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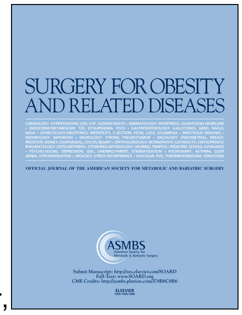

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Bariatric surgery before and after kidney transplantation: a propensity score-matched analysis

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Authorship

YF, LO, HJANK, JNMIJ and RCM participated in the research design.

YF, LO, AAEJ, JWHH and RAP performed acquisition of data.

YF, LO, HJANK and RCM participated in data analysis.

All authors were involved in writing the paper and had final approval of the submitted and published versions.

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Abstract

Background Obesity is becoming more prevalent in end-stage renal disease population. Bariatric surgery (BS) is increasingly considered in as an approach to become eligible for kidney transplantation (KT) or reduce obesity-related morbidities.

Objectives To assess short- and long-term outcome of patients who underwent both BS and KT and to determine the optimal timing of BS.

Setting Erasmus Medical Center and University Medical Center Groningen, the Netherlands.

Methods Patients who underwent both KT and BS between January 2000 and December 2020 were included and stratified according to the sequence of the two operations. The primary outcomes were patient and graft survival. Secondary outcomes were postoperative complications and efficacy of weight loss.

Results Twenty-two patients were included in the KT first group and 34 in the BS first group. Death-uncensored graft survival in the KT first group was significantly higher than the BS first group (90.9% vs. 71.4%, P=0.009), without significant difference in patient survival and death-censored graft survival (100% vs. 90.5%, P=0.082; and 90.9% vs. 81.0%, P=0.058). There was no significant difference in one-year total weight loss (1y TWL: median [IQR], 36.0 [28.0-42.0] vs. 29.6 [21.5-40.6] kg, P=0.424), one-year percentage of excess weight loss (1y %EWL: median [IQR], 74.9 [54.1-99.0] vs. 57.9 [47.5-79.4], P=0.155), and the incidence of postoperative complications (36.4% vs. 50.0%, P=0.316) between the KT first and BS first groups.

Conclusions Both pre- and post-transplant BS are effective and safe. Different conditions of each transplant candidate should be considered in detail to determine the optimal timing of BS.

Keywords bariatric surgery; weight loss; end-stage renal disease; kidney transplantation.

Introduction

Obesity, defined as a body mass index (BMI) ≥ 30 kg/m^2 is becoming more prevalent in patients with end-stage renal disease (ESRD).[1] Patients with obesity are predisposed to diabetic nephropathy, hypertensive nephrosclerosis and focal and segmental glomerulosclerosis, which accelerates the progression of chronic kidney failure.[2, 3] Moreover, although obesity is not an absolute contra-indication for kidney transplantation (KT), patients with obesity have reduced access to receive KT[4] since it is associated with a higher incidence of posttransplant complications, such as surgical site infection, new onset of diabetes after transplantation and delayed graft function (DGF).[5, 6]

Recent evidence suggests that bariatric surgery (BS) plays an effective role in achieving long-term weight loss and reducing obesity-related complications in kidney transplant patients.[7] To the kidney transplant recipients, BS improved renal function, graft survival and decreased obesity-related comorbidities such as diabetes mellitus and hypertension.[8, 9] To the kidney transplant candidates, BS has been proven to be effective in weight loss and improving eligibility for KT.[10-12] Meanwhile, the question on what is the optimal timing of BS in the kidney transplant population has not been answered unequivocally. A systematic review which enrolled 15 clinical studies with a total of 119 patients who underwent BS either before or after transplant showed that it was the safest to perform BS after transplant.[8] However, a certain group of patients also benefited from pre-transplant BS, as complication rates were acceptable and BS improved eligibility for kidney transplant.

To our knowledge, there has been no clinical trial to directly compare the outcomes of patients who underwent both operations in different order. The aim of this study is to assess short- and long-term outcomes of ESRD patients who underwent both BS and KT, trying to determine the optimal timing of BS for ESRD patients with obesity.

Materials and Methods

Study design

In this retrospective cohort study, all patients ≥18 years who have undergone both KT and BS between January 2000 and January 2020 were screened using the transplant database of Erasmus Medical Center (EMC) and University Medical Center Groningen (UMCG). All the individuals accepting BS prior to KT were to lose weight to be eligible for transplant. These patients were stratified into two groups according to the sequence of the two operations, group 1: patients who underwent KT before BS (KT first group), group 2: patients who underwent BS before KT (BS first group). A standardized immunosuppressive protocol was applied after transplantation. All patients had induction therapy with basiliximab (20mg) on postoperative day (POD) 0 and 4, tacrolimus (0.1mg per kg per day to maintain trough levels of 7-10ng/mL), mycophenolate mofetil (500mg twice daily) and prednisolone (20mg daily). ABO incompatible, cross-match positive, or high panel reactive antibody patients were treated according to local protocol. All patients were followed up until death or June 2021. All clinical data was obtained from the electronic patient dossier of EMC and UMCG. Patient demographics, co-morbidities, surgical details, postoperative complications and follow-up results were recorded. This study was approved by the Ethics Committee of the Erasmus Medical Center Rotterdam (MEC-2018-1699) and conducted in accordance with the provisions of the declaration of Helsinki.

Kidney transplantation related outcome

Patient and graft survival, duration of hospital stay and postoperative complications were analyzed. Patient survival was defined as the time from transplantation to death or the last follow-up. Uncensored graft survival was defined as the time from transplantation to graft failure or death or the last follow-up with a functioning graft. Death-censored graft survival was defined as the time from transplantation to graft failure or the last follow-up with a functioning graft, with censoring death with a functioning graft. Postoperative complications were recorded up to 90 days after transplantation except for the incidence of incisional hernia and rejection, which was recorded throughout the follow-up after transplantation. Allograft rejection was based on renal graft biopsy-proven diagnosis (Category 2, 3 and 4 according to Banff classification). DGF was defined as the need for dialysis in the first posttransplant week or failure of creatinine to decrease in the first 24 hours. Primary nonfunction (PNF) was defined as the absence of graft function immediately after transplantation and dialysis for 3 months post-transplant. Graft failure was defined as the need for retransplant or long-term dialysis.

Bariatric surgery related outcome

Efficacy of BS and postoperative complications were analyzed. Pre- and postoperative BMI, one-year total weight loss (TWL), and one-year percentage of excess weight loss (%EWL) were calculated to determine the efficacy. As a BMI of 25 was the upper limit of normal body weight, excess weight was defined as the extra weight over the BMI of 25.[13, 14] %EWL was calculated using the formula: $\frac{postoperative\ weight - preoperative\ weight}{preoperative\ excess\ weight} \times 100$. Postoperative complications were registered up to 90 days and classified according to the Clavien-Dindo classification.[15]

Statistical analysis

Baseline characteristics and both outcomes of KT and BS were compared between the two groups. Continuous variables were reported as mean ± standard deviation (SD) if normally distributed or median with interquartile range (IQR) if data was skewed using Kolmogorov-Smirnov test. Categorical variables were described as numbers and percentages. Continuous variables were compared using student's t-test or Mann–Whitney U test. Categorical variables were compared using χ^2 test or Fisher's exact test. Kaplan-Meier curves and log-rank test were used to compare patient and graft survival. Since the age at transplantation was statistically inconsistent between the two groups, the propensity score matching (PSM) was used to avoid the age-related bias when analyzing transplant related outcomes. The nearest neighbor-matching algorithm with a maximum caliper of 0.25 was used to match patients in KT first group with comparable patients in BS first group according to the age at transplantation. Statistical analyses and Kaplan-Meier curves were performed using Stata/SE 16.0. The bar graph was plotted using GraphPad Prism 9.3.1. A p-value of < 0.05 was considered statistically significant.

Results

Baseline characteristics

A total of 56 patients were eligible for the study, with 22 patients (77.3% female) in the KT first and 34 patients (67.6% female) in the BS first group. Baseline characteristics of these patients are shown in Table 1. The age at transplantation in the KT first group was significantly lower than the BS first group (42.7±8.6 vs. 52.5±10.0 years, P<0.001). 14 (63.6%) and 23 (67.6%) patients were dialysis dependent before transplantation in the KT first and BS first groups respectively with a similar dialysis vintage (median [interquartile range (IQR)], 27 [19.5-44.5] vs. 27 [20-43] months; P=0.822). A significantly higher proportion of patients in the KT first group received a retransplant compared to the BS first group (36.4% vs. 2.9%, P=0.002). No significant difference was found in the causes of ESRD, smoking history, donor sources and co-morbidities between the two groups. After PSM, 21 patients were included in the matched BS first group. There was no significant difference in age at transplantation (42.7 ± 8.6 vs. 48.3 ± 9.9 years, P<0.054) and the other baseline characteristics between the two groups (Table 1).

Kidney transplantation related outcome

The KT related complications are shown in Table 2. While not reaching statistical significance, the KT first group had a shorter duration of hospital stay compared to the matched BS first group (median [IQR], 10.5 [10.0-17.5] vs. 13.0 [10.0-15.0] days; P=0.788). The incidence of urological, vascular, incisional and cardio-cerebrovascular complications was similar between the matched BS first group and KT first group (RR, 1.29; 95%CI, 0.85-1.97; P=0.232; and RR, 0.84; 95%CI, 0.26-2.70; P=1.000; and RR, 1.31; 95%CI, 0.41-4.22; P=0.721; and RR, 2.10; 95%CI, 0.21-21.42; P=0.607, respectively). Within 30 days after transplantation, DGF occurred in 3 (13.6%) and 4 (19.0%) patients in the KT first and the matched BS first groups. PNF occurred in 1 (4.8%) patient in the matched BS first group.

Mean follow-up after KT was 9.4 years in the KT first group, and 4.4 years in the BS first group. During follow-up, 5 (22.7%) and 8 (38.1%) patients in the KT first and matched BS first groups were diagnosed with biopsy-proven rejection (RR, 1.68; 95%CI, 0.65-4.31; P=0.273). Two

(9.1%) grafts were lost in the KT first group due to chronic rejection, at 66.0 and 98.1 months after transplantation respectively. Four (19.0%) grafts were lost in the BS first group due to chronic rejection (n=2), PNF (n=1) and oxalate nephropathy (n=1), at 31.7, 68.6, 0.3 and 55.1 months after transplantation. All four were included after PSM. Four patients died in the BS first group with functioning grafts due to esophageal cancer (n=1), pneumosepsis (n=1), Covid-19 infection (n=1) and drug intoxication (n=1) respectively, and 2 cases were included in the matched BS first group. In the baseline groups, there was a significant difference in patient and graft survival (100% vs. 88.2%, P=0.041, Figure 1A; and 90.9% vs. 76.5%, P=0.009, Figure 1B), but not in death-censored graft survival (90.9% vs. 88.2%, P=0.130, Figure 1C). Whereas after PSM, graft survival was still significantly higher in the KT first group than in the matched BS first group (90.9% vs. 71.4%, P=0.009, Figure 1E), no statistical difference was found in patient survival and death-censored graft survival between the two groups (100% vs. 90.5%, P=0.082, Figure 1D; and 90.9% vs. 81.0%, P=0.058, Figure 1F).

Bariatric surgery related outcome

The BS related outcomes are shown in Table 3. In the KT first group, BS included sleeve gastrectomy (n=17) and Roux-en-Y gastric bypass (n=5). In the BS first group, they were sleeve gastrectomy (n=16), Roux-en-Y gastric bypass (n=16) and gastric banding (n=2). The age at BS was similar between the two groups (48.3±9.4 vs. 48.3±10.9 years, P=0.998). The preoperative BMI was not different between the KT first and BS first group (median [IQR], 39.7 [37.9-44.0] vs. 42.0 [40.0-45.8] kg/m^2, P=0.090). The median interval between KT and BS was 5.5 years (IQR 2.4-6.4) in the KT first group and 2.7 years (IQR 1.5-6.7) in the BS first group. Mean follow-up after BS was 3.8 years in the KT first group, and 8.7 years in the BS first group. After one year's follow-up the BMI of both groups was within the range of obesity but showed comparable reduction (30.1±6.5 vs. 32.0±4.1, P=0.215). There was no significant difference in one-year TWL and %EWL between the KT first and BS first groups (1y TWL: median [IQR], 36.0 [28.0-42.0] vs. 29.6 [21.5-40.6] kg, P=0.424; 1y %EWL: median [IQR], 74.9 [54.1-99.0] vs. 57.9 [47.5-79.4], P=0.155). Figure 2 illustrates the different types of BS performed between 2000 and 2020. Operations that were done in the early 2000s mainly included gastric bypass and adjustable gastric banding, while sleeve gastrectomy was not commonly used until 2009-2012. Obviously, over the last decade the sleeve has become the most common procedure.

Postoperative complications were classified according to the Clavien-Dindo classification (Table 4). Only grade I to III complications were found in both groups and there was no significant difference in the incidence of each grade and total complications (KT first vs. BS first, grade I: 18.2% vs. 8.8%, P=0.415; grade II: 13.6% vs. 14.7%, P=1.000; grade IIIa: 0% vs. 2.9%, P=1.000; grade IIIb: 4.5% vs. 23.5%, P=0.074; total: 36.4% vs. 50.0%, P=0.316).

Discussion

In this retrospective cohort study, we compared baseline characteristics, postoperative complications, and outcomes between patients with either a KT first or BS first approach. Our analysis showed that death-uncensored graft survival in the KT first group was significantly higher than the BS first group, but there was no significant difference in patient survival, death-censored graft survival or post-transplant complications. Both pre- and post-transplant BS achieved remarkable weight loss and the incidence of postoperative complications is acceptable. Ideally, BS should be initiated as early as possible. A randomized clinical trial by Cohen et al. showed that BS is associated with remission of albuminuria and improvement of renal function in patients with early-stage chronic kidney disease, which may help patients eventually avoid KT.[16] However, when it comes to patients with ESRD, another study showed that BS only improved transplant candidacy and stable weight loss, but not renal function[17]. Moreover, pre-transplant BS may have prolonged time on dialysis to establish sufficient weight loss and recover from long-term complications, which remains an independent predictor of mortality after KT.[18] When transplant is technically feasible despite being overweight, patients with an expected long waiting time because of blood type O or B, might decide to have BS first. However, because kidney donors are so scarce, the opportunity to receive a donor kidney may often postpone the consideration of BS. In our study, patients with severe obesity (BMI ≥ 40 kg/m^2) were more likely to have BS before transplant, which caused higher baseline BMI in the BS first group. During the long-term follow-up, four patients in the BS first group died. On this basis, we directly compared the outcomes of patients who underwent BS before and after KT. Our results demonstrated that the difference in mortality was not statistically significant, but death-uncensored graft survival was significantly higher in the cohort with post-transplant BS. In the recently published study comparing pre- and post-transplant BS with matched controls respectively, Cohen et al. found that mortality was significantly lower in the patients with post-transplant BS, but not the pre-transplant BS.[19] Although the findings of the two studies are different, both show that patients undergoing BS after KT benefit more.

Roux-en-Y gastric bypass, as one of the bariatric surgeries, aims to induce decreased absorption of nutrients in the small intestine. This raises the concern of malabsorption of immunosuppressive agents in transplant recipients. A pilot study by Rogers et al. showed that transplant recipients with gastric bypass surgery required higher dosage of immunosuppressive agents to maintain similar concentrations compared to non-bypass patients.[20] The study by

Yemini et al. observed that tacrolimus blood concentrations declined slightly but remained within therapeutic range without serious rejection among transplanted patients who underwent laparoscopic Roux-en-Y gastric bypass.[21] However, it is not advisable to increase the tacrolimus dose solely based on bodyweight. Our previous experience found that such practices resulted in overexposure in more than half of overweight patients.[22] In this data, graft rejection occurred in 7 (33.3%) patients receiving Roux-en-Y gastric bypass and 8 (32.0%) patients receiving other types of BS (RR 1.04, 95% CI 0.45-2.39, P=0.923). Although not significantly different, more research into the pharmacokinetics of immunosuppressive agents among transplant recipients with obesity is needed.

Another potential complication of BS is the formation of calcium oxalate stones in the kidneys. Obesity itself can increase the risk of kidney stone formation.[23] Furthermore, Roux-en-Y gastric bypass is associated with oxalate nephropathy and graft loss.[24, 25] In a systematic review evaluating the risk of hyperoxaluria in patient who underwent BS, it was concluded that Roux-en-Y gastric bypass was associated with increased urine oxalate and these patients had a significantly higher risk of stone formation.[26] In our study, oxalate deposits were found in four patients, all of whom had undergone Roux-en-Y gastric bypass. One of them lost the graft due to oxalate nephropathy. For this reason, sleeve gastrectomy may be a preferred choice compared to Roux-en-Y gastric bypass. Dietary interventions such as a low oxalate and salt diet show promising results in decreasing oxaluria and calcium oxalate relative supersaturation indexes.[27] Our colleagues first proposed that a systematic low-oxalic acid diet with supplementation of calcium, cholestyramine and sodium bicarbonate and intensifying dialysis effectively prevented oxalate nephropathy in a cohort of patients with enteric hyperoxaluria.[28] It may be beneficial for the transplant candidates and recipients who have undergone Roux-en-Y gastric bypass to adhere to such a low-oxalic acid diet.

Due to the introduction of minimally invasive and robotic surgery, it is currently possible to perform robot-assisted kidney transplantation (RAKT). By RAKT, the graft is placed in the abdominal cavity through a Pfannenstiel incision, and vascular and ureteral anastomoses are then performed robotically. Although the Pfannenstiel incision seems the same length as the open surgery, RAKT has its own advantages in specific populations. For patients with centripetal obesity, it provides more flexible operation space in the pelvic region while the operative area of iliac fossa is difficult to expose due to abdominal fat accumulation using open surgical approach. With the help of RAKT, patients who were previously declined may have the opportunity of transplant. Spaggiari et al. were the first to publish their randomized trial in which 11 patients underwent simultaneous robotic-assisted kidney transplantation and sleeve gastrectomy.[29] Compared to patients with class II (BMI 35-39.9 kg/m^2) and class III obesity (BMI $\geq$ 40 kg/m^2) who received RAKT alone, estimated blood loss, readmission rates, incidence of surgical complications and graft survival at one-year follow-up were comparable. Also, renal graft function was similar, indicating that performing kidney transplantation and sleeve gastrectomy simultaneously does not have a negative effect on graft function. As long-term data is not yet available, it is premature to conclude that simultaneous KT and BS should become the gold standard in ESRD patients.

Our study is limited by several factors. Firstly, the present study is a retrospective cohort analysis, of which a potential selection bias is unavoidable. To minimize this bias, we combined the data of two high volume transplant centers, which resulted in one of the largest cohorts of ESRD patients who underwent both BS and KT. However, the baseline BMI of patients in the

BS first group was still higher and they may have a potentially higher risk of postoperative complications. Secondly, in this population of ESRD patients with obesity, some died after BS while awaiting KT. Unfortunately, these data were not collected prospectively. Thirdly, as the study involves patients over a 21-year period, the safety and public acceptance of BS have been tremendously improved. This dynamic change should be also taken into consideration when evaluating the robustness of the results.

Conclusions

In conclusion, both pre- and post-transplant BS are effective and safe approaches to lose weight among ESRD patients. The optimal timing of BS should be individualized, the severity of obesity, expected waiting time and willingness of patients should all be considered. With the major advances in robotic surgery, simultaneous KT and BS may become an additional option in the future. Nonetheless, careful attention should be warranted in both preoperative evaluation and postoperative management and more studies are needed to elucidate the optimal treatment for this group of patients.

Disclosure: All authors declare no conflicts of interest.

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Table 1. Clinical characteristics at the time of transplantation

BMI, body mass index; BS, bariatric surgery; ESRD, end-stage renal disease; IQR, interquartile range; KT, kidney transplantation.

Table 2. Postoperative complications after transplantation

BS, bariatric surgery; DGF, delayed graft function; KT, kidney transplantation; NODAT, new onset diabetes mellitus after transplantation; PNF, primary nonfunction; UTI, urinary tract infection.

Table 3. Clinical outcomes at and after bariatric surgery

BS, bariatric surgery; BMI, body mass index; GB, gastric banding; IQR, interquartile range; KT, kidney transplantation; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; TWL, total weight loss; %EWL, the percentage of excess weight loss

Table 4. Postoperative complications after bariatric surgery according to the Clavien-Dindo classification

Figure 1 Before propensity score matching (PSM): A. Patient survival, B. Graft survival, C. Death-censored graft survival. After PSM: D. Patient survival, E. Graft survival, F. Death-censored graft survival. Kaplan-Meier method was used to assess patient and graft survival from the time of transplantation. P-values according to log-rank test. The blue curve represents the group who underwent kidney transplantation after bariatric surgery, and the red curve represents the group who underwent kidney transplantation prior to bariatric surgery.

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Figure 2. Number of bariatric surgeries undertaken in different periods.

GB, gastric banding; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

Table 1. Clinical characteristics at the time of transplantation

	Before matching			After matching		
	KT first (n=22)	BS first (n=34)	P-value	KT first (n=22)	BS first (n=21)	P-value
Age at KT (years), mean ± SD	42.7 ± 8.6	52.5 ± 10.0	< 0.001	42.7 ± 8.6	48.3 ± 9.9	0.054
Male, n (%)	5 (22.7)	11 (32.4)	0.436	5 (22.7)	6 (28.6)	0.661
BMI at KT (kg/m^2), mean ± SD	35.8 ± 4.0	32.1 ± 4.4	0.002	35.8 ± 4.0	31.8 ± 4.5	0.003
Cause of ESRD, n (%)			0.234			0.213
Diabetes mellitus	8 (36.4)	17 (50.0)		8 (36.4)	13 (62.0)	
Primary hypertension	2 (9.1)	5 (14.7)		2 (9.1)	0 (0)	
Glomerulonephritis	4 (18.2)	7 (20.6)		4 (18.2)	4 (19.0)	
Congenital nephropathy	5 (22.7)	5 (14.7)		5 (22.7)	4 (19.0)	
Others	3 (13.6)	0 (0)		3 (13.6)	0 (0)	
Smoking history, n (%)	9 (40.9)	9 (26.5)	0.259	9 (40.9)	3 (14.3)	0.052
Dialysis, n (%)	14 (63.6)	23 (67.6)	0.757	14 (63.6)	16 (76.2)	0.370
Duration on dialysis (months), median (IQR)	27 (19.5-44.5)	27 (20-43)	0.988	27 (19.5-44.5)	29.5 (18.5-53.5)	0.822
Donor source, n (%)			0.289			0.168
Living-related	16 (72.7)	20 (58.8)		16 (72.7)	11 (52.4)	
Deceased	6 (27.3)	14 (41.2)		6 (27.3)	10 (47.6)	
Transplantation, n (%)			0.002			0.021
First transplant	14 (63.6)	33 (97.1)		14 (63.6)	20 (95.2)	
Retransplant	8 (36.4)	1 (2.9)		8 (36.4)	1 (4.8)	
Co-morbidities, n (%)						
Diabetes mellitus	8 (36.4)	21 (61.8)	0.063	8 (36.4)	13 (61.9)	0.094
Hypertension	13 (59.1)	23 (67.6)	0.514	13 (59.1)	13 (61.9)	0.850
Cardiac disease	9 (40.9)	17 (50.0)	0.505	9 (40.9)	7 (33.3)	0.607
Cerebrovascular disease	0 (0)	1 (2.9)	1.000	0 (0)	1 (4.8)	0.488
Peripheral vascular disease	6 (27.3)	4 (11.8)	0.167	6 (27.3)	2 (9.5)	0.240
Respiratory disease	3 (13.6)	6 (17.6)	1.000	3 (13.6)	3 (14.3)	1.000
Malignancy	0 (0)	2 (5.9)	0.514	0 (0)	1 (4.8)	0.488

BMI, body mass index; BS, bariatric surgery; ESRD, end-stage renal disease; IQR, interquartile range; KT, kidney transplantation.

Table 2. Postoperative complications after transplantation

	Before matching				After matching			
	KT first (n=22)	BS first (n=34)	RR (95% CI)	P-value	KT first (n=22)	BS first (n=21)	RR (95% CI)	P-value
Duration of hospital stay (days), median (IQR)	10.5 (10.0-17.5)	12.5 (8.8-17.0)	-	0.619	10.5 (10.0-17.5)	13.0 (10.0-15.0)	-	0.788
Urological complications, n (%)	13 (59.1)	24 (70.6)	1.20 (0.79-1.80)	0.375	13 (59.1)	16 (76.2)	1.29 (0.85-1.97)	0.232
UTI	7 (31.8)	13 (38.2)	1.20 (0.57-2.53)	0.625	7 (31.8)	8 (38.1)	1.20 (0.53-2.72)	0.666
Urinary leak	2 (9.1)	4 (11.8)	1.29 (0.26-6.48)	1.000	2 (9.1)	2 (9.5)	1.05 (0.16-6.77)	1.000
Hydronephrosis	1 (4.5)	2 (5.9)	1.29 (0.13-13.43)	1.000	1 (4.5)	2 (9.5)	2.10 (0.21-21.42)	0.607
Ureteric stricture	3 (13.6)	3 (8.8)	0.65 (0.14-2.92)	0.670	3 (13.6)	2 (9.5)	0.70 (0.13-3.77)	1.000
Hematuria	0 (0)	2 (5.9)	-	0.514	0 (0)	2 (9.5)	-	0.233
Vascular complications, n (%)	5 (22.7)	5 (14.7)	0.65 (0.21-1.98)	0.491	5 (22.7)	4 (19.0)	0.84 (0.26-2.70)	1.000
Renal artery thrombosis	3 (13.6)	1 (2.9)	0.22 (0.02-1.94)	0.289	3 (13.6)	0 (0)	-	0.233
Perigraft bleeding	1 (4.5)	2 (5.9)	1.29 (0.13-13.43)	1.000	1 (4.5)	2 (9.5)	2.10 (0.21-21.42)	0.607
Lymphocele	1 (4.5)	2 (5.9)	1.29 (0.13-13.43)	1.000	1 (4.5)	2 (9.5)	2.10 (0.21-21.42)	0.607
Incisional complications, n (%)	4 (18.2)	13 (38.2)	2.10 (0.79-5.63)	0.111	4 (18.2)	5 (23.8)	1.31 (0.41-4.22)	0.721
Incisional hernia	2 (9.1)	6 (17.6)	1.94 (0.43-8.77)	0.460	2 (9.1)	2 (9.5)	1.05 (0.16-6.77)	1.000
Surgical wound dehiscence	0 (0)	5 (14.7)	-	0.145	0 (0)	3 (14.3)	-	0.108
Surgical site infection	1 (4.5)	2 (5.9)	1.29 (0.13-13.43)	1.000	1 (4.5)	0 (0)	-	1.000
Abdominal wall infection	1 (4.5)	0 (0)	-	0.393	1 (4.5)	0 (0)	-	1.000
Cardio-cerebrovascular complications, n (%)	1 (4.5)	3 (8.8)	1.94 (0.22-17.50)	1.000	1 (4.5)	2 (9.5)	2.10 (0.21-21.42)	0.607
Angina pectoris	0 (0)	1 (2.9)	-	0.393	0 (0)	0 (0)	-	-
Atrial fibrillation	0 (0)	2 (5.9)	-	1.000	0 (0)	2 (9.5)	-	0.233
Transient ischemic attack	1 (4.5)	0 (0)	-	0.514	1 (4.5)	0 (0)	-	1.000
Others, n (%)	10 (45.5)	18 (52.9)	1.17 (0.67-2.03)	0.584	10 (45.5)	13 (61.9)	1.36 (0.77-2.40)	0.280
Rejection	5 (22.7)	10 (29.4)	1.29 (0.51-3.28)	0.581	5 (22.7)	8 (38.1)	1.68 (0.65-4.31)	0.273
DGF	3 (13.6)	4 (11.8)	0.86 (0.21-3.49)	1.000	3 (13.6)	4 (19.0)	1.40 (0.35-5.51)	0.698
PNF	0 (0)	1 (2.9)	-	1.000	0 (0)	1 (4.8)	-	0.488
NODAT	1 (4.5)	2 (5.9)	1.29 (0.13-13.43)	1.000	1 (4.5)	0 (0)	-	1.000
Anemia	1 (4.5)	1 (2.9)	0.65 (0.04-9.82)	1.000	1 (4.5)	0 (0)	-	1.000

BS, bariatric surgery; DGF, delayed graft function; KT, kidney transplantation; NODAT, new onset diabetes mellitus after transplantation; PNF, primary nonfunction; UTI, urinary tract infection.

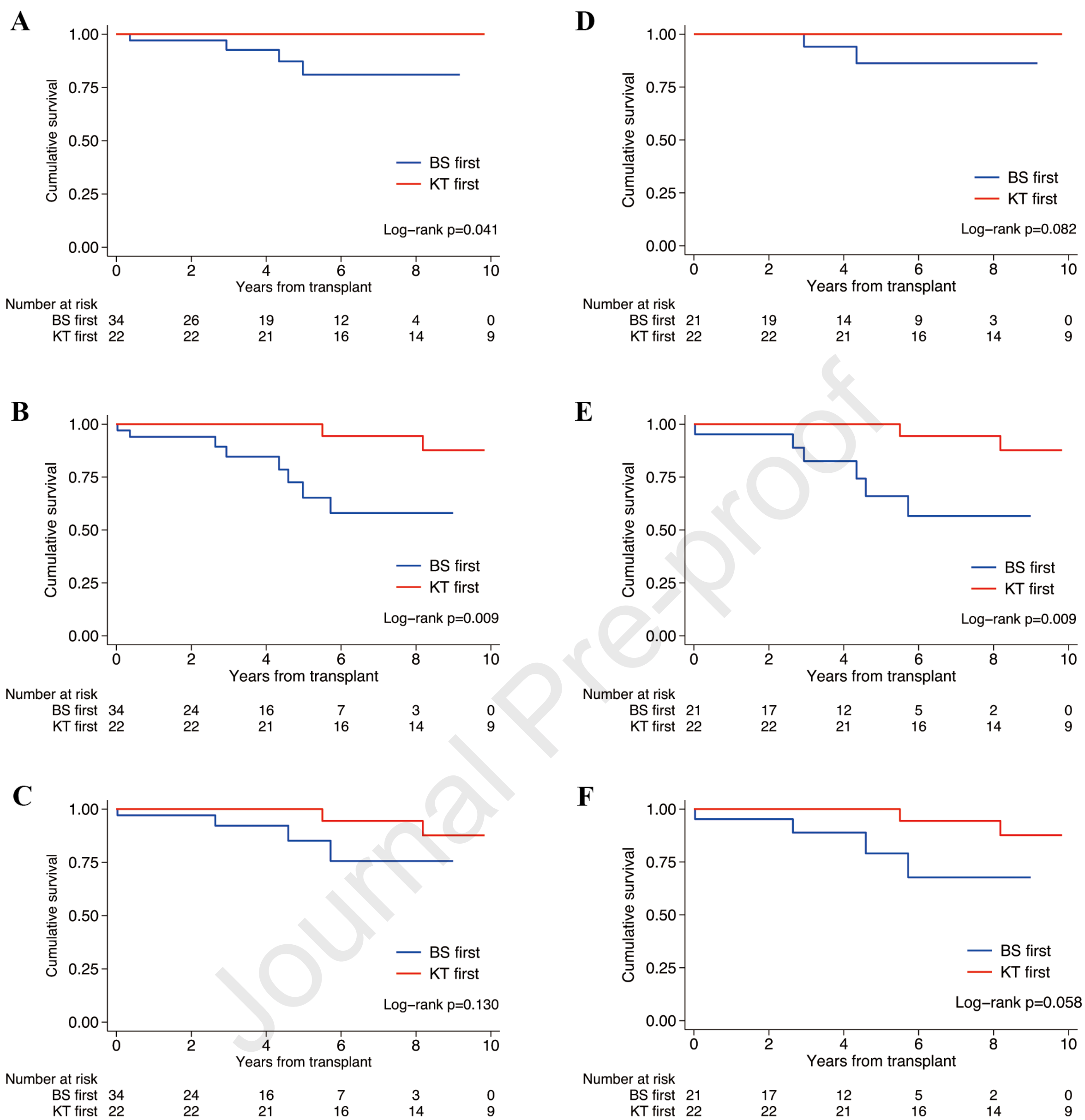
Table 3. Clinical outcomes at and after bariatric surgery

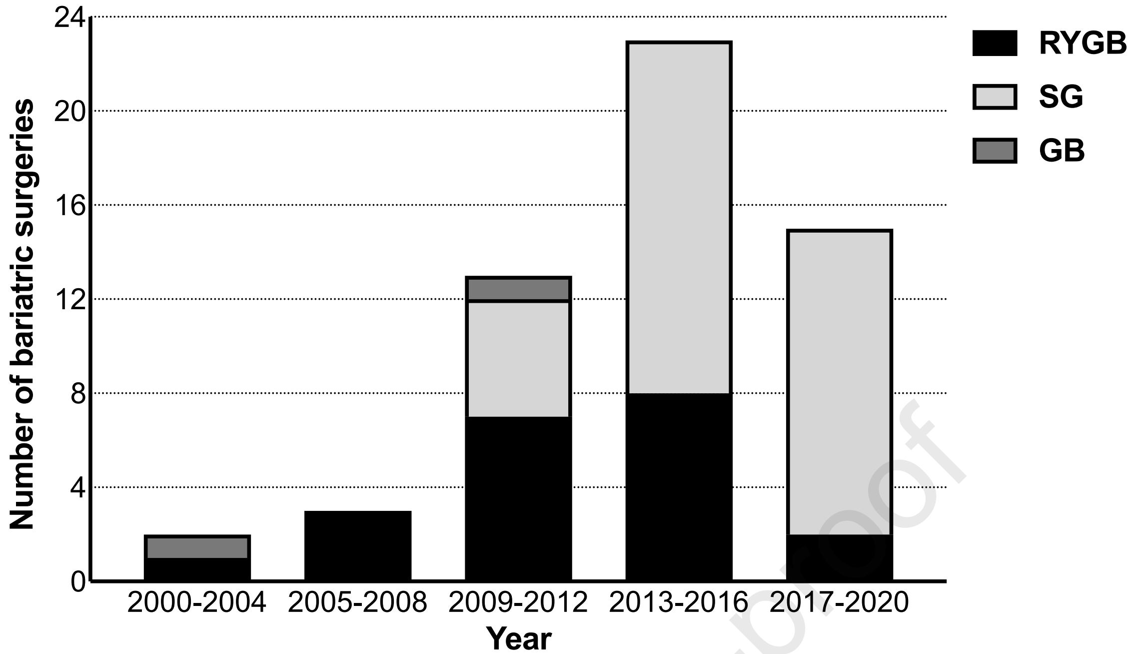
	KT first (n=22)	BS first (n=34)	P-value
Age at BS (years), mean ± SD	48.3 ± 9.4	48.3 ± 10.9	0.998
Pre-BS BMI (kg/m^2), median (IQR)	39.7 (37.9-44.0)	42.0 (40.0-45.8)	0.090
Type of BS, n (%)			0.063
SG	17 (77.3)	16 (47.1)	
RYGB	5 (22.7)	16 (47.1)	
GB	0 (0)	2 (5.8)	
Time between KT and BS (years), median (IQR)	5.5 (2.4-6.4)	2.7 (1.5-6.7)	0.123
BMI at one year after BS (kg/m^2), mean (SD)	30.1 ± 6.5	32.0 ± 4.1	0.215
One-year TWL (kg), median (IQR)	36.0 (28.0-42.0)	29.6 (21.5-40.6)	0.424
One-year %EWL, median (IQR)	74.9 (54.1-99.0)	57.9 (47.5-79.4)	0.155
SG	74.9 (54.1-107.4)	52.5 (40.0-73.4)	
RYGB	67.1 (32.5-93.5)	63.7 (54.0-89.1)	
GB	-	46.0 (37.2-54.8)	

BS, bariatric surgery; BMI, body mass index; GB, gastric banding; IQR, interquartile range; KT, kidney transplantation; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; TWL, total weight loss; %EWL, the percentage of excess weight loss.

Table 4. Postoperative complications after bariatric surgery according to the Clavien-Dindo classification

Complications	KT first (n=22)	BS first (n=34)	p-value
Grade I, n (%)	**4 (18.2)**	**3 (8.8)**	0.415
Persistent vomiting requiring antiemetics	1	0	
Transient elevation of serum creatinine	3	0	
Dyspnea requiring oxygen therapy	0	1	
Dumpling syndrome	0	1	
Postoperative atrial fibrillation	0	1	
Grade II, n (%)	**3 (13.6)**	**5 (14.7)**	1.000
Anastomotic bleeding requiring hemostatics	0	1	
Urinary tract infection requiring antibiotics	1	1	
Splenic lesion requiring blood transfusions	0	1	
Infected abdominal hematoma requiring antibiotics	2	1	
Postoperative anemia requiring blood transfusions	0	1	
Grade IIIa, n (%)	**0 (0)**	**1 (2.9)**	1.000
Abscess caused by port infection requiring drainage	0	1	
Grade IIIb, n (%)	**1 (4.5)**	**8 (23.5)**	0.074
Anastomotic stenosis requiring surgical reconstruction	0	2	
Anastomotic bleeding requiring surgical hemostasis	0	2	
Anastomotic leak requiring surgical repair	0	1	
Gastric perforation requiring surgical repair	0	1	
Internal herniation treated by surgery	1	1	
Small intestine damage repairing surgical repair	0	1	
Grade IVa, n (%)	**0 (0)**	**0 (0)**	-
Grade IVb, n (%)	**0 (0)**	**0 (0)**	-
Grade V, n (%)	**0 (0)**	**0 (0)**	-
Total, n (%)	**8 (36.4)**	**17 (50.0)**	0.316


A
Cumulative survival
1.00
0.75
0.50
0.25
0.00
BS first
KT first
Log−rank p=0.041
0 2 4 6 8 10
Years from transplant
Number at risk
BS first 34 26 19 12 4 0
KT first 22 22 21 16 14 9
D
Cumulative survival
BS first
KT first
Log−rank p=0.082
Years from transplant
Number at risk
BS first 21 19 14 9 3 0
KT first 22 22 21 16 14 9
B
Cumulative survival
BS first
KT first
Log−rank p=0.009
Years from transplant
Number at risk
BS first 34 24 16 7 3 0
KT first 22 22 21 16 14 9
E
Cumulative survival
BS first
KT first
Log−rank p=0.009
Years from transplant
Number at risk
BS first 21 17 12 5 2 0
KT first 22 22 21 16 14 9
C
Cumulative survival
BS first
KT first
Log−rank p=0.130
Years from transplant
Number at risk
BS first 34 24 16 7 3 0
KT first 22 22 21 16 14 9
F
Cumulative survival
BS first
KT first
Log−rank p=0.058
Years from transplant
Number at risk
BS first 21 17 12 5 2 0
KT first 22 22 21 16 14 9



24
20
16
12
8
4
0
Number of bariatric surgeries
2000-2004
2005-2008
2009-2012
2013-2016
2017-2020
Year
RYGB
SG
GB

Highlights

- Both pre- and post-transplant bariatric surgery (BS) are safe and effective.
- The optimal timing of BS for patients with renal failure should be individualized.
- Different conditions of each transplant candidate should be considered in detail.