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ORIGINAL ARTICLE

Robotic-assisted kidney transplantation in obese recipients compared to non-obese recipients: the European experience

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Abstract

Purpose The main objective was to compare minor (Clavien I–II) and major (Clavien ≥ III) intra- and postoperative complications of living donor robotic assisted kidney transplantation (RAKT) in obese (≥ 30 kg/m^2 BMI), overweight (< 30/≥ 25 kg/m^2 BMI) and non-overweight recipients (< 25 kg/m^2 BMI).

Methods For the present retrospective study, we reviewed the multi-institutional ERUS-RAKT database to select consecutive living donor RAKT recipients. Functional outcomes, intra- and postoperative complications were compared between obese, overweight and non-overweight recipients.

Results 169 living donor RAKTs were performed, by 10 surgeons, from July 2015 to September 2018 in the 8 European centers. 32 (18.9%) recipients were obese, 66 (39.1%) were overweight and 71 (42.0%) were non-overweight. Mean follow-up was 1.2 years. There were no major intra-operative complications in either study group. Conversion to open surgery occurred in 1 obese recipient, in 2 overweight recipients and no conversion occurred in non-overweight recipients ($p = 0.3$). Minor and major postoperative complications rates were similar in the 3 groups. At one-year of follow-up, median eGFR was similar in all groups [54 (45–60) versus 57 (46–70) versus 63 (49–78) ml/min/1.73 m^2 in obese, overweight and non-overweight recipient groups, respectively, $p = 0.5$]. Delayed graft function rate was similar in the 3 groups. Only the number of arteries was an independent predictive factor of suboptimal renal function at post-operative day 30 in the multivariate analysis.

Conclusion RAKT in obese recipients is safe, compared to non-overweight recipients and yields very good function, when it performed at high-volume referral centers by highly trained transplant teams.

Keyword Obese patients · Kidney transplantation · Robot-assisted kidney transplantation · Robotic surgery · Vascular anastomosis

Abbreviations

BMI	Body Mass Index
CIT	Cold ischemia time
DGF	Delayed graft function
eGFR	Estimated glomerular function rate
ERUS	European robotic urological section
ESRD	End-stage renal disease
Hb	Hemoglobin
IDEAL	Innovation, development, exploration, assessment, long-term study
KT	Kidney transplantation
LSG	Laparoscopic sleeve gastrectomy
MDRD	Modified diet in renal disease
MRA	Multiple renal arteries
OKT	Open kidney transplantation
PE	Pulmonary embolism
POD	Post-operative day
RAKT	Robotic assisted kidney transplantation
RT	Rewarming time
SRA	Single renal artery
VAS	Visual Analog Scale
WIT	Warm ischemia time

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Introduction

The World Health Organization defines overweight and obesity as having a body mass index (BMI in kg/m^2) of ≥ 25 kg/m^2 and ≥ 30 kg/m^2, respectively. In 2016, more than 1.9 billion adults were overweight and over 650 million were obese [1]. According to the 2011 epidemiological data, 20–50% of patients on dialysis for end-stage renal disease (ESRD) were obese [2] and grade III obesity reduces the opportunity for male patients with ESRD to access transplantation [3].

Kidney transplantation (KT) in obese recipients presents several challenges related to surgical procedure. Indeed, several studies reported technical difficulties in KT surgeries in obese recipients with traditional open approaches [4] and a higher post-operative complication rate, including wound dehiscence, surgical site infection, and lymphocele formation [5]. Consequently, many transplant centers tend to contraindicate obese recipients of KT. However, compared to remaining on a waiting list, KT in obese recipients improves long-term survival [6] and enhances quality of life [7], even though morbid obesity is strongly associated with reduced long-term patient and graft survival, increased risk of DGF and acute rejection unlike non-obesity [8, 9].

The first case of robotic-assisted kidney transplantation (RAKT) in an obese recipient was reported by Giulianotti et al. [10]. Since then, RAKT with regional hypothermia has been developed to reduce the surgical morbidity of KT. Prospective study using the Innovation, Development, Exploration, Assessment, Long-term study (IDEAL) framework for assessing surgical innovations have demonstrated that RAKT with regional hypothermia accurately reflects the surgical principles of open kidney transplantation (OKT) while adding all the advantages of minimally invasive surgery [11]. Recently, Breda et al. [12] and Territo et al. [13] confirmed the feasibility, reproducibility and safety of RAKT when performed by skilled robotic surgeons. Robotic surgery presents several advantages, such as lower wound infection occurrence, a frequent complication of obese patients [14].

Recently, few studies from the University of Illinois at Chicago group (Garcia Roca et al. [15], Oberholzer et al. [14] and Spaggiari et al. [16]) have evaluated the feasibility and safety of RAKT in obese recipients in comparison with OKT. However, no studies have evaluated the feasibility and safety of RAKT in obese versus non-obese recipients.

The main objective of this present study, from the European Robotic Urological Section (ERUS) group, was to compare minor (Clavien I–II [17]) and major (Clavien ≥ III) intra- and postoperative complications of living donor RAKT, in obese recipients (≥ 30 kg/m^2 BMI), overweight recipients (< 30/ ≥ 25 kg/m^2 BMI) and non-overweight recipients (< 25 kg/m^2 BMI). The secondary objective was to compare functional results (delayed graft function, eGFR) between obese, overweight, and non-overweight recipients.

Patients and methods

Patients and database

The ERUS–RAKT Project has been previously described [12, 18]. After receiving approval from the Ethical Committee and informed consent from the patients, data were prospectively collected into the multi-institutional ERUS-RAKT common database. For this study, we reviewed our database to select consecutive living donor RAKT with regional hypothermia, between July 1st 2015 and September 30th 2018 at the 8 European Centers included in the ERUS-RAKT Project. We defined overweight and obesity as having a body mass index (BMI = weight in kg/m^2 height) ≥ 25 kg/m^2 and ≥ 30 kg/m^2, respectively. Computed tomography was performed for both recipients and donors in order to identify renal vascular anomalies and iliac artery atherosclerosis. All living donor nephrectomies (LDN) were minimal invasive surgical procedure (robotic assisted LDN or pure LDN).

Inclusion and exclusion criteria

Inclusion criteria for this study were: (a) ABO compatible living donor RAKT; (b) ABO incompatible living donor RAKT; (c) > 18 year of age. Exclusion criteria for this study were: a) deceased donor RAKT.

Study variables and outcomes

Surgical, intra-operative, and post-operative outcomes considered in this study have been previously described [12]. The first standardization of RAKT was described by Menon et al. [11] in the IDEAL phase 2a study. The surgical procedure was standardized in all participating centers. The pneumoperitoneum pressure during vascular anastomosis was 12 mmHg. After reperfusion, pressures were reduced to 7 mmHg. Warm ischemia time (WIT) was the period between renal circulatory arrest and the beginning of cold storage, during LDN. Cold ischemia time (CIT) was defined as the duration of cold storage, with or without perfusion, with a storage solution, before graft introduction into the recipient. Overall operative time was defined as the duration of the surgical procedure from incision to closure, including trocar placement and

intraoperative ultrasound. Console time was defined as the duration of the robotic surgical procedure.

Variables collected in the prospective database included recipient characteristics, graft characteristics, intraoperative parameters and postoperative parameters, with a one-year follow-up. The recipient data that were collected included: age (years), gender, BMI (kg/m^2), preemptive transplantation, median dialysis duration (days), preoperative creatinine level (µmol/l), glomerular function rate (eGFR) (ml/min/1.73 m^2), hemoglobin level (g/dl) and a medical history of high blood pressure. Graft data collected were: kidney location side and numbers of arteries, veins and ureters per kidney. The intraoperative data reviewed were: operative time (minutes), console time (minutes), arterial anastomosis time (minutes), venous anastomosis time (minutes), ureterovesical anastomosis time (minutes), warm ischemia time (minutes), cold ischemia time (minutes), estimated blood loss (milliliters), necessity of conversion to open surgery, and intraoperative complications. Intraoperative complications included intraoperative vascular injuries and the need for vascular anastomosis revision. The postoperative parameters collected included: serum creatinine (µmol/l), eGFR (ml/min/1.73 m^2) and hemoglobin (g/dl) on postoperative days (POD) 1, 3, 7, and 30. eGFR was calculated using the Modified Diet in Renal Disease (MDRD) equation [19]. Delayed graft function (DGF) was defined as a need for dialysis in the first postoperative week. Postoperative pain was evaluated using the visual analog scale (VAS) at 12, 24 and 48 h. Early (30 days) postoperative complications were reported according to the Clavien-Dindo classification [17].

Statistical analysis

Quantitative data were expressed as medians (interquartile range) and means (standard error of the mean) and qualitative data as numbers and proportions. Recipients' characteristics, graft characteristics, intraoperative, and postoperative outcomes were compared between obese, overweight and non-overweight recipients. Quantitative values were compared using the ANOVA tests. Qualitative values were compared with the χ^2 test or Fisher's exact test. A multivariate analysis was performed using the log-rank test for categorical variables and the Cox proportional-hazards model for continuous variables [relationships between donor-, recipient- or RAKT-related variables and POD-30 renal function (considered a continuous variable) were analyzed using the Pearson test]. All reported p values were two-sided with a significance level at $p < 0.05$. A statistical analysis was performed using S Prism 7.0a (GraphPad Software Inc, La Jolla, CA, USA) and SPSS 20.0 (SPSS Inc., Arlington, Virginia).

Results

Recipients characteristics

The characteristics of the recipients were summarized in Table 1. A total of 169 living donor RAKT with regional hypothermia were performed by 10 surgeons, from July 2015 to September 2018 in the 8 European centers. Of these, 32 (18.9%) recipients were obese (≥ 30 kg/m^2 BMI), 66 (39.1%) were overweight ($< 30/\geq 25$ kg/m^2 BMI) and 71 (42.0%) were non-overweight (< 25 kg/m^2 BMI). The mean follow-up was 1.2 years.

Overweight and non-overweight recipients were statistically younger than obese recipients [Median age (IQR): 54 (44–57) versus 49 (39–58) versus 38 (27–45) years in obese, overweight and non-overweight recipients groups, respectively, $p < 0.0001$]. The proportion of males was significantly higher in obese and overweight groups (20/32 (62.5%) versus 51/66 (77.3%) versus 24/71 (33.8%) in obese, overweight and non-overweight recipients groups, respectively, $p < 0.0001$). The median BMI (IQR) was 33 (30–35), 26 (25–28) and 22 (21–23) kg/m^2 in obese, overweight and non-overweight groups, respectively, $p < 0.0001$.

Graft characteristics

121 left kidneys and 48 right kidneys were used to perform RAKT. The proportion of right kidneys was similar in obese, overweight and non-overweight recipients. The number of arteries, veins and ureters per graft was similar in obese, overweight and non-overweight recipients. The graft characteristics were summarized in Table 2.

Intraoperative parameters

The intraoperative parameters were shown in Table 3. Overall operative time and console time were similar in obese, overweight and non-overweight recipients groups. The proportion of left recipient side was significantly higher in obese recipients group (16/32 (50%) versus 14/66 (21%) versus 15/71 (21%) in obese, overweight and non-overweight recipients groups, respectively, $p = 0.004$).

Median times to complete arterial, venous and ureterovesical anastomoses did not statistically differ between obese, overweight and non-overweight recipients, Fig. 1. LDN warm ischemia time and cold ischemia time were similar in the 3 groups. There were no major intra-operative complications (Clavien $\geq$ III) in either study group. Conversion to open surgery occurred in 1 obese recipient due to a difficult

Table 1 Recipient characteristics

	Overall population $n=169$	Obese recipients (≥ 30 kg/m^2 BMI) $n=32$	Overweight recipients ($<30/\geq 25$ kg/m^2 BMI) $n=66$	Non-overweight recipients (<25 kg/m^2 BMI) $n=71$	p
Age (years)					
Median (IQR)	43 (36–55)	54 (44–57)	49 (39–58)	38 (27–45)	**< 0.0001**
Mean (SEM)	44 (1)	52 (2)	48 (1)	38 (2)	
Sex					
Male (*n*, %)	95 (56.2%)	20 (62.5%)	51 (77.3%)	24 (33.8%)	**< 0.0001**
Female (*n*, %)	74 (43.8%)	12 (37.5%)	15 (22.7%)	47 (66.2%)	
BMI (kg/m^2)					
Median (IQR)	25 (22–28)	33 (30–35)	26 (25–28)	22 (21–23)	**< 0.0001**
Mean (SEM)	26 (0)	33 (0)	26 (0)	21 (0)	
Preemptive					
Yes (*n*, %)	98 (58.0%)	17 (53.2%)	40 (60.6%)	41 (57.7%)30	0.8
No (*n*, %)	71 (42.0%)	15 (46.9%)	26 (39.4%)	30 (42.3%)	
Dialysis duration (days)					
Median (IQR)	360 (120–420)	365 (8–365)	360 (75–660)	315 (150–420)	1
Mean (SEM)	408 (56)	386 (135)	414 (80)	415 (88)	
Medical history of high blood pressure (*n*, %)	29 (17.2%)	4 (12.5%)	11 (16.7%)	14 (19.7%)	0.7
Preoperative Hb (g/dl)					
Median (IQR)	11 (10–12)	11 (10–12)	11 (10–13)	11 (10–12)	0.7
Mean (SEM)	12 (1)	11 (0)	13 (2)	11 (0)	
Preoperative serum creatinine (µmol/l)					
Median (IQR)	522 (414–690)	511 (424–774)	525 (391–684)	524 (415–666)	0.9
Mean (SEM)	572 (18)	605 (44)	568 (31)	561 (26)	
Preoperative eGFR (ml/min/1.73 m^2)					
Median (IQR)	10 (7–13)	8.5 (6–13)	9 (7–12)	10 (7–13)	0.5
Mean (SEM)	9 (1)	10 (1)	11 (1)	10 (0)	

Bold values indicate $p < 0.05$

Table 2 Graft characteristics

	Overall population $n=169$	Obese recipients (≥ 30 kg/m^2 BMI) $n=32$	Overweight recipients ($<30/\geq 25$ kg/m^2 BMI) $n=66$	Non-overweight recipients (<25 kg/m^2 BMI) $n=71$	p
Donor kidney side					
Left (*n*, %)	121 (71.6%)	28 (87.5%)	46 (69.7%)	47 (66.2%)	0.08
Right (n, %)	48 (28.4%)	4 (12.5%)	20 (30.3%)	24 (33.8%)	
Number of arteries					
1 (*n*, %)	151 (89.3%)	29 (90.6%)	60 (90.9%)	62 (87.3%)	0.8
2 (*n*, %)	17 (10.1%)	3 (9.4%)	6 (9.1%)	8 (11.3%)	
3 (*n*, %)	1 (0.6%)	0 (0%)	0 (0%)	1 (1.4%)	
Number of veins					
1 (*n*, %)	167 (98.8%)	32 (100%)	66 (100%)	69 (97.2%)	0.2
2 (*n*, %)	2 (1.2%)	0 (0%)	0 (0%)	2 (2.8%)	
Number of ureters					
1 (*n*, %)	168 (99.4%)	32 (100%)	65 (98.5%)	71 (100%)	0.5
2 (*n*, %)	1 (0.6%)	0 (0%)	1 (1.5%)	0 (0%)	

Table 3 Intraoperative parameters

	Overall population $n=169$	Obese recipients (≥ 30 kg/m^2 BMI) $n=32$	Overweight recipients ($<30/\geq 25$ kg/m^2 BMI) $n=66$	Non-overweight recipients (<25 kg/m^2 BMI) $n=71$	p
Overall operative time (min)					
Median (IQR)	246 (215–350)	198 (161–243)	250 (220–350)	245 (210–342)	0.6
Mean (SEM)	246 (11)	202 (13)	264 (11)	261 (12)	
Console time (min)					
Median (IQR)	160 (121–190)	127 (101–188)	170 (118–190)	156 (134–200)	0.8
Mean (SEM)	159 (4)	147 (12)	160 (7)	162 (7)	
Recipient side					
Left (n, %)	45 (27%)	16 (50%)	14 (21%)	15 (21%)	**0.004**
Right (n, %)	124 (73%)	16 (50%)	52 (79%)	56 (79%)	
Arterial anastomosis time (min)					
Median (IQR)	18 (15–22)	19 (14–22)	20 (15–22)	18 (15–22)	0.7
Mean (SEM)	19 (1)	18 (1)	20 (1)	19 (1)	
Venous anastomosis time (min)					
Median (IQR)	20 (15–24)	19 (14–23)	20 (16–24)	20 (15–24)	0.7
Mean (SEM)	21 (1)	20 (1)	21 (1)	21 (1)	
Ureterovesical anastomosis time (min)					
Median (IQR)	21 (18–25)	20 (17–27)	21 (19–25)	21 (18–25)	1
Mean (SEM)	23 (1)	23 (2)	23 (1)	23 (1)	
LDN Warm Ischemia time (min)					
Median (IQR)	2 (2–4)	3 (2–4)	3 (2–4)	2 (2–4)	0.4
Mean (SEM)	3 (0)	3 (0)	3 (0)	3 (0)	
Cold ischemia time (min)					
Median (IQR)	26 (1–42)	34 (28–64)	15 (1–40)	12 (1–42)	0.1
Mean (SEM)	46 (9)	92 (35)	29 (6)	29 (6)	
Estimated blood loss (ml)					
Median (IQR)	125 (74–170)	100 (50–150)	130 (83–170)	150 (80–200)	0.5
Mean (SEM)	135 (8)	118 (16)	141 (14)	139 (11)	
Intraoperative complications					
Major (Clavien $\geq$ III) (n, %)	− 0 (0%)	− 0 (0%)	− 0 (0%)	− 0 (0%)	1
Bleeding (requiring blood transfusions) (n, %)	− 4 (2.4%)	− 1 (3.1%)	− 2 (3.0%)	− 1 (1.4%)	0.8
Conversion to open surgery (n, %): reason	3 (1.8%)	1 (3.1%): difficult graft placement	2 (3.0%): intraoperative bleeding	0 (0%)	0.3

Bold indicates $p < 0.05$

graft placement, in 2 overweight recipients because of intraoperative bleeding and no conversion occurred in non-overweight recipients ($p=0.3$). Bleeding requiring blood transfusion occurred in 1 obese recipient, in 2 overweight recipients and in 1 non-overweight recipient ($p=0.8$).

Postoperative parameters

The postoperative parameters are summarized in the Table 4. The postoperative serum creatinine values were similar in obese, overweight, and non-overweight recipients groups, except at POD 3 [Median (IQR) serum creatinine at POD 3: 202 (129–431) versus 155 (125–221) versus 127 (96–183) µmol/l in obese, overweight, and non-overweight recipient groups, respectively, $p=0.01$], Fig. 2. eGFR was statistically higher in overweight and non-overweight recipients groups at POD 3, POD 7 and POD 30. However, at one-year of follow-up, eGFR was similar in obese, overweight, and non-overweight recipients groups.

The change in hemoglobin levels were similar in obese, overweight, and non-overweight recipients groups, except

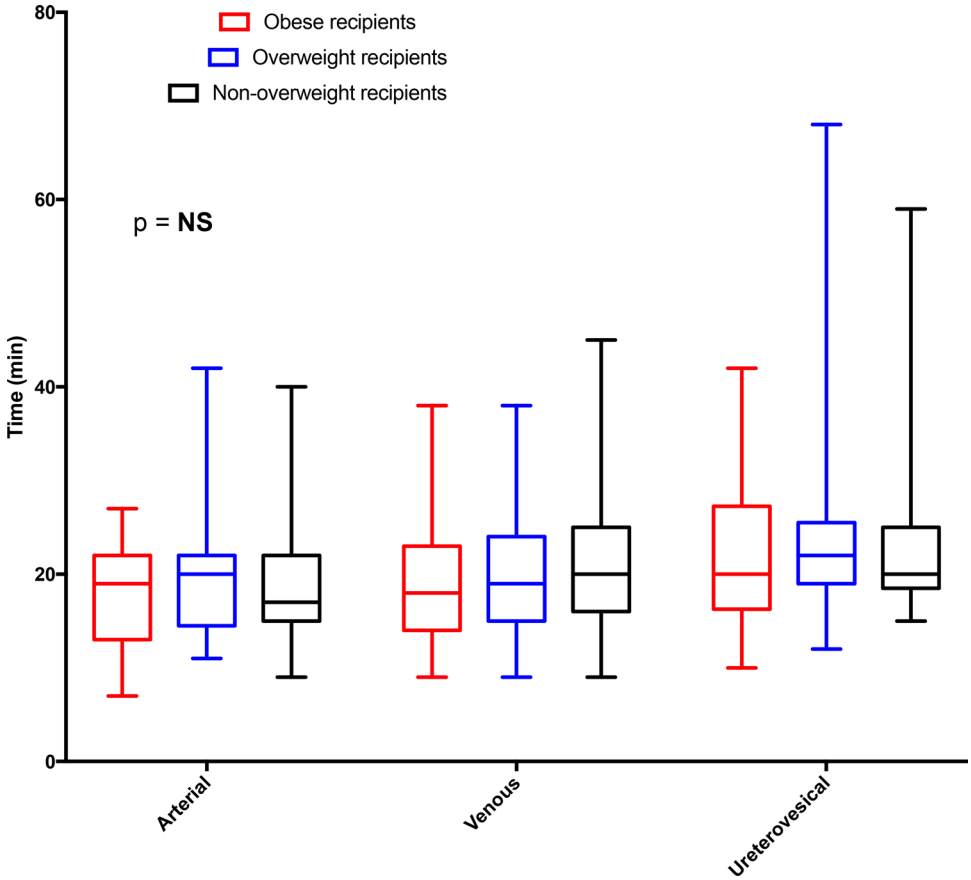

Fig. 1 Box plot showing median arterial, venous and ureterovesical anastomosis time in obese, overweight and non-overweight recipients (Median and IQR)

at POD 1 (Median (IQR) delta Hb values at POD 1: 0.7 (− 0.1–1.2) versus 0.3 (− 0.7–1.5) versus 1.1 (0–2.5) g/dl in obese, overweight, and non-overweight recipients, respectively, $p = 0.03$). The rates of delayed graft function and median POD JJ stent removal were similar.

In terms of minor complications (Clavien I–II), one wound infection occurred in each group. All wound infections required surgical drainage under local anesthesia with antibiotic treatment. One case of postoperative ileus was reported in the overweight recipient group, which was managed with a conservative approach (nasogastric tube). One case of pulmonary embolism was reported in the obese recipient group, which was managed with anticoagulation. Bleeding requiring transfusions occurred in 2 patients in the overweight recipients group and in 3 patients in the non-overweight recipient group. No cases occurred in obese recipients.

With regards to major complications (Clavien ≥ III), nephrostomy tube placement, due to ureterovesical anastomosis leakage, was performed in 1 obese recipient and in 1 overweight recipient. Percutaneous drainage of compressive pelvic lymphocele was performed in 1 case in the non-overweight recipient group. Graft nephrectomies, due to vascular thrombosis, occurred in 1 overweight recipient and in 2 non-overweight recipient. Surgical re-exploration, due to active bleeding, was performed in 1 obese patient and in 1 overweight patient. Radiologic embolization, due to active bleeding, was performed in 2 non-overweight recipients.

Data on functional outcomes on POD 30 were available for 107/169 patients (63.3%). Of these 107 patients, 25 had a suboptimal renal function on POD 30 (eGFR < 45 ml/min/1.73 m^2).

Age, BMI, the rate of patients with BMI > 30 kg/m^2 and the number of graft arteries were significant predictors of suboptimal renal function on POD 30 (Table 5) in the univariate analysis. Only the number of arteries was an independent predictive factor of suboptimal renal function (eGFR < 45 ml/min/1.73 m^2) on POD 30 in the multivariate analysis (Table 6).

The intra- and post-operative outcomes of RAKT performed in gender identical donor/recipient paired (male to male or female to female) versus in gender different donor/recipient paired (male to female or female to male) are summarized in the Supplementary Table 1. The recipient age, BMI and donor kidney side were similar in all groups. Postoperative outcomes (1-year recipient serum creatinine, 1-year recipient eGFR, DGF rate, minor and major postoperative complications rates) were similar in gender identical versus gender different.

Table 4 Postoperative parameters

	Overall population $n=169$	Obese recipients (≥ 30 kg/m^2 BMI) $n=32$	Overweight recipients (<30 / ≥ 25 kg/m^2 BMI) $n=66$	Non-overweight recipients (<25 kg/m^2 BMI) $n=71$	p
Serum creatinine (µmol/l)					
POD 3					
Median (IQR)	155 (111–221)	202 (129–431)	155 (125–221)	127 (96–183)	**0.01**
Mean (SEM)	210 (15)	291 (38)	218 (27)	163 (14)	
POD 7					
Median (IQR)	128 (101–160)	141 (115–322)	133 (107–165)	111 (91–148)	0.2
Mean (SEM)	174 (14)	223 (32)	169 (22)	155 (22)	
POD 30					
Median (IQR)	130 (100–155)	132 (106–158)	131 (108–156)	110 (97–152)	0.2
Mean (SEM)	147 (9)	149 (12)	166 (21)	128 (8)	
1-year					
Median (IQR)	120 (106–158)	125 (108–155)	120 (104–167)	124 (109–158)	0.5
Mean (SEM)	149 (16)	133 (11)	174 (43)	135 (8)	
eGFR (ml/min/1.73 m^2)					
POD 3					
Median (IQR)	44 (29–63)	31 (12–51)	42 (29–56)	56 (35–66)	**0.002**
Mean (SEM)	45 (2)	35 (4)	44 (3)	52 (3)	
POD 7					
Median (IQR)	53 (40–69)	45 (21–62)	50 (39–66)	61 (49–75)	**0.001**
Mean (SEM)	53 (2)	42 (4)	52 (3)	60 (2)	
POD 30					
Median (IQR)	61 (47–78)	51 (34–63)	60 (48–75)	73 (52–84)	**0.001**
Mean (SEM)	61 (2)	51 (4)	59 (3)	69 (3)	
1-year					
Median (IQR)	57 (48–71)	54 (45–60)	57 (46–70)	63 (49–78)	0.5
Mean (SEM)	59 (3)	54 (5)	58 (5)	62 (4)	
Delayed graft function rate n (%)	26 (15.4%)	6 (18.8%)	11 (16.7%)	9 (12.7%)	0.6
Delta Hb values (g/dl)					
Preoperative—POD 1					
Median (IQR)	0.7 (− 0.1–1.9)	0.7 (− 0.1–1.2)	0.3 (− 0.7–1.5)	1.1 (0–2.5)	**0.03**
Mean (SEM)	0.7 (0.2)	0.6 (0.3)	0.3 (0.3)	1.1 (0.2)	
Preoperative—POD 3					
Median (IQR)	1.3 (0.4–2.3)	1.3 (0.6–1.9)	1.2 (0.1–2.1)	1.7 (0.4–3.1)	0.2
Mean (SEM)	1.3 (0.1)	1.2 (0.3)	1.1 (0.2)	1.7 (0.2)	
Preoperative—POD 7					
Median (IQR)	1.1 (− 0.1–2.4)	1.1 (− 0.1–2.4)	0.9 (− 0.4–2)	1.6 (0.2–2.8)	0.2
Mean (SEM)	1.2 (0.2)	1.2 (0.4)	0.8 (0.2)	1.4 (0.2)	
Preoperative—POD 30					
Median (IQR)	− 0.9 (− 2.1–1.1)	− 0.6 (− 1.8–0.7)	− 1.1 (− 2.6–1.2)	− 0.3 (− 3.0–1.2)	0.7
Mean (SEM)	− 0.6 (0.3)	− 0.4 (0.5)	− 1.0 (0.5)	− 0.4 (0.6)	
JJ stent removal POD					
Median (IQR)	30 (28–39)	30 (15–41)	30 (28–39)	30 (29–40)	0.2
Mean (SEM)	32 (1)	26 (4)	34 (2)	32 (1)	
Early postoperative complications (POD 30) (Clavien-Dindo classification)					

Table 4 (continued)

	Overall population $n=169$	Obese recipients (≥ 30 kg/m^2 BMI) $n=32$	Overweight recipients (<30 / ≥ 25 kg/m^2 BMI) $n=66$	Non-overweight recipients (<25 kg/m^2 BMI) $n=71$	p
I					
Wound infection	3 (infections)	1 (infection)	1 (infection)	1 (infection)	0.8
Postoperative ileus	1 (ileus)	0 (ileus)	1 (ileus)	0 (ileus)	0.5
II					
Pulmonary embolism	1 (PE)	1 (PE)	0 (PE)	0 (PE)	0.1
Bleeding requiring transfusions	5 (transfusions)	0 (transfusions)	2 (transfusions)	3 (transfusions)	0.5
IIIa					
Nephrostomy tube placement	2 (nephrostomies)	1 (nephrostomy)	1 (nephrostomy)	0 (nephrostomy)	0.4
Percutaneous drainage of pelvic lymphocele	1 (percutaneous drainage)	0 (percutaneous drainage)	0 (percutaneous drainage)	1 (percutaneous drainage)	0.5
IIIb					
Graft nephrectomy (reason: vascular thrombosis)	3 (graft nephrectomies)	0 (graft nephrectomy)	1 (graft nephrectomy)	2 (graft nephrectomies)	0.6
Surgical re-exploration [reason: bleeding ($n=2$)]	2 (re-exploration)	1 (re-exploration)	1 (re-exploration)	0 (re-exploration)	0.4
Radiologic embolization	2 (radiologic embolization)	0 (radiologic embolization)	0 (radiologic embolization)	2 (radiologic embolization)	0.2

Bold values indicate $p < 0.05$

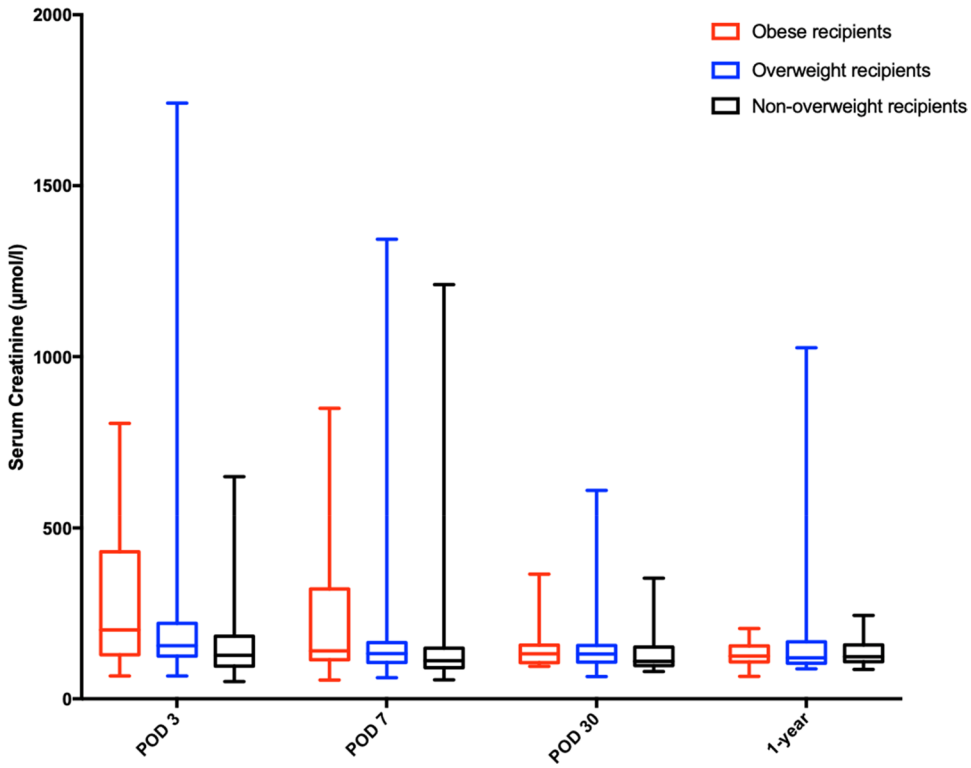

Fig. 2 Box plot showing serum creatinine levels (µmol/l) at POD 3, POD 7, POD 30 and at 1-year of follow-up in obese, overweight and non-overweight recipients (Median and IQR)

Table 5 Univariate analysis evaluating donor-, recipient- and surgery-related factors associated with suboptimal renal function on POD 30 (eGFR < 45 ml/min/1.73 m^2)

	Overall population $n = 107$	POD 30 < 45 ml/min eGFR group $n = 25$	POD 30 > 45 ml/min eGFR group $n = 82$	p
Sex				
Male (n, %)	70 (65.4%)	20 (80.0%)	50 (61.0%)	0.08
Female (n, %)	37 (34.6%)	5 (20.0%)	32 (39.0%)	
Age (years)				
Median (IQR)	45 (36–56)	50 (43–58)	43 (32–54)	**0.01**
Mean (SEM)	44 (1)	50 (2)	43 (1)	
BMI (kg/m^2)				
Median (IQR)	26 (23–30)	27 (24–32)	25 (22–29)	**0.006**
Mean (SEM)	26 (0)	29 (1)	26 (1)	
BMI > 30 kg/m^2 n, %	6 (5.6%)	5 (20.0%)	1 (1.2%)	**0.0003**
Preemptive				
Yes (n, %)	43 (40.2%)	11 (44.0%)	32 (39.0%)	0.7
No (n, %)	64 (59.8%)	14 (56.0%)	50 (61.0%)	
Cold ischemia time (minutes)				
Median (IQR)	33 (30–41)	30 (30–40)	33 (29–42)	0.2
Mean (SEM)	52 (8)	71 (30)	47 (6)	
LDN warm ischemia time (minutes)				
Median (IQR)	3 (2–4)	4 (2–5)	2 (2–4)	0.1
Mean (SEM)	3 (0)	3 (0)	3 (0)	
Delayed graft function n, %	22 (20.6%)	4 (16.0%)	18 (22.0%)	0.5
Number of graft arteries				
1 (n, %)	87 (81.3%)	16 (64.0%)	71 (86.6%)	**0.01**
2 (n, %)	20 (18.7%)	9 (36.0%)	11 (13.4%)	
Number of graft veins				
1 (n, %)	95 (88.8%)	22 (88.0%)	73 (89.0%)	0.9
2 (n, %)	12 (11.2%)	3 (12.0%)	9 (11.0%)	
Donor kidney side				
Left (n, %)	78 (72.9%)	18 (72.0%)	60 (73.2%)	0.9
Right (n, %)	29 (27.1%)	7 (28.0%)	22 (26.8%)	

Bold values indicate $p < 0.05$

Table 6 Multivariate analysis of preoperative criteria evaluating suboptimal renal function on POD 30 (eGFR < 45 ml/min/1.73 m^2)

	Odds ratio	95% CI	Z	p
Age	0.99	0.98–1.00	0.144	0.1
BMI	0.98	0.96–1.00	0.28	0.3
Number of arteries	0.71	0.55–0.94	0.01	**0.02**

Bold indicates$p < 0.05$

Discussion

Kidney transplantation is the best therapeutic option in patients with ESRD. In fact, survival is significantly higher in recipients compared to age-matched patients who are maintained on dialysis and age-matched patients who are awaiting KT [20]. However, grade III obesity reduces the opportunity for male patients with ESRD to access transplantation [3]. Indeed, Chan et al. [21] assessed by questionnaire the knowledge of nephrologists on how to asses and manage obesity in the context of ESRD. They reported that BMI limit for KT was most commonly 40 kg/m^2 (62%), followed by 35 kg/m^2.

In their recent systematic review and meta-analysis, Sood et al. [22] compared OKT in obese and non-obese recipients. They reported a higher risk of death [HR: 1.19 (95% CI, 1.10–1.31)], a higher rate of graft loss [HR: 1.54 (95% CI, 1.38–1.68)] and a higher rate of DGF [OR: 1.81 (95% CI, 1.51–2.13)] in obese recipients. However, in their systematic review, Khwaja et al. [23] concluded that obesity increase the risk of complications such as wound infections and delayed graft function, but in case of optimal

obese patients selection, KT ensures good outcomes post-transplantation with similar risks of graft failure than other recipient co-morbidities such as diabetes mellitus. These data are reinforced by the study of Krishnan et al. [24] evaluated the effect of BMI on mortality in transplanted patients and patients who remained on the waiting list in the United Kingdom. One- and five-year patient survival were significantly better in all BMI categories (<18.5, 18.5 to <25, 25 to <30, 30 to <35, 35 to <40, and $40+$ kg/m^2) in the transplant group when compared to those who remained on the waiting list ($p<0.0001$).

Therefore, several centers have proposed bariatric surgery before transplantation to optimize recipients and reduce time on the waiting list. In fact, Freeman et al. [25] presented the results of a prospective evaluation of laparoscopic sleeve gastrectomy (LSG) in obese recipients, prior to transplantation. The average preoperative BMI was 43.0 ± 5.4 kg/m^2 (range 35.8–67.7 kg/m^2). The last BMI recorded was 36.3 ± 5.3 kg/m^2 (range 29.2–49.8 kg/m^2) with 29 (55.8%) patients achieving a goal of a BMI <35 kg/m^2 at 92 days (range 13–420 days). The advantage of RAKT is that transplant surgery does not have to be delayed by first performing bariatric surgery. In fact, RAKT can be performed as soon as the donor and recipient are medically cleared and weight loss can be encouraged after the transplantation.

Our main postoperative outcomes were similar between obese, overweight and non-overweight recipients except for serum creatinine values at POD 3, which was higher in obese recipients. This may be explained by a higher DGF rate in the obese group even though the difference is not statistically significant. Three graft loss, due to vascular thrombosis occurred in the overall population. This 3 vascular thrombosis occurred at the beginning of the experience of the centers involved in RAKT. Actually, in order to prevent the risk of thrombosis, an intra-operative or immediate postoperative (on table) evaluation of graft reperfusion, using ultrasound is performed. Development of fluorescence vascular imaging will be interesting in this context.

We reported a DGF incidence in the overall population of 15.4%, which is higher than the DGF incidence reported in other RAKT studies in obese recipients (3% [15]; 3.6% [14, 16]). Redfield et al. [26] reported that CIT > 12-h, recipient female gender, right nephrectomy, and dialysis status were independent predictors of DGF in living-donor kidney transplantation. However, we reported shorter median CIT, similar recipient female gender rate and higher preemptive transplantation rate than other RAKT studies in obese recipients [14]. Marzouk et al. [27] reported that an anastomosis time > 29 min was associated with a 3.5 fold higher risk of DGF. In our series, median overall anastomosis time (venous and arterial) was about 40 min; which was shorter than overall anastomosis time reporter by Oberholzer et al. (47.7 min) [14]. Likewise, our median LDN warm ischemia time (2 min) was shorter than recent warm ischemia time reported [28].

Therefore, we have to consider a possible influence of high-pressure prolonged pneumoperitoneum on the DGF incidence. Indeed, the potential graft damage of pneumoperitoneum is not fully known. In their systematic review, Demyttenaere et al. [29] reported that both renal function and renal blood flow are decreased during pneumoperitoneum, potentially leading to graft impairment. These decreases depend on preoperative renal function, hydration, pneumoperitoneum pressure and duration. In all ERUS-RAKT centers, a pneumoperitoneum pressure of 12 mmHg during vascular anastomosis was used.

Moreover, in our study, the number of arteries was an independent predictive factor of suboptimal renal function (eGFR < 45 ml/min/1.73 m^2) on POD 30 in the multivariate analysis. The suboptimal renal function was determined according to previous studies on RAKT [18]. These findings are consistent with recent meta-analyses and systematic reviews that compare living-donor kidney transplantation with multiple renal arteries (MRAs) and single renal artery (SRA). Zorgdrager et al. [30] reported significantly more DGF (10.3% versus 8.2%, OR 1.333, $p=0.022$), higher complication rates (13.8% versus 11.0%, OR 1.393, $p<0.0001$), and a lower one-year graft survival rate (93.2% versus 94.5%, OR 0.819, $p=0.034$) with MRA grafts. Our MRA kidney transplants rate (10.7%) was higher than the rate reported by Oberholzer et al. (7.1%) [14].

In our series, in the case of MRAs, an ex-situ vascular reconstruction was performed according to the graft vascular anatomy: (1) conjoined (side-to-side) arterial anastomosis, (2) reimplantation (end-to-side) of a polar artery into the main artery, or (3) combination of these techniques in the event of greater than or equal to three renal arteries and/or complex vascular anatomy.

This study has several limitations; it is a retrospective study, although data were prospectively collected, with a limited sample size. Indeed, a limited number of recipients were included in the study. This can be explained by the cost limitations of the procedure and patient preference. We only evaluated the short-term perioperative and postoperative outcomes after RAKT. Considering that this series included all consecutive RAKTs since each center started performing this procedure, an inclusion bias might be present. In addition, RAKT was performed at high-volume referral centers by highly trained transplant teams. Therefore, our findings might not be generalizable to all clinical scenarios.

Our results provide a foundation for further research perspectives. However, while other studies have examined open versus robotic approaches for KT, this study addresses outcomes and safety solely of the robotic approach, based on BMI groups.

Conclusion

Living donor RAKT performed in obese recipients presents similar postoperative outcomes than living donor RAKT performed in overweight and non-overweight recipients. Since there is an increase in the number of obese patients on the waiting list, transplant centers must adapt to allow access to transplantation for obese patients.

Thus, living donor RAKT is a safe procedure and, in a properly selected group of obese patients, provides very good graft function and low complications rate.

BMI above 30 kg/m^2 and age above 50 years are potentials risk factors for postoperative outcomes and should be considered when counselling donors and recipients.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

Informed consent Patients have given prior consent.

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