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Original Article

Robot-assisted vs open kidney transplantation from deceased donors

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Objectives

To test the hypothesis that the type of surgical approach, robot-assisted kidney transplantation (RAKT) vs open kidney transplantation (OKT), impacts intra-operative and postoperative surgical outcomes of patients receiving kidney transplantation from deceased donors.

Materials and Methods

This was a multicentre retrospective cohort study including 676 patients who received RAKT or OKT in the period 2015 to 2023 in one of seven European academic centres. Patient heterogeneity at baseline was balanced using 2:1 nearest neighbour propensity-score matching. Intra- and postoperative complications were reported according to the Clavien–Dindo classification system. Kaplan–Meier estimates and the log-rank test were used to compare dialysis-free survival (DFS), graft survival (GS), reintervention-free survival (RFS) and overall survival (OS) according to the surgical approach used.

Results

After propensity-score matching, two cohorts of 72 recipients (65%) in the OKT group and 37 (35%) in the RAKT group with similar baseline characteristics were obtained. The site of transplantation was the right iliac fossa in 59 (82%) and 28 patients (76%) undergoing OKT and RAKT, respectively. RAKT was associated with shorter rewarming time (53 vs 39 min), total vascular anastomosis time (55 vs 36 min), and arterial (25 vs 17 min) and venous (28 vs 18 min) anastomosis times (all $P < 0.001$), whereas OKT was associated with reduced surgical time (180 vs 200 min; $P = 0.01$). Intra-operative complications were more commonly reported in recipients undergoing OKT (8.3% vs 2.7%; $P = 0.4$). During follow-up, no differences in terms of postoperative complications, DFS, GS, RFS or OS were detected.

Conclusions

This is the largest comparative study of RAKT vs OKT in the deceased donor setting. While it confirms the safety of RAKT from deceased donors, it underscores the superiority of RAKT in selected patients in terms of achieving vascular anastomosis and rewarming time in a shorter timeframe.

Keywords

open kidney transplantation, robot-assisted kidney transplantation, deceased donors, kidney transplantation, renal transplantation

Introduction

Robot-assisted kidney transplantation (RAKT) is a safe and effective surgical alternative to the traditional open kidney transplantation (OKT) that has been utilised in Europe since 2015 [1,2]. By 2023, a total of 622 heterotopic RAKT procedures had been conducted using kidneys from living donors [3]. Initially restricted to carefully selected patients, advances in handling more complex cases – such as those involving obese recipients or grafts with multiple vessels – have broadened the scope of RAKT [4–6]. This procedure has consistently shown favourable peri-operative outcomes and excellent long-term graft function and survival rates [7]. However, evidence of the surgical and functional safety of RAKT with kidneys from deceased donors is lacking [8]. Campi et al. [9] published the only study comparing RAKT and OKT from deceased donors, showing that a higher proportion of patients undergoing OKT experienced delayed graft function (DGF) but that patient-related factors rather than the surgical approach were predictors of DGF. Another large retrospective study identified that cold ischaemia time (CIT) impacted DGF similarly in patients undergoing RAKT and OKT [10]. Both studies were retrospective in nature and gave limited information on which one of the two techniques provides better functional or surgical outcomes.

The aim of our study, therefore, was to compare RAKT and OKT from deceased donors by leveraging data from a multicentre cohort. We focused on assessing postoperative functional and surgical outcomes to address evidence gaps in this field.

Patients and Methods

This was a multicentre, retrospective study evaluating patients who underwent RAKT or OKT from deceased donors between July 2015 and July 2023 at seven European centres participating in the ERUS-RAKT network. At each centre, a single surgeon performed RAKT, while OKT was carried out by multiple experienced kidney transplant (KT) surgeons. Ethical standards were adhered to across all sites. All patients underwent preoperative CT, and patients showing calcifications in the iliac vessels or undergoing orthotopic KT were excluded from the study. KT was contraindicated in patients with active cancer, ongoing infections, or severe cardiac, pulmonary, or liver-related illnesses. RAKT was not performed in cases involving highly complex vascular anatomy, such as kidneys with more than three arteries, multiple small accessory arteries, or more than two veins, as well as in multi-organ transplant cases.

Data Collected

Donor demographic data included age, sex, and preoperative estimated glomerular filtration rate (eGFR). For recipients, variables such as age, sex, American Society of Anesthesiologists (ASA) score, body mass index (BMI), history of abdominal surgery, smoking status, preemptive KT status, cause of end-stage renal disease (ESRD), previous transplants, and blood group compatibility were recorded. Intra-operative data captured details of the kidney and vascular anatomy, surgical incision type, vesico-ureteric anastomosis type, total operating time, warm ischaemia time (WIT), CIT, rewarming time, estimated blood loss, intra-operative complications, conversion rates, and use of intra-abdominal drainage. CIT was defined as the time the kidney was stored in cold conditions before implantation, while rewarming time referred to the time from kidney removal from cold storage to the start of reperfusion.

Postoperative outcomes included length of hospital stay, time to removal of the JJ stent and drains, incidence of DGF, need for postoperative renal biopsy, and complications. Complications were categorised as early (within 30 days) or late (31–90 days) and classified using the Clavien–Dindo system.

Surgical Procedures

Standard OKT techniques were followed, including placing the patient in a supine position, accessing the retroperitoneal space, and performing vascular anastomoses with the external iliac vessels or, in some cases, with the common iliac vessels [11]. For RAKT, patient positioning and trocar placement was carried out according to the Vattikuti-Medanta technique, using the da Vinci® Surgical System (Si, X or Xi models) [12–14]. JJ catheter stenting was performed during bench surgery for RAKT and during vesico-ureteric anastomosis for OKT. The vesico-ureteric anastomosis was performed using the Lich-Gregoir technique. Intra-abdominal drain placement was determined by surgeon preference. Patients with grafts presenting more than three arteries or multiple small accessory vessels were excluded to avoid introducing excessive surgical variability; although such cases are feasible with RAKT [5], they represent highly complex scenarios that could jeopardise the comparability of outcomes.

Endpoints

The primary endpoint was to compare renal function between RAKT and OKT 1 month post-transplant. Secondary endpoints included intra-operative complications, early and late postoperative complications, dialysis-free survival (DFS), graft survival (GS), reintervention-free survival (RFS) and overall survival (OS).

Statistical Analysis

Categorical variables were analysed using the chi-squared test. Continuous variables were analysed using the two-sample independent *t*-test if normally distributed, or the Wilcoxon rank-sum test if non-normally distributed. Missing baseline data were imputed using multiple imputations with chained equations. The customary bias associated with the heterogeneity in baseline characteristics of OKT and RAKT was addressed using 2:1 nearest neighbour propensity-score matching without replacement (calliper: 0.1), estimated using logistic regression. The two treatments groups were matched for relevant preoperative characteristics: recipient age; ASA score; preemptive KT status; blood group compatibility; type of dialysis; and donor age. Balance was evaluated by calculating the *P* value and the standardised mean difference. Kaplan–Meier estimates and the log-rank test were used to compare results in terms of DFS, GS, RFS and OS.

Table 1 Baseline characteristics of 676 patients receiving open kidney transplantation and robot-assisted kidney transplantation from deceased donors.

Variables	Overall (*N* = 676 100%)	Unmatched cohort			Matched cohort		
		OKT (*N* = 637, 95%)	RAKT (*N* = 39, 5%)	*P* value	OKT (*N* = 72, 65%)	RAKT (*N* = 37, 35%)	*P* value
Recipients' features							
Age, median (IQR) years	53 (44–61)	53 (44–62)	48 (38–55)	*0.01*	47 (41–56)	48 (39–56)	0.8
Male, *n* (%)	420 (62)	397 (62)	23 (59)	0.8	48 (67)	23 (62)	0.7
ASA score, *n* (%)							
1–2	120 (17.8)	102 (16)	18 (46)	*<0.001*	25 (35)	16 (43)	0.5
3–4	555 (82.1)	534 (83.8)	21 (54)		47 (65)	21 (57)	
Missing	1 (0.1)	1 (0.2)	0		–	–	
CCI score (age unadjusted), *n* (%)							
0–2	560 (82.8)	530 (83.2)	30 (77)	0.5	61 (84.7)	28 (76)	0.3
3–5	114 (16.9)	105 (16.5)	9 (23)		10 (13.9)	9 (24)	
6–12	2 (0.3)	2 (0.3)	0		1 (1.4)	0	
BMI, median (IQR) kg/m^2	25 (22–28)	25 (22–28)	25 (22–27)	0.5	24 (21.9–27)	24.6 (21.9–27)	0.6
Previous abdominal surgery, *n* (%)	281 (42)	270 (42)	11 (28)	0.1	21 (29)	11 (29)	1
Smoking status, *n* (%)							
Never smoker	147 (21.7)	142 (22)	5 (12.8)	0.7	31 (43)	18 (49)	0.8
Previous smoker	109 (16.1)	107 (17)	2 (5.1)		20 (28)	9 (24)	
Active smoker	51 (7.5)	50 (8)	1 (2.6)		21 (29)	10 (27)	
Missing	369 (54.6)	338 (53)	31 (79.5)		–	–	
Preemptive KT status, *n* (%)	53 (7.8)	43 (7)	10 (26)	*<0.001*	15 (21)	9 (24)	0.8
Type of dialysis, *n* (%)							
No dialysis	53 (7.8)	43 (6.8)	10 (25.6)	*<0.001*	37 (51)	19 (51)	1
Haemodialysis	451 (66.7)	430 (67.5)	21 (53.8)		35 (49)	18 (49)	
Peritoneal dialysis	172 (25.4)	164 (25.7)	8 (20.5)		0	0	
Aetiology of ESRD, *n* (%)							
Diabetes mellitus	38 (5.6)	36 (6)	2 (5)	0.5	3 (4.2)	2 (5.4)	0.4
Hypertension	52 (7.7)	48 (7)	4 (10)		10 (13.9)	3 (8.1)	
Glomerulonephritis	128 (18.9)	121 (19)	7 (18)		14 (19.4)	6 (16.2)	
ADPKD	121 (17.9)	112 (18)	9 (23)		8 (11.1)	9 (24.3)	
Interstitial nephritis	9 (1.3)	8 (1)	1 (3)		1 (1.4)	1 (2.7)	
IgA nephropathy	43 (6.4)	38 (6)	5 (13)		4 (5.6)	5 (13.5)	
Others*	285 (42.2)	274 (43)	11 (28)		32 (44.4)	11 (29.7)	
Previous KT, *n* (%)	85 (12.6)	83 (13)	2 (5.1)	0.2	9 (12)	2 (5)	0.4
AB0 compatibility, *n* (%)	305 (45.1)	297 (46.6)	8 (20.5)	*0.002*	17 (23)	8 (21)	1
Donors' features							
Donor age, *n* (%)	53 (44–61)	53 (44–61.7)	48 (38–55)	*0.008*	47 (41–56)	48 (39–56)	0.7
Male sex, *n* (%)	203 (30)	183 (29)	20 (51)	0.9	36 (50)	20 (54)	0.8
Missing	300 (44)	299 (47)	1 (2.6)				
Type of donor, *n* (%)							
Deceased after brain death	623 (92.2)	587 (92.2)	36 (92.3)	1	58 (81)	34 (92)	0.9
Deceased after cardiac death	53 (7.8)	50 (7.8)	3 (7.7)		14 (19)	3 (8)	
Donor eGFR, median (IQR)	90 (66–104)	90 (65–103)	99 (79–109)	0.1	75 (48–104)	94 (53–108)	0.2

Italic values represent statistically significant results
*ADPKD, autosomal dominant polycystic kidney disease; ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson Comorbidity Index; eGFR, estimated glomerular filtration rate (mL/min/1.73 m^2); ESRD, end-stage renal disease; IgA, immunoglobulin A; IQR, interquartile range; KT, kidney transplantation; OKT, open kidney transplantation; RAKT, robot-assisted kidney transplantation; SMD, standardised mean difference. *Includes unknown and amyloidosis.*

Reported P values are two-sided; a P value $\leq$0.05 was taken to indicate statistical significance. Statistical analyses were performed using the latest version of the R software (version 4.4.2, R Foundation for Statistical Computing, Vienna, Austria, 2020).

Results

Baseline Characteristics

The demographic data and baseline characteristics of 676 donors and recipients are described in Table 1. The median age at surgery for donors was 53 years, and the median preoperative eGFR was 90 mL/min/1.73 m^2. Overall, 30% of donors were male (29% in the OKT group and 51% in the RAKT group).

For recipients, the median (interquartile range [IQR]) age at surgery was 53 (44–62) years for the OKT group and 48 (38–55) years for the RAKT group (P = 0.01). Male recipients comprised 62% of OKT and 59% of RAKT cases (P = 0.8). An ASA score of 1–2 was more frequent in the RAKT group (46% vs. 16% in the OKT group; P < 0.001), while Charlson Comorbidity Index scores were similar across groups. The median BMI was 25 kg/m^2 for both groups. Smoking status and preemptive KT status were not significantly different between groups, although more patients in the RAKT group were preemptive KT (26% vs. 7%; P < 0.001). The most common aetiology of ESRD was glomerulonephritis (19% in OKT vs. 18% in RAKT). Prior KT was less common in the RAKT group (5% vs. 13%; P = 0.2), and AB0 compatibility was observed in 47% of OKT and 21% of RAKT cases (P = 0.002).

After propensity-score matching, two groups of patients balanced for baseline characteristics were obtained.

Intra-operative Characteristics

Intra-operative data are summarised in Table 2. The left kidney was donated in 53% of cases overall (60% OKT vs 40% RAKT; P = 0.07). The vascular anatomy was comparable between groups, with 28% of cases having a single artery and vein.

The transplantation site was primarily the right iliac fossa for both groups (80% overall). Incision types differed significantly: Gibson incisions were used in 100% of OKT cases, while Pfannenstiel (68%) and peri-umbilical incisions (30%) were used in RAKT. The median surgical times were longer in RAKT (200 vs 180 min; P = 0.01). RAKT was linked with shorter rewarming time (39 vs 52 min), total anastomosis time (36 vs 55 min), arterial anastomosis time (17 vs. 25 min) and venous anastomosis time (18 vs. 28 min; all P < 0.001). Intra-operative complications were rare and similar in the two groups (6.4% overall).

Table 2 Surgical characteristics of 109 patients receiving open kidney transplantation and robot-assisted kidney transplantation from deceased donors.

Variables	Overall (*N* = 109, 100%)	OKT (*N* = 72, 65%)	RAKT (*N* = 37, 35%)	*P* value
Bench surgery				
Donor kidney side (left), *n* (%)	58 (53)	43 (60)	15 (40)	0.07
Vascular anatomy, *n* (%)				
1 artery, 1 vein	30 (27.5)	17 (23.6)	13 (35.1)	0.5
≥1 arteries, 1 vein	8 (7.3)	6 (8.3)	2 (5.4)	
1 artery, ≥1 veins	2 (1.8)	2 (2.8)	0	
Missing	69 (63.3)	47 (65.3)	22 (59.5)	
Ureteric anomalies, *n* (%)	1 (0.9)	1 (1.4)	0	1
KT				
Transplantation site: right iliac fossa, *n* (%)	87 (80)	59 (82)	28 (76)	0.8
Type of incision, *n* (%)				
Gibson	73 (67)	72 (100)	1 (2.7)	*0.02*
Peri-umbilical incision	11 (10)	0	11 (29.7)	
Pfannestiel incision	25 (23)	0	25 (67.6)	
Surgical time, median (IQR) min	185 (170–220)	180 (165–210)	200 (175–240)	*0.01*
WIT, median (IQR) min	2 (1–2)	2 (1–2)	1 (1–2)	0.5
CIT, median (IQR) min	900 (703.5–1080)	900 (720–1020)	900 (600–1140)	0.8
Rewarming time, median (IQR) min	47 (38–58)	53.5 (45–61)	39 (30–48)	*<0.001*
Total duration of the anastomosis, median (IQR) min	47 (38–58)	55 (47–60)	36 (29–44)	*<0.001*
Duration of arterial anastomosis, median (IQR) min	23 (17–28)	25 (23–31)	17 (15–21)	*<0.001*
Duration of venous anastomosis, median (IQR) min	23 (19–29)	28 (23–31)	18 (15–22)	*<0.001*
Time for vesico-ureteric anastomosis, median (IQR) min	19.5 (15–25)	20 (17–27)	15 (13–24)	0.3
Estimated blood loss, median (IQR) mL	160 (100–250)	195 (137–260)	150 (100–150)	0.2
Intra-operative complications, *n* (%)	7 (6.4)	6 (8.3)	1 (2.7)	0.4
Conversion to open surgery (if robotic approach), *n* (%)	1 (0.9)	–	1 (2.7)	–
Drainage placement, *n* (%)	88 (81)	58 (81)	30 (81)	1

Italic values represent statistically significant results
CIT, cold ischaemia time; IQR, interquartile range; KT, kidney transplantation; OKT, open kidney transplantation; RAKT, robot-assisted kidney transplantation; WIT, warm ischaemia time.

Table 3 Peri-operative data of 109 patients receiving open kidney transplantation or robot-assisted kidney transplantation from deceased donors.

Variable	Overall (N = 109, 100%)	OKT (N = 72, 65%)	RAKT (N = 37, 35%)	P value
Length of hospital stay, median (IQR) days	14 (10–22)	14 (11–24)	13 (10–17)	0.2
Days to drain removal, median (IQR)	3 (2–4.5)	2 (2–4)	4 (4–4)	0.8
Days to JJ stent removal, median (IQR)	36 (30–44)	34 (30–43)	39 (31–45)	0.1
Delayed graft function, n (%)	30 (27)	21 (29)	9 (24)	0.7
Postoperative graft biopsy, n (%)	21 (19)	14 (19)	7 (19)	0.7
Postoperative complications, n (%)	66 (61)	43 (60)	23 (62)	0.9
Early* postoperative complications, n (%)	63 (58)	41 (57)	22 (59)	0.9
Early* postoperative complications Clavien–Dindo grade ≥3, n (%)	9 (8.3)	5 (6.9)	4 (11)	0.7
Late† postoperative complications, n (%)	10 (9.2)	5 (6.9)	5 (13)	0.4
Late† postoperative complications Clavien–Dindo grade ≥3, n (%)	5 (4.6)	4 (5.6)	1 (2.7)	0.8

*IQR, interquartile range; OKT, open kidney transplantation; RAKT, robot-assisted kidney transplantation. *Early = within 30 days from kidney transplantation (KT). †Late = 31–90 days from KT.*

Table 4 Description of early (within 30 days) and late (31–90 days) postoperative complications according to the Clavien-Dindo classification in 109 patients undergoing open kidney transplantation or robot-assisted kidney transplantation from deceased donors.

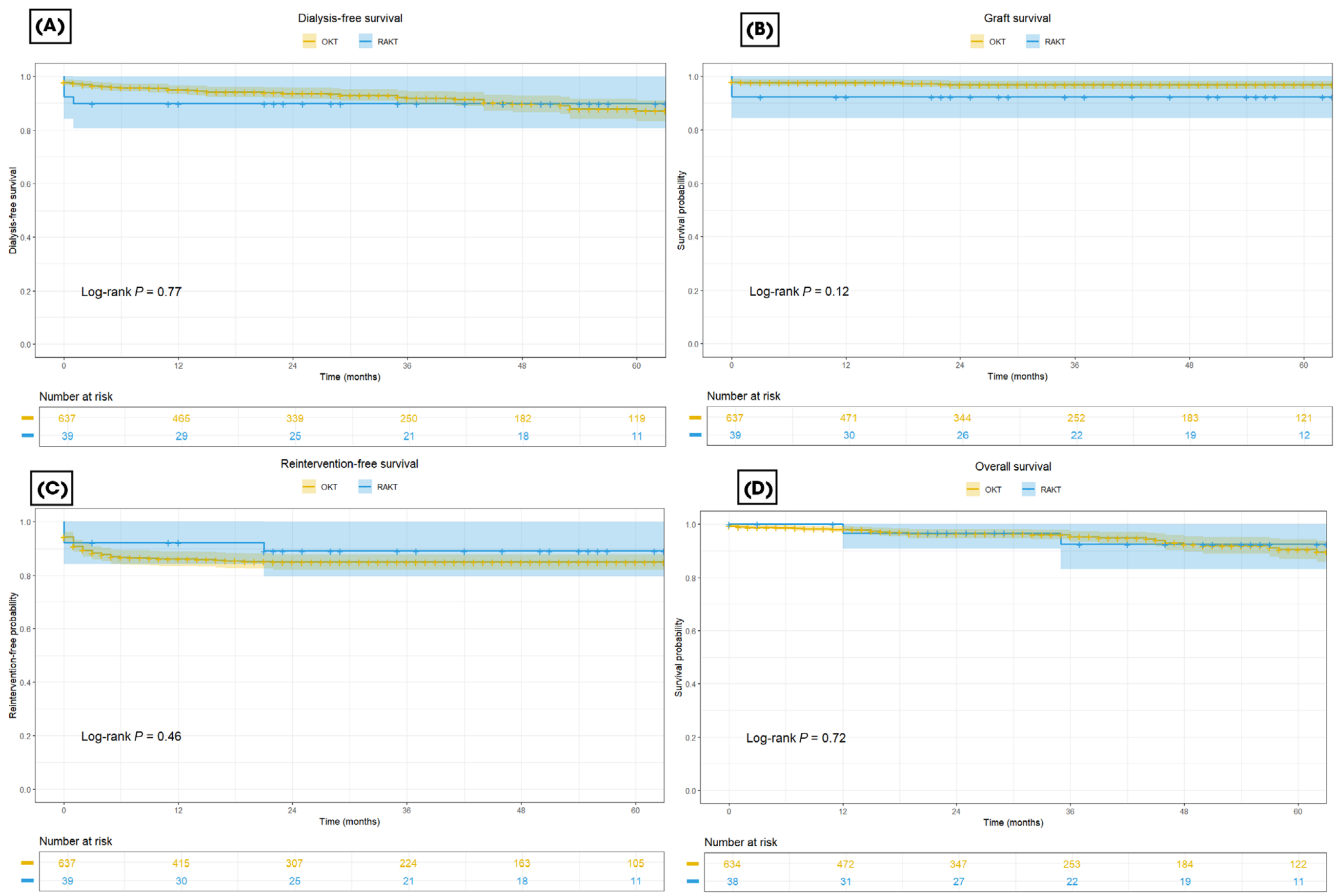
Complication type	Early postoperative complications				Late postoperative complications			
	Grades 1 and 2		Grades 3 and 4		Grades 1 and 2		Grades 3 and 4	
	OKT (N = 35)	RAKT (N = 16)	OKT (N = 5)	RAKT (N = 4)	OKT (N = 1)	RAKT (N = 5)	OKT (N = 4)	RAKT (N = 1)
Infective, n (%)								
UTI	6 (17.1)	4 (25)	–	–	–	1 (20)	–	–
Sepsis	1 (2.9)	–	–	–	–	–	–	–
CMV/BK infection	1 (2.9)	2 (12.5)	–	–	1 (100)	–	–	–
Cardiac, n (%)								
Myocardial infarction	–	–	2 (40)	–	–	–	–	–
Atrial fibrillation/flutter	1 (2.9)	–	1 (20)	–	–	–	–	–
Respiratory, n (%)								
Pneumonia	1 (2.9)	1 (6.3)	–	–	–	1 (20)	–	–
Surgical, n (%)								
Bleeding/haematoma	4 (11.4)	–	1 (20)	1 (25)	–	–	–	–
Ureteric stenosis	–	–	–	–	–	–	1 (25)	–
Lymphocele	1 (2.9)	2 (12.5)	–	–	–	–	3 (75)	–
Vascular, n (%)								
DVT/thromboembolic event	4 (11.4)	–	–	–	–	2 (40)	–	–
Graft venous thrombosis	–	–	1 (20)	1 (25)	–	–	–	–
Stenosis of renal artery	–	–	–	–	–	–	–	1 (100%)
Kidney graft infarction	1 (2.9)	–	–	–	–	–	–	–
Urogenital, n (%)								
Acute urinary retention	1 (2.9)	–	–	–	–	–	–	–
Functional								
Acute kidney injury	–	–	–	–	–	1 (20)	–	–
Acute rejection (graft nephrectomy)	–	–	–	2 (50%)	–	–	–	–
Acute rejection (graft biopsy)	1 (2.9)	–	–	–	–	–	–	–
DGF (need for dialysis)	5 (14.3)	3 (18.8)	–	–	–	–	–	–
General/systemic								
Anaemia (transfusions)	6 (17.1)	4 (25)	–	–	–	–	–	–
Neuropathic pain in the femoral area	1 (2.9)	–	–	–	–	–	–	–

Postoperative complications are reported as the worst complication per patient. CMV, cytomegalovirus; DGF, delayed graft function; DVT, deep vein thrombosis; IDC, intravascular disseminated coagulation; OKT, open kidney transplantation; RAKT, robot-assisted kidney transplantation.

Postoperative Data

The peri-operative outcomes are presented in Table 3. The median length of hospital stay was similar in the two groups (14 days OKT vs 13 days RAKT; P = 0.2), and DGF occurred in 27% of cases overall (29% OKT and 24% RAKT; P = 0.7). Postoperative complications occurred in 61% of cases (60% OKT vs 62% RAKT; P = 0.9). Early

Fig. 1 Kaplan–Meier curves with 60 months landmark estimating (**A**) dialysis-free survival, (**B**) graft survival, (**C**) reintervention-free survival and (**D**) overall survival in 109 patients undergoing open kidney transplantation (OKT) or robot-assisted kidney transplantation (RAKT) from deceased donors.



complications were seen in 58% (57% OKT vs. 59% RAKT; $P = 0.9$), with Clavien–Dindo grade ≥3 complications in 8.3% (6.9% OKT vs. 11% RAKT; $P = 0.7$). Late complications were slightly more frequent in RAKT (13% vs. 6.9% in OKT; $P = 0.4$). A detailed list of specific complications according to the Clavien–Dindo grade is reported in Table 4.

Functional Outcomes

There was no significant difference in early or long-term eGFR improvements between OKT and RAKT. At 30 days, the median (IQR) eGFR was 41 (29–59) mL/min/1.73 m^2 for RAKT vs 36 (22–51) mL/min/1.73 m^2 for OKT ($P = 0.1$). At a median follow-up of 36 (12–62) months, the median (IQR) eGFR was 60 (40–69) mL/min/1.73 m^2 for RAKT and 49 (35–65) mL/min/1.73 m^2 for OKT.

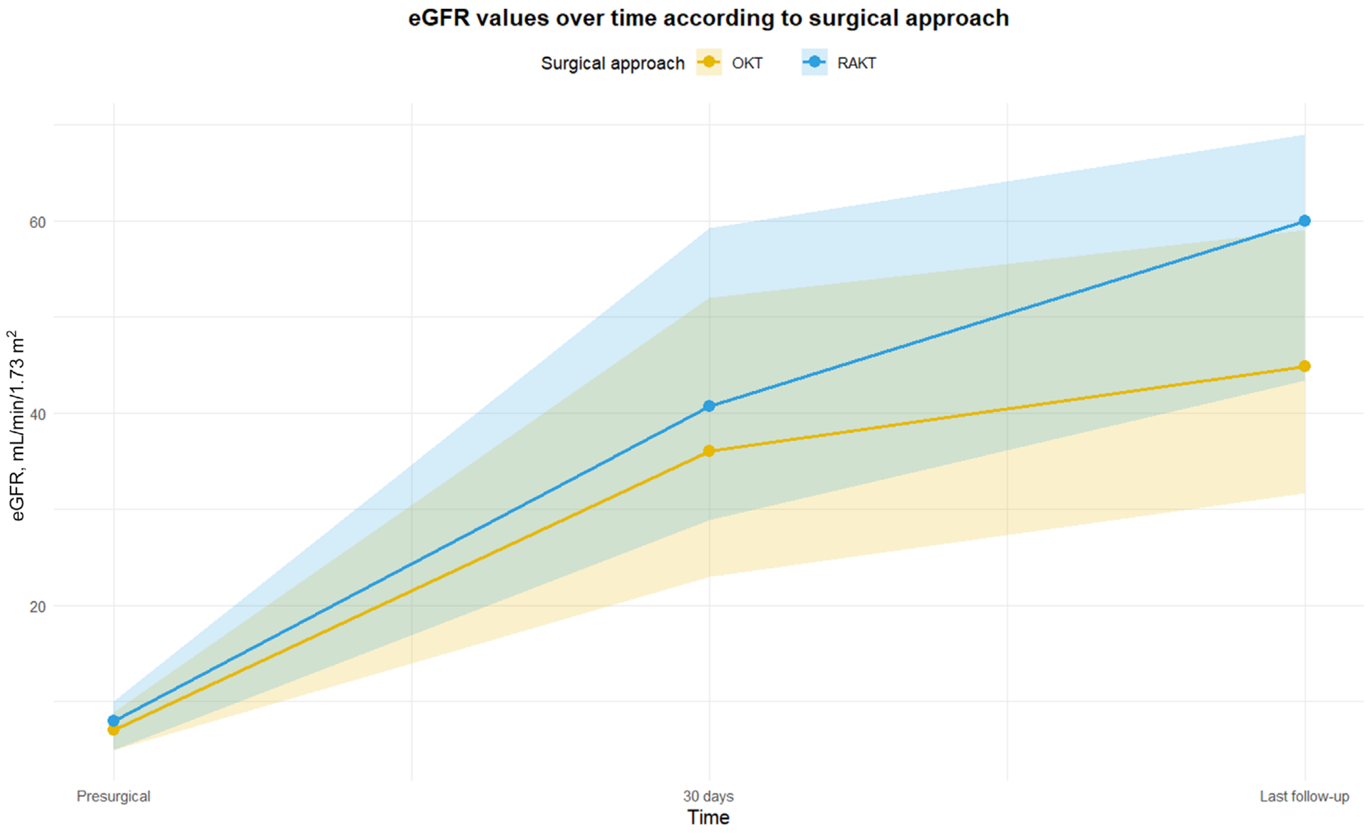
Follow-up Data

Kaplan–Meier estimates are displayed in Fig. 1. At a median follow-up of 36 months, there was no difference in terms of DFS, GS, RFS or OS between RAKT and OKT. There was no difference in terms of renal function between the two groups during follow-up, as shown in Fig. 2.

Discussion

For decades, OKT remained the 'gold standard' for managing ESRD [15]. The laparoscopic approach was later introduced, but its widespread adoption was hindered by the high technical complexity and a steep learning curve [16,17]. In contrast, there has been increasing interest in RAKT globally due to its minimally invasive nature, standardisation of the procedure, and increasing evidence supporting its safety and feasibility in complex scenarios [8,12,18]. However, its integration in the setting of deceased donor KT has been slow, mainly due to logistical issues [8]. In fact, KT from deceased donors might take place outside of the regular working schedule, therefore, adequately trained personnel or surgeons for the use of the robot might not be available. Moreover, the preclinical evaluation could be insufficient to guarantee the eligibility of a robot-assisted procedure. Lastly,

Fig. 2 Estimated glomerular filtration rate (eGFR) levels in 109 patients undergoing open kidney transplantation (OKT) or robot-assisted kidney transplantation (RAKT) from deceased donors.



even during daytime, the robotic platform might not be available due to concomitant and postponable robotic procedures. Otherwise, RAKT in the deceased donor setting has been tested in different institutions, providing similar results to OKT in terms of DGF [9,10].

To strengthen the evidence on RAKT in comparison with OKT in the deceased donor setting, we designed the first propensity-score matched study comparing surgical and functional results between the two techniques. Our study shows that OKT is a shorter operation, but rewarming time and time needed for vascular anastomosis tends to be longer in comparison with RAKT. Moreover, it shows that peri-operative rates of complications, DGF, and long-term functional outcomes tend to be similar between OKT and RAKT from deceased donors.

The importance of this work is severalfold. First, it shows that functional outcomes are the same for both RAKT and OKT; the surgical approach does not seem to influence either DGF or long-term DFS, GS, RFS and OS. Moreover, a significant improvement in renal function is to be expected over time both in RAKT and OKT. These results are in line with previous observations; as demonstrated by Petrochenkov et al. [10], the patterns of DGF seem to be similar in patients treated with RAKT and OKT, and dependent on the length of CIT.

Second, although the rate of late complications was slightly higher in RAKT (13% vs 7%), this difference was mainly driven by a greater number of Clavien–Dindo grade I–II complications in the RAKT group (10% vs 1.3%), including cases of pneumonia, UTI, deep vein thrombosis, and acute kidney injury. In contrast, Clavien–Dindo grade III–IV complications were more frequent in the OKT group (5.6% vs 3%), with ureteric stenosis and symptomatic lymphocele being predominant. These results might be attributable to the population selected for RAKT being typically more favourable and having fewer comorbidities, which may reduce the risk of complications.

Third, the performance of a vascular anastomosis tends to be faster with the robotic approach, probably owing to the stability of the surgical field and the easier technique used for the vascular anastomosis. Nonetheless, in our study this aspect did not seem to have a relevant impact on peri-operative surgical and functional outcomes. Therefore, its role needs to be further evaluated.

It is to be noted that in our work the median number of days to both drain and JJ stent removal were shorter for OKT in comparison to RAKT (2 vs 4 days and 34 vs 39 days). In the centres involved in this study, the removal of the JJ stent typically follows the same general timeline: after 3–4 weeks in RAKT and after approximately 1 month in OKT. Drain removal is generally performed when the output falls below 100 ml. However, in clinical practice, the actual timing is often left to the surgeon's discretion, which might explain the slight variability in timing observed.

Our study has some limitations. First, it was retrospective in nature, and thus exposed to a series of biases inherent to this type of design. Second, surgeons of different expertise performed OKT in the different centres; conversely, RAKT was performed with surgeons with high expertise in both OKT and RAKT. Third, although we adopted a matched pair analysis, some imbalances might have persisted for unmeasured confounders. Fourth, although RAKT is a standardised technique, some variations in the performance of OKT might have been present.

Nonetheless, this study is the first to adopt a matched cohort of patients and, as such, it should be regarded as the strongest evidence in terms of comparison between RAKT and OKT. Future efforts should be directed towards evaluating series from surgeons with similar levels of expertise and identifying which patients would benefit the most from a robotic approach vs the standard open technique.

In conclusion, RAKT and OKT demonstrated comparable short- and long-term functional outcomes for deceased donor KT. Complication rates tended to be similar between the two surgical approaches. Although RAKT was associated with reduced rewarming time and vascular anastomosis time, its peri-operative impact needs to be further investigated.

Disclosure of Interests

The authors declare that they have no conflict of interest.

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Ethics

This study did not contain any studies/experiments with human participants or animals performed by any of the authors. All persons gave their informed consent to use their data (deidentified).

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Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CIT, cold ischaemia time; DFS, dialysis-free survival; DGF, delayed graft function; eGFR, estimated glomerular filtration rate; ESRD, end-stage renal disease; GS, graft survival; IQR, interquartile range; KT, kidney transplantation; OKT, open kidney transplantation; OS, overall survival; RAKT, robot-assisted kidney transplantation; RFS, reintervention-free survival; WIT, warm ischaemia time.

