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Original Article

Robot-assisted versus conventional open kidney transplantation: a propensity matched comparison with median follow-up of 5 years

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Abstract: Background: RAKT is a relatively newer approach for kidney transplant and has to be proven against the established approach, OKT. RAKT may be beneficial in obese patients as described in literature. Hence, we compared pre-, intra- and postoperative parameters with one year follow-up of both approaches by propensity matching similar characteristics patients. Methods: Data of 28 OKT and 28 RAKT propensity matched patients was collected during 2014 to 2022 through the institutional transplant registry. OKT and RAKT patients were propensity matched for confounding factors like donor age, eGFR, side along with recipient age, BMI and comorbidities. All graft kidneys were harvested laparoscopically. Results: Both the groups were comparable in terms of recipient age and BMI, donor age, creatinine, BMI, eGFR and comorbidities. Total ischemia time (P<0.001) and postoperative day (POD) 1 creatinine (P<0.001) was significantly more in RAKT. However, postoperative 1 month (P=0.12), 3 months (P=0.60) and 1 year (P=0.10) creatinine was comparable in both approaches. Postoperative complications (P=0.90) including hemoglobin drop (P=0.72) were comparable in both the groups. The days to half the creatinine from preoperative values was significantly less in OKT group (P=0.009). Serum Tacrolimus levels at day 3 (P=0.08) and day 7 (P=0.112) were also comparable in both the groups. Graft survival was 78.5% in OKT group and 82.14% in RAKT group with median follow-up of 60 months in both the groups. Conclusion: In this comprehensive propensity matched analysis of RAKT with OKT, we conclude that RAKT has similar outcomes as OKT at 1 year and 5 years follow-up. CIT, TIT, time to half creatinine and POD 1 creatinine values were higher in RAKT group, but eventually have comparable outcomes at further follow-up. Thus, RAKT, a novel approach is non-inferior to established OKT approach. However, further larger trials are required.

Keywords: OKT, RAKT, surgical complications, propensity matched

Introduction

Renal transplantation is the gold standard for the management of end stage renal disease [1]. Traditionally, kidney transplantation is performed by a pararectal curvilinear incision from the symphysis in the midline, curving in a lateral and superior direction to the iliac crest (inverted J-shaped incision), for enhanced exposure [2]. These incisions cause morbidity, including abdominal wall relaxation of up to 24%, abdominal wound dehiscence (4%), and incisional hernia (up to 16%). In addition, larger incisions have been associated with an increased risk of surgical site infection (SSI), especially in recipients with obesity, diabetes, critical illness, and immunosuppression. Wound healing complications are a major cause of morbidity in kidney transplant recipients [3-6]. Minimally invasive surgical techniques have replaced much of the open traditional surgical procedures in surgical field. Such development in the specialty of renal transplantation remains however novice.

Robotic-assisted surgery provides advantages over standard open surgery, such as high-definition 3D imaging, increased magnification and camera stability, and articulation of instruments aiding in suturing. Enhanced ergonom-

ics, improved outcomes, and shorter length of stay resulting from minimally invasive surgical approaches have been shown by several centers. The da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) was first used as an adjunct to open kidney transplantation (OKT) by Hoznek et al. in 2001. It was a hybrid procedure with an open incision and robotic-assisted dissection, isolation of vessels, and anastomosis, with an assistant providing retraction [7]. In 2009 Giulianotti et al. described an Robotic-Assisted Kidney Transplant (RAKT) performed on an obese man, where surgeons manipulated the graft intracorporeally using hand-assistance [8]. The feasibility of Robot Assisted Kidney Transplant (RAKT) was described by many studies including prospective multicenter studies within the EAU Robotic Urology Section (ERUS)-RAKT Working Group [9-15] Development, Exploration, Assessment, Long-term study [IDEAL] phase 0-1. We had also previously described the safety and feasibility of RAKT [16].

The major advantage the minimally invasive technique provides is in the cases of obese recipients in which the abdominal fat layer is thick and the transplant bed lies deep making open surgery challenging. Moreover, these obese recipients are more prone to surgical site infections and longer hospital stay. RAKT offers a better surgical option especially for these patients with less surgical site infections and better suturing during vascular anastomosis. However RAKT is associated with a longer WIT, CIT and TIT during surgery.

Our aim is to compare whether different variables, preoperatively, intraoperatively and postoperatively have any difference in overall outcome of graft and patient survival in the two techniques used, namely OKT or RAKT.

There are many confounding factors for graft and patient survival in kidney transplantation. So, these confounding factors need to be propensity matched to appropriately compare RAKT with OKT. The primary objective of this study was to compare the graft survival of open kidney transplant (OKT) vs Robot Assisted Kidney Transplant (RAKT) with the secondary objectives of comparing total operative time, cold ischemia time, creatinine and eGFR at POD 1, 1 month, 3 month and 1 year. Hemoglobin drop, any intraoperative or post operative complications according to Clavein-dindo classification and hospital stay would also be compared.

Material and methods

Study design

This was a retrospective propensity matched single institutional comparative study performed after approval of institutional ethics committee. We retrospectively reviewed and analyzed the data of kidney transplantation done at our institute between January 2014 to January 2022. All kidney transplantations done by both standard open technique and robot assisted technique were included in analysis.

Study methods

The inclusion criteria included adult patients with end stage renal disease. The exclusion criteria were previous kidney transplant and complex abdominal surgeries. The required data was retrieved from institutional transplant registry and the above cases were propensity matched using comparable baseline variables using XL-stats. A total of 56 cases were selected and 28 propensity matched cases in each open and robot assisted arm. Preoperative parameters including demographic details, BMI, co morbidities, preoperative laboratory parameters were recorded.

OKT procedure

All grafts were procured using laparoscopic donor nephrectomy. All patients underwent renal recipient surgery under general anesthesia. OKT was performed using the standard retroperitoneal approach using modified Gibson's incision. Vascular anastomoses were performed with 6-0 PROLENE (Ethicon, Somerville, NJ) sutures using 2.5-magnification loupes. Ureteroneocystostomy was performed using the modified Lich-Gregoir technique with 5-0 Vicryl sutures.

RAKT procedure

RAKT was performed using da Vinci Si or X surgical system (Intuitive Surgical, Sunnyvale, CA, USA). External iliac artery and external iliac vein were dissected robotically for anastomoses. The table preparation was completed in standard fashion. Kidney was then wrapped in ice-gauze jackets with marking stitches to maintain orientation before implantation. Pfannenstiel

incision was used for engraftment. All vascular anastomoses were performed with 6-0 GORE-TEX (Gore Medical, Flagstaff, AZ) sutures. 5-0 Vicryl (Ethicon, Somerville, NJ) suture was used for ureteroneocystostomy (modified Lich-Gregoir technique) over DJ stent.

Parameters

Preoperative parameters which were propensity matched included recipient age, BMI, diabetes mellitus and donor BMI, side, eGFR, comorbidity. Intraoperative parameters included total operative time, warm ischemia time (WIT), cold ischemia time (CIT), total ischemia time (TIT) and use of ureteral stents. Post operative parameters were analyzed in detail. Operative blood loss was determined in terms of drop in hemoglobin in post operative period. Immediate post operative parameters included recipient post operative day 1 creatinine, days to half creatinine as compared to preoperative value, serum tacrolimus levels on POD 1 and POD 7. Immediate post operative complications including surgical and medical graft complications, vascular complications and surgical site infections were analyzed. Delayed post operative follow up data included serum creatinine and eGFR determination at 1 month and 1 year. Death censored graft survival (calculated from the date of transplantation to the date of irreversible graft failure signified by return to long-term dialysis (or retransplantation) or the date of last follow-up during the period when the transplant was still functioning. In the event of death with a functioning graft, the follow-up period was censored at the date of death) and patient survival (calculated from the date of transplantation to the date of death or the date of the last follow-up) was calculated in both the groups.

Statistical analysis

Propensity match has been done using XL-Stat. RAKT (N=28) where matched with OKT (N= 1045) using propensity matching. The basic characteristics used for the propensity matching were recipient age, recipient BMI, donor eGFR, donor operating side. Distance matrix (minimum value in distance matrix) and logistic regression (propensity match score) were used to identify OKT: 28 cases out of 1045 cases (2.67%) which matched with RAKT. Further these all RAKT and identified OKT cases were used for statistical analysis.

All statistical analysis has been done using IBM SPSS 25.0. All quantitative parameters were tested for its significance between two group averages using Independent sample t-test after checking normality assumption. All qualitative parameters association with two groups (Robot and Open) were tested using chi-square test. All hypothesis tests conducted in this research paper based on 5% level of significance and *P*-value less than 0.05 considered to be significant.

Results

A total of 56 patients were analyzed, 28 each in OKT and RAKT group respectively.

Pre-operative parameters

The demographic data of both the groups is as in **Table 1**. The baseline characteristics including recipient age, BMI, diabetes mellitus and donor BMI, sex, side, eGFR, comorbidity were comparable in both groups.

Intra-operative parameters

The intraoperative parameters are presented in **Table 2**. The total operative time in OKT (291.25 ± 48.18 minutes) was comparable to that in RAKT (310 ± 42.8 minutes) (P=0.13). Warm ischemia time was also comparable in both the groups (OKT-5.71 ± 0.81 minutes v/s RAKT-5.9 ± 0.32 minutes, P=0.282). There was significant difference in the two groups in terms of cold ischemia time and total ischemia time. The cold ischemia time in OKT was 60.68 ± 15.32 minutes while in RAKT was 108.93 ± 25.65 minutes (P<0.001). Similarly, total ischemia time was 66.39 ± 15.36 minutes in OKT and 114.93 ± 25.65 minutes in RAKT (P<0.001).

Ureteral stent treatment is significantly associated with the type of surgical technique used, in OKT stents were placed in 13 (46.43%) patients while in RAKT stents were placed in all 28 (100%) patients (*P*-value <0.001). Hospital stay (in days) was comparable in both groups (OKT: 11.07 ± 2.88 v/s RAKT: 12.79 ± 3.55, *P*-value =0.056).

Post-operative parameters

The post operative parameters are as described in **Table 3**. The post operative Day 1 creatinine was significantly less in OKT group (OKT:

Table 1. Pre-operative parameters

Variable		Open (n=28)	Robotic (n=28)	*P*-value
Recipient Age (years)		36.54 ± 10.99 (20-58)	40.43 ± 13.14 (15-63)	0.234
Recipient BMI (kg/m²)		26.15 ± 4.64 (17.5-34.7)	26.1 ± 4.75 (18.6-35.9)	0.966
Recipient Sex	F	10	5	0.131
	M	18	23	
Recipient DM	N	21	20	0.763
	Y	7	8	
Donor Creatinine (mg/dl)		0.66 ± 0.17 (0.4-1.12)	0.67 ± 0.13 (0.44-0.93)	0.729
Donor BMI (kg/m²)		26.66 ± 3.64 (17.68-34.1)	25.84 ± 3.72 (18.5-31.12)	0.407
Donor eGFR (mL/min/1.73 m²)		103.5 ± 24.5 (44-159.5)	108.59 ± 37.03 (65.6-226.7)	0.549
D_Comorbidity	DM	1 (3.57%)	1 (3.57%)	0.796
	HTN	2 (7.14%)	2 (7.14%)	
	Hypothyroid	0	1 (3.57%)	
	No	25 (89.29%)	24 (85.72%)	

All figure in table either represented as mean ± SD (range) or No. of patients (%).

Table 2. Intra-operative parameters

Variable	Open (n=28) mean ± SD, range	Robotic (n=28) mean ± SD, range	*P*-value
Total operative time (min)	291.25 ± 48.18 (195-385)	310 ± 42.8 (240-420)	0.13
Warm Ischemia Time (min)	5.71 ± 0.81 (3-7)	5.9 ± 0.32 (4.6-6.4)	0.282
Cold Ischemia Time (min)	60.68 ± 15.32 (34-107)	108.93 ± 25.65 (64-151)	<0.001
Total Ischemia time (min)	66.39 ± 15.36 (40-113)	114.93 ± 25.65 (70-157)	<0.001
Ureteral Stent	13 (46.43%)	28 (100%)	<0.001
Hospital Stay (days)	11.07 ± 2.88 (8-22)	12.79 ± 3.55 (8-20)	0.056

All figure in table either represented as mean ± SD (range) or No. of patients (%).

Table 3. Post-operative parameters

Variable	Open (n=28) mean ± SD, range	Robotic (n=28) mean ± SD, range	*P*-value
Recipient preoperative creatinine (mg/dl)	4.68 ± 1.4 (1.9-8.29)	4.55 ± 1.56 (2.3-9.47)	0.745
Postoperative day 1 creatinine (mg/dl)	2.04 ± 0.71 (0.88-4.04)	3.16 ± 1.47 (0.95-6.47)	0.001
Day to half creatinine	1.10 ± 0.41 (1-3)	3.46 ± 2.60 (1-20)	0.009
Postoperative 1 month creatinine (mg/dl)	1.13 ± 0.27 (0.6-1.89)	1.26 ± 0.34 (0.7-2.02)	0.119
Postoperative 3 months creatinine (mg/dl)	1.46 ± 1.36 (0.7-6.86)	1.32 ± 0.36 (0.72-2.26)	0.605
Latest Creatinine (mg/dl)	2.7 ± 2.09 (0.88-7.47)	3.08 ± 4 (0.62-15.21)	0.652
Postoperative 1 year creatinine (mg/dl)	1.91 ± 1.63 (0.7-6.91)	1.38 ± 0.43 (0.74-2.27)	0.104
Hb drop (mg/dl)	2.12 ± 1.25 (0.7-5.8)	2.02 ± 0.85 (0.8-3.8)	0.72
eGFR @ 1 month	82.36 ± 21.89 (43-124)	76.21 ± 24.24 (45-129)	0.324
eGFR @ 1 year	65.85 ± 32.19 (7-120)	69.36 ± 21.71 (39-121)	0.637
Tac level @ Day 3	11.38 ± 5.56 (0.8-27.70)	13.92 ± 5.12 (6.90-23.90)	0.080
Tac level @ Day 7	8.44 ± 4.30 (1.70-22.10)	10.21 ± 3.90 (4.50-19)	0.112
Follow up (years)	5.17 ± 3.12 (1-11)	5.0 ± 2.14 (1-8)	0.804

All figure in table either represented as mean ± SD (range) or No. of patients (%).

2.04 ± 0.71 mg/dl v/s RAKT: 3.16 ± 1.47 mg/dl, P<0.001). The days to half the creatinine from preoperative values was significantly less in OKT group (OKT: 1.10 ± 0.41 days v/s RAKT: 3.46 ± 2.60 days, P=0.009). The postoperative haemoglobin drop was comparable in both groups (OKT: 2.12 ± 1.25 mg/dl v/s RAKT: 2.02 ± 0.85 mg/dl, P=0.72). Serum Tacrolimus lev-

els at day 3 (OKT: 11.38 ± 5.56 vs RAKT: 13.92 ± 5.12, P=0.08) and day 7 (OKT: 8.44 ± 4.30 vs RAKT: 0.21 ± 3.90, P=0.112) were also comparable in both the groups. Post operative 1 month, 3 month, 1 year creatinine and eGFR at 1 month and 1 year were comparable in both groups (**Table 3**). The last follow-up serum creatinine was statistically comparable in both the groups (OKT: 2.7 ± 2.09, RAKT: 3.08 ± 4, P=0.65).

Post-operative complications

In terms of post operative complications, 1 patient in both group had surgical site infections, whereas vascular complications was present in one patients in open group and none in robot assisted group - the difference being non-significant (P=0.313). Lymphocele requiring intervention occurred in 1 patient (3.57%) in RAKT group. One patient in both groups required graft re-exploration in immediate post operative period.

Graft survival

The graft survival was 22/28 (78.5%) in OKT group and 23/28 (82.14%) in RAKT group, and it was comparable (P=0.737). Overall, patient survival was also comparable in both groups - 22/28 patients (78.5%) in OKT group and 24/28 patients (85.71%) in RAKT group (P=0.485).

Discussion

Robotic assisted kidney transplantation (RAKT) is a newer alternative to open kidney transplantation (OKT). RAKT would have less wound related complications and better cosmesis. Graft and patient survival are the final outcomes in renal transplantation and RAKT as an alternative need to match with OKT in terms of these factors to provide comparable patients outcomes. CIT, TIT, time to half creatinine and POD 1 creatinine values were higher in RAKT group, but eventually have comparable outcomes at further follow-up. RAKT has similar outcomes as OKT at 1 year and 5 years follow-up.

Ulrich et al. [17] presented the largest series of RAKT in Germany comparing RAKT and OKT. Patient survival and graft survival was 100% (mean follow-up 12.9 ± 8.6 month). Mean incision to closure time was 306.1 ± 45.5 min, mean handling time 70.8 ± 13.1 min in RAKT compared to 212.1 ± 40.6 min and 51.7 ± 9.9 min, respectively, in OKT group. This study had comparable complication rates and graft function with significant reduction in median length of hospital stay (14 vs 20 days). So, authors concluded that RAKT appears to be safe in selected patients without influencing graft outcome or higher complication ratecompared to OKT.

In a 1:3 matched cohort (robotic 126, open 378) study by Ahlawat et al. [18], RAKT had lower rates of wound infections (P=0.023), symptomatic lymphoceles (P=0.003), less blood loss and reduced postoperative pain. The median hospital stay was 8 days in both groups. The graft function (delayed graft function P=0.081), graft rejection (P=0.643), graft survival (95.2% vs 96.3% at 36 months, P=0.266) and overall survival (94.5% vs 98.1% at 36 months, P=0.307) was also comparable in both groups. So, they concluded that RAKT with regional hypothermia was associated with a lower rate of postoperative complications and improved patient comfort.

Francis et al. [19] performed first US study to propensity match a retrospective review (2016 to 2018) with a 1:1 propensity score matching performed on recipient/donor age, sex, body mass index, race, preoperative dialysis, and calculated panel reactive antibodies. RAKT recipients had longer warm ischemic times (P<0.001) and less blood loss (P=0.005). The operative time and length of stay were similar between groups. Postoperative serum creatinine was similar during a 2-y follow-up. This cohort had four open conversion and excluding those four conversion, RAKT had lower operative time (P=0.04), lower 30-d (P=0.02) and 90-d (P=0.01) Clavien-Dindo grade ≥3 complications, concluding that RAKT is a safer alternative to OKT. Our study also had comparable operative times in both the groups, but more ischemia times in RAKT group. Post operative 1 month, 3 month, 1 year creatinine and eGFR at 1 month and 1 year were comparable in both groups.

Sven et al. [20], in a systematic review comparing minimally invasive techniques with OKT found no differences in graft or patient survival. Minimally invasive operative recipient tech-

Table 4. Comparison with previous published literature

Study name	Sample size		BMI		CIT		TIT		Total operative time		1 month creatinine		3 month creatinine		1 year creatinine		Follow-up (months)		Graft survival		Patient survival		Rejections	
	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT	OKT	RAKT
Oberholzer et al., 2013	28	28	38.1 ± 5.4	42.6 ± 7.8	49.2 ± 25.2	47.7 ± 7.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	6	100%	100%	100%	100%	0%	0%
Garcia-Roca et al., 2016	545	67	28.2 ± 4.4	30.2 ± 7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5 ± 1.0	1.42 ± 0.38	36	36	91.74	92.53	NA	NA	4.47%	3.30%
Tugcu et al., 2017	40	40	25.3 ± 2.17	23.2 ± 3.29	32.76 ± 7.45	40.47 ± 13.38	71.32 ± 8.38	96.7 ± 30.02	250.25 ± 41.3	265.37 ± 46.6	1.56 ± 1.40	1.59 ± 1.48	1.35 ± 1.62	1.04 ± 1.03	NA	NA	6	6	95	100	95	100	NA	NA
Maheshwari et al., 2020	152	55	24.35 + 5.01	26.2 + 6.9	52.73 + 15.71	55.66 + 22.49	NA	NA	NA	NA	1.19 ± 0.66	1.41 ± 0.68	1.19 + 0.57	1.29 + 0.4	NA	NA	NA	NA	84.21	81.81%	97.36	98.18	10.52%	9.09%
Pein U et al., 2020	21	21	26.4 ± 5.7	25.5 ± 4.1	27.8 ± 8.2	32.4 ± 10.1	79.6 ± 12.2	103.2 ± 13.8	212.1 ± 40.6	306.1 ± 45.5	2.07 ± 1.31	1.65 ± 0.51	NA	NA	NA	NA	NA	NA	95.20%	100%	NA	NA	NA	NA
Patil et al.	28	28	26.15 ± 4.64	26.1 ± 4.75	60.68 ± 15.32	108.93 ± 25.65	66.39 ± 15.36	114.93 ± 25.65	291.25 ± 48.18	310 ± 42.8	1.13 ± 0.27	1.26 ± 0.34	1.46 ± 1.36	1.32 ± 0.36	1.91 ± 1.63	1.38 ± 0.43	62 ± 32.75	60.28 ± 25.71	78.50%	82.14%	78.50%	85.71%	3.57%	0.00%

niques showed lowest surgical site infection. Incisional hernia rates along with improved cosmetic result and postoperative recovery. This came at the cost of prolonged cold ischemia time, warm ischemia time, and total operation time. This was corroborated by our study. The authors concluded that minimally invasive techniques showed promising results with regard to complications and recovery, although the level of evidence was generally low.

A prospective observational study performed by Riccardo et al. [21] compared RAKT vs OKT from deceased donors. The ischemia times, postoperative complications and eGFR were comparable in both the groups. Contrary to our study, OKT group had higher delayed graft function. At a median follow-up of 31 month, there was no difference between the groups regarding the dialysis-free and overall survival. The study provided preliminary evidence supporting the noninferiority of RAKT vs OKT for deceased donors.

Purdhomme et al. [22] compared RAKT in obese vs non obese patients. 169 living donor RAKTs were performed by 10 surgeons from July 2015 to September 2018 in the 8 European centers with a mean follow-up of 1.2 years. The post-operative complications, eGFR at one year follow-up was comparable in both the groups. Delayed graft function rate was also comparable both the groups. The study concluded that RAKT is safein obese recipients and yields very good function, when it performed at high-volume referral centers by highly trained transplant teams.

Finally, a meta-analysis performed by Liu et al. [23] comprised six nonrandomized controlled studies including 263 patients with RAKT and 804 patients with OKT. RAKT had significant higher rewarming time (P<0.001) and total ischemia time (P=0.008), lower incidence of surgical site infection (P=0.03). The hospital stay (P=0.21) and delayed graft function (P= 0.82) was comparable between groups. The incidence of graft rejection (P=0.53), follow-up creatinine (P=0.42), graft failure (P=0.79) and all-cause mortality (P=0.77) was comparable in both the groups at median follow-up of 31 months. These findings were also reflected in our studies. The various parameters of our study as compared to other studies on RAKT vs OKT ware described in **Table 4**. There was a hypothesis that tacrolimus levels are more in RAKT group due to increased gastro-intestinal absorption of drug owing to prolonged ileus because of perigraft ice slush to maintain graft hypothermia, but day 3 and day 7 tacrolimus levels were comparable in both the groups of our study.

The strength of our study is propensity matched analysis of RAKT and OKT and longer follow-up (median follow-up 5 years) especially in Indian population. The limitation of our study being the retrospective nature of the study. The sample size is moderate, but larger multi-centric randomized trials are required to compare these two approaches.

Conclusion

In this comprehensive propensity matched analysis of RAKT with OKT, we conclude that RAKT has similar outcomes as OKT at 1 year and 5 years follow-up. CIT, TIT, time to half creatinine and POD 1 creatinine values were higher in RAKT group, but eventually have comparable outcomes at further follow-up. Thus, RAKT, a novel approach is non-inferior to established OKT approach. However, further larger trials are required.

Disclosure of conflict of interest

None.

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