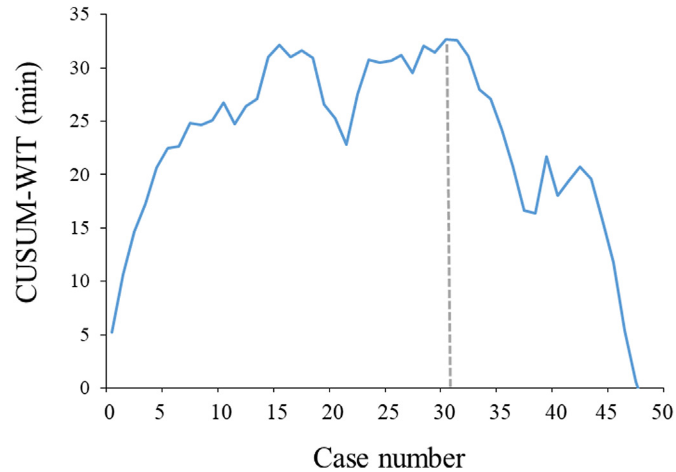

Fig. 2. The cumulative sum (CUSUM) analysis of warm ischemia time in kidney transplantation.

and 504 (34%) were deceased donors. The number of KTX per patient was as follows: first KTX, 1223 (83%); second, 185 (13%); and third or more, 58 (4%). Regarding operative outcomes, mean operative time, blood loss and WIT were 131 min, 349 mL, and 22 min, respectively. The incidence of postoperative complications included urological complications (10.6%, n = 155), vascular complications (1.1%, n = 16), and postoperative bleeding (2.5%, n = 37).

The surgical outcomes of each of the eight groups is shown in Table 1. Learning curve of operative outcomes including operative time, blood loss, and WIT were demonstrated in Fig. 1. Operative time and blood loss varied between the eight groups, however WIT was significantly shorter in groups where surgeons had performed more than 30 KTX. The CUSUM analysis of WIT identified the flexion point after 31 cases, showing dramatic improvement which continues until 50 procedures (Fig. 2). The postoperative outcomes and LOS were not significantly different between the eight groups.

Outcomes comparing low (1–30) and high (31≥) volume based on surgeon volume were demonstrated in Table 2. The high-volume group had significantly shorter operative time (129 versus 135 min, $P < 0.001$), WIT (20.9 versus 24.2 min, $P < 0.001$), and LOS (14.0 versus 14.7 days, $P = 0.03$) with no significant differences in the incidence of postoperative complications. PSM was performed due to significant differences among preoperative factors (gender, the type of donor, and the number of previous KTX). After PSM, two equal groups of 494 patients were identified. Operative time and WIT were significantly shorter in the high-volume group; however postoperative outcomes were similar in both groups.

The comparison of outcomes between residents (n = 28), fellows (n = 4), and consultant surgeons (n = 19) was represented in Table 3. Regarding the operative outcomes, operative time was significantly shorter in consultant surgeons' group. In contrast, residents had longest WIT compared to fellows and consultant surgeons (25.2 versus 21.0 versus 21.5 min, $P < 0.01$ respectively). However, no significant differences were found in postoperative complications and LOS. Consultant surgeons tended to perform more complex cases with third or more KTX, therefore PSM was adopted combining residents and fellows into the same group.

The results comparing residents/fellows and consultant surgeons before and after PSM were depicted in Table 4. After adjusting preoperative factors by PSM, consultant surgeons had significantly shorter operative time (128 versus 135 min, $P < 0.01$) and WIT (21.8 versus 22.7 min, $P < 0.01$), however postoperative outcomes were comparable among two groups.

Table 2
Recipient characteristics and outcomes based on surgeons' volume: overall and propensity score matching cohort.

	Before PSM			After PSM		
	Low-volume (1–30)	High-volume (31 ≥)	P value	Low-volume (1–30)	High-volume (31 ≥)	P value
No. of KTX	494	972		494	494	
Age (years)	55.9 (13.5)	54.8 (14.6)	0.37	55.9 (13.5)	55.0 (14.5)	0.49
Gender						
Male	295 (60%)	634 (65%)	0.04	295 (60%)	295 (60%)	1.00
Female	199 (40%)	338 (35%)		199 (40%)	199 (40%)	
BMI (kg/m2)	26.5 (4.8)	26.4 (4.9)	0.61	26.5 (4.8)	26.7 (5.0)	0.60
Donor type						
Living	293 (59%)	669 (69%)	< 0.001	293 (59%)	293 (59%)	1.00
Deceased	201 (41%)	303 (31%)		201 (41%)	201 (41%)	
Number of KTX						
1st	425 (86%)	798 (82%)	0.026	425 (86%)	425 (86%)	1.00
2nd	58 (12%)	127 (13%)		58 (12%)	58 (12%)	
3rd or more	11 (2%)	47 (5%)		11 (2%)	11 (2%)	
Operative time (min)	135 (38)	129 (43)	< 0.001	135 (38)	129 (39)	< 0.001
Blood loss (mL)	359 (426)	344 (436)	0.15	359 (426)	336 (437)	0.23
WIT (min)	24.2 (7.1)	20.9 (7.4)	< 0.001	24.2 (7.1)	20.8 (7.0)	< 0.001
Complication	69 (14.0%)	131 (13.5%)	0.80	69 (14.0%)	62 (12.6%)	0.51
Urological	58 (11.7%)	97 (10.0%)	0.30	58 (11.7%)	43 (8.7%)	0.11
Vascular	5 (1.1%)	11 (1.1%)	0.83	5 (1.1%)	7 (1.4%)	0.56
Bleeding	12 (2.4%)	25 (2.6%)	0.87	12 (2.4%)	12 (2.4%)	1.00
LOS (days)	14.7 (10.8)	14.0 (9.9)	0.03	14.7 (10.8)	14.1 (10.6)	0.06

Data were presented as mean (standard deviation) and numbers (percentages).
PSM propensity score matching, *KTX* kidney transplantation, *BMI* body mass index, *WIT* warm ischemia time, *LOS* length of stay.

Table 3
Recipient characteristics and outcomes between residents, fellows, and consultant surgeons.

	Resident (n = 28)	Fellow (n = 4)	Consultant surgeon (n = 19)	P value
No. of KTX	241	341	884	
Age (years)	56.3 (13.1)	55.6 (13.8)	54.6 (14.7)	0.47
Gender				
Male	143 (59%)	219 (64%)	567 (64%)	0.37
Female	98 (41%)	122 (36%)	317 (36%)	
BMI (kg/m2)	26.6 (4.6)	27.0 (4.8)	26.4 (5.0)	0.06
Donor type				
Living	126 (52%)	257 (75%)	579 (66%)	< 0.001
Deceased	115 (48%)	84 (25%)	305 (34%)	
Number of KTX				
1st	211 (88%)	294 (86%)	718 (81%)	0.005
2nd	27 (11%)	39 (12%)	119 (14%)	
3rd or more	3 (1%)	8 (2%)	47 (5%)	
Operative time (min)	138 (35)	134 (34)	128 (45)	< 0.001
Blood loss (mL)	356 (392)	297 (347)	368 (470)	0.14
WIT (min)	25.2 (6.3)	21.0 (5.9)	21.5 (8.0)	< 0.001
Complication	27 (11.2%)	48 (14.1%)	125 (14.1%)	0.47
Urological	23 (9.5%)	40 (11.7%)	92 (10.4%)	0.68
Vascular	1 (0.4%)	5 (1.5%)	10 (1.1%)	0.42
Bleeding	4 (1.7%)	5 (1.5%)	28 (3.2%)	0.13
LOS (days)	14.6 (10.7)	13.8 (9.1)	14.3 (10.5)	0.09

Data were presented as mean (standard deviation) and numbers (percentages).
KTX kidney transplantation, *BMI* body mass index, *WIT* warm ischemia time, *LOS* length of stay.

4. Discussion

The present study shows that surgeon volume did not have any impact on perioperative short-term outcomes including the incidence of perioperative complications and LOS in a high-volume center. The CUSUM analysis for surgical skills reveals dramatic improvement in WIT after 31 procedures. Furthermore, we found that training residents and fellows had no effect on perioperative outcomes except for operative time and WIT.

The effect of surgeon volume has been investigated in many fields of surgical procedures [15–18]. A nationwide study from Taiwan has reported that post-transplant outcomes of KTX treated by experienced surgeons and in high-volume hospitals were superior to those by inexperienced surgeons and in low-volume hospitals [19]. However, our results similarly resembled those of a previous report by Wolff et al. [8], showing no effect of surgeon volume on post-transplant outcomes. Only operative time and WIT were significant factors associated with differences between the low- and high-volume groups but without clinical consequences.

A previous systematic review examined the effects of hospital volume of surgery, surgeon volume and specialization on outcome (LOS, mortality and complication rate) [20]. One Hundred and sixty-three articles were included in the meta-analysis examining 42 different surgical procedures, spanning 13 surgical specialities including three articles about transplantation. Their conclusion was that high surgeon volume and specialization were associated with improved patient outcome, while high hospital volume was of limited benefit. A small number of articles focusing on hospital volume in transplant procedures only (heart, pancreas, liver and kidney) have been published [21–24]. All 4 articles revealed better postoperative outcome in high-volume centers. Logistics may play an important and crucial role in better outcome in high-volume and specialized centers. All personnel (nephrologists, anesthesiologists, OR nurses etc.) are more familiar with KTX, streamlining the whole perioperative procedure and reducing human mistakes and medical errors.

Fechner et al. showed that operative time and WIT significantly decreased after 40 procedures [6]. Our learning curve model using the CUSUM analysis indicated that WIT improved after 31 procedures. We believe that WIT is a good indicator which reflects effective surgical skills and is less affected during difficult cases such as third or more KTX than operative time or blood loss.

We demonstrate that our training program is safe allowing residents and fellows to perform KTX properly, and provide patients the highest quality regardless their experience. It is possible that our standardized protocol during KTX minimizes potential medical and technical errors.

There are several limitations in the present study that should be noted. This retrospective study in a single center could have selection bias and information bias for patients. Normally, residents start their learning curve with deceased donor KTX due to longer vessels. After becoming familiar with the surgical steps they will join the living donor

Table 4
Recipient characteristics and outcomes between residents/fellows and consultant surgeons: overall and propensity score matching cohort.

	Before PSM			After PSM		
	Resident/Fellow (n = 32)	Consultant surgeon (n = 19)	P value	Resident/Fellow (n = 32)	Consultant surgeon (n = 19)	P value
No. of KTX	582	884		576	576	
Age (years)	55.9 (13.5)	54.6 (14.7)	0.23	55.9 (13.5)	55.8 (14.5)	0.76
Gender						
Male	362 (62%)	567 (64%)	0.45	357 (62%)	371 (64%)	0.39
Female	220 (38%)	317 (36%)		219 (38%)	205 (36%)	
BMI (kg/m2)	26.9 (4.7)	26.4 (5.0)	0.028	26.8 (4.7)	26.9 (4.7)	0.75
Donor type						
Living	383 (66%)	579 (66%)	0.90	382 (66%)	372 (65%)	0.54
Deceased	199 (34%)	305 (34%)		194 (34%)	204 (35%)	
Number of KTX						
1st	505 (87%)	718 (81%)	< 0.001	502 (87%)	498 (86%)	0.93
2nd	66 (11%)	119 (14%)		64 (11%)	68 (12%)	
3rd or more	11 (2%)	47 (5%)		10 (2%)	10 (2%)	
Operative time (min)	135 (34)	128 (45)	< 0.001	135 (34)	128 (46)	< 0.001
Blood loss (mL)	321 (367)	368 (470)	0.48	317 (360)	365 (461)	0.47
WIT (min)	22.8 (6.4)	21.5 (8.0)	< 0.001	22.7 (6.4)	21.8 (8.6)	< 0.001
Complication	75 (12.9%)	125 (14.1%)	0.49	75 (13.0%)	82 (14.2%)	0.55
Urological	63 (10.8%)	92 (10.4%)	0.80	63 (10.9%)	65 (11.3%)	0.85
Vascular	6 (1.0%)	10 (1.1%)	0.86	6 (1.0%)	3 (0.5%)	0.31
Bleeding	9 (1.6%)	28 (3.2%)	0.046	9 (1.6%)	15 (2.6%)	0.21
LOS (days)	14.2 (9.8)	14.3 (10.5)	0.52	14.2 (9.9)	14.2 (10.1)	0.30

Data were presented as mean (standard deviation) and numbers (percentages).
PSM propensity score matching, *KTX* kidney transplantation, *BMI* body mass index, *WIT* warm ischemia time, *LOS* length of stay.

kidney program. Therefore, we performed PSM to reduce the effect of selection bias. The present analyses do not take into account the prior experiences of trainees at other centers. Some trainees might have had experiences in vascular surgery or transplantation at other centers, however we focused only on procedures at our center, as it is likely that standardized protocols differ between centers. Moreover, we investigated the learning curve of KTX focusing on short-term outcomes, however long-term outcomes such as kidney function and graft survival were not evaluated. Some studies have reported no impact of surgeon volume as well as surgeon experience on long-term outcomes after KTX [6,25], but other studies have demonstrated the negative effect of surgeon volume on graft function [19]. Therefore it is recommended that further studies be conducted to clarify the effect of surgeon volume on the long term outcomes after KTX.

5. Conclusions

The present study demonstrates that surgeon volume did not have any impact on perioperative outcomes, except for operative time and WIT in patients undergoing KTX. Approximately 30 procedures are necessary for surgeons to improve their surgical skills in KTX. Moreover, no effect of surgeon's type on postoperative outcomes was shown under the careful selection of the surgeon and a standardized protocol in KTX.

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Ethical approval

The approval of the Ethics Committee of the Erasmus MC was obtained (MEC-2019-0373).

Research registration Unique Identifying number (UIN)

1. Name of the registry:UMIN-CTR
2. Unique Identifying number or registration ID:UMIN000040213
3. Hyperlink to your specific registration (must be publicly accessible and will be checked):https://upload.umin.ac.jp/cgi-open-bin/ctr_e/ctr_view.cgi?recptno=R000045866

Guarantor

Kosei Takagi.

Data statement

The database used and/or analyzed during the current study are not publicly available, but can be available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Kosei Takagi: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft. **Loubna Outmani:** Resources, Data curation, Writing - review & editing. **Hendrikus J.A.N. Kimenai:** Resources, Data curation, Writing - review & editing. **Turkan Terkivatan:** Resources, Data curation, Writing - review & editing. **Khe T.C. Tran:** Resources, Data curation, Writing - review & editing. **Jan N.M. Ijzermans:** Conceptualization, Writing - review & editing, Supervision, Project administration. **Robert C. Minnee:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare that there are no conflicts of interest regarding this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2020.06.047.

References

[1] D.M. Chaput de Saintonge, D.W. Vere, Why don't doctors use cusums? Lancet 1

(1974) 120–121.
[2] H. Wohl, The cusum plot: its utility in the analysis of clinical data, N. Engl. J. Med. 296 (1977) 1044–1045.
[3] B.A. Boone, M. Zenati, M.E. Hogg, et al., Assessment of quality outcomes for robotic pancreaticoduodenectomy: identification of the learning curve, JAMA Surg 150 (2015) 416–422.
[4] J.S. Park, H.K. Ahn, J. Na, et al., Cumulative sum analysis of the learning curve for video-assisted minilaparotomy donor nephrectomy in healthy kidney donors, Medicine (Baltim.) 97 (2018) e0560.
[5] M.B. Bokhari, C.B. Patel, D.I. Ramos-Valadez, et al., Learning curve for robotic-assisted laparoscopic colorectal surgery, Surg. Endosc. 25 (2011) 855–860.
[6] G. Fechner, I. Seifert, S. Hauser, et al., Impact of a learning curve model in kidney transplantation on functional outcome and surgical complications in a small volume centre: does size really matter? Int. Urol. Nephrol. 44 (2012) 1411–1415.
[7] M. Thomas, M. Rentsch, M. Drefs, et al., Impact of surgical training and surgeon's experience on early outcome in kidney transplantation, Langenbeck's Arch. Surg. 398 (2013) 581–585.
[8] T. Wolff, M. Schumacher, S. Dell-Kuster, et al., Surgical complications in kidney transplantation: no evidence for a learning curve, J. Surg. Educ. 71 (2014) 748–755.
[9] J.A. Lafranca, S.M. Hagen, L.F. Dols, et al., Systematic review and meta-analysis of the relation between body mass index and short-term donor outcome of laparoscopic donor nephrectomy, Kidney Int. 83 (2013) 931–939.
[10] R. Agha, A. Abdall-Razak, E. Crossley, et al., STROCSS 2019 Guideline: Strengthening the reporting of cohort studies in surgery, Int. J. Surg. 72 (2019) 156–165.
[11] L.S. Ooms, J.I. Roodnat, F.J. Dor, et al., Kidney retransplantation in the ipsilateral iliac fossa: a surgical challenge, Am. J. Transplant. 15 (2015) 2947–2954.
[12] P. Domagala, T. van den Berg, K. Tran, et al., Surgical safety and efficacy of third kidney transplantation in the ipsilateral iliac fossa, Ann. Transplant. 24 (2019) 132–138.
[13] K. Takagi, Y. Umeda, R. Yoshida, et al., The outcome of complex Hepato-Pancreato-Biliary surgery for elderly patients: a propensity score matching analysis, Dig. Surg. 36 (2019) 323–330.
[14] K. Takagi, H.J.A.N. Kimenai, J.N.M. IJzermans, et al., Obese living kidney donors: a comparison of hand-assisted retroperitoneoscopic versus laparoscopic living donor nephrectomy, Surg. Endosc. (2019), https://doi.org/10.1007/s00464-019-07276-x.
[15] C.A. Goossens-Laan, G.A. Gooiker, W. van Gijn, et al., A systematic review and meta-analysis of the relationship between hospital/surgeon volume and outcome for radical cystectomy: an update for the ongoing debate, Eur. Urol. 59 (2011) 775–783.
[16] S.R. Markar, M. Penna, A. Karthikesalingam, et al., The impact of hospital and surgeon volume on clinical outcome following bariatric surgery, Obes. Surg. 22 (2012) 1126–1134.
[17] F.I.B. Macedo, P. Jayanthi, M. Mowzoon, et al., The impact of surgeon volume on outcomes after pancreaticoduodenectomy: a meta-analysis, J. Gastrointest. Surg. 21 (2017) 1723–1731.
[18] H. Hoshijima, Z. Wajima, H. Nagasaka, et al., Association of hospital and surgeon volume with mortality following major surgical procedures: meta-analysis of meta-analyses of observational studies, Medicine (Baltim.) 98 (2019) e17712.
[19] S.F. Weng, C.C. Chu, C.C. Chien, et al., Renal transplantation: relationship between hospital/surgeon volume and postoperative severe sepsis/graft-failure. a nation-wide population-based study, Int. J. Med. Sci. 11 (2014) 918–924.
[20] M.M. Chowdhury, H. Dagash, A. Pierro, A systematic review of the impact of volume of surgery and specialization on patient outcome, Br. J. Surg. 94 (2007) 145–161.
[21] S.J. Schurman, D.M. Stablein, S.A. Perlman, et al., Center volume effects in pediatric renal transplantation. A report of the North American Pediatric renal transplant cooperative study, Pediatr. Nephrol. 13 (1999) 373–378.
[22] E.B. Edwards, J.P. Roberts, M.A. McBride, et al., The effect of the volume of procedures at transplantation centers on mortality after liver transplantation, N. Engl. J. Med. 341 (1999) 2049–2053.
[23] J.D. Hosenpud, T.J. Breen, E.B. Edwards, et al., The effect of transplant center volume on cardiac transplant outcome. A report of the United Network for Organ Sharing Scientific Registry, J. Am. Med. Assoc. 271 (1994) 1844–1849.
[24] T. Alhamad, A.F. Malone, D.C. Brennan, et al., Transplant center volume and the risk of pancreas allograft failure, Transplantation 101 (2017) 2757–2764.
[25] H. Cash, T. Slowinski, A. Buechler, et al., Impact of surgeon experience on complication rates and functional outcomes of 484 deceased donor renal transplants: a single-centre retrospective study, BJU Int. 110 (2012) E368–E373.