Research Square

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Long-term Renal Outcomes in Patients with Type 2 Diabetes After Metabolic Bariatric Surgery: The Taiwan Diabesity Study

Yi-Chang Chang
National Taiwan University Hospital
Keong Chong
Min Sheng General Hospital
Chih-Neng Hsu
National Taiwan University Hospital Yunlin Branch
Gwo-Tsann Chuang
National Taiwan University
Hsiao-Lin Lee
National Taiwan University Hospital
Wei-Shun Yang
National Taiwan University Hospital HsinChu Branch
Siow-Wey Hee
National Taiwan University Hospital
Tai-Shuan Lai
National Taiwan University Hospital
Seh-Huang Chao
Jen-Ai Hospital
Ching-Chu Chen
China Medical University Hospital
Kong-Han Ser
Ten Chen Hospital
Yu-Yao Huang
Chang Gung Memorial Hospital
Chun-Fu Lai
National Taiwan University Hospital
Yi-Chih Lee
Chien Hsin University of Science and Technology
Chih-Cheng Hsu
National Health Research Institutes
Zih-Yi Teng

National Taiwan University
Shu-Chun Chen
Min Sheng General Hospital
Daniel Liao
University of Chicago
Po-Jen Yang
National Taiwan University Hospital
Po-Chu Lee
National Taiwan University Hospital
Wen-Yi Li
National Taiwan University Hospital Yunlin Branch
Lee-Ming Chuang
National Taiwan University Hospital
Wei-Jei Lee
obessurg_tw@yahoo.com.tw

National Taiwan University Hospital

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Abstract

Background:

Concerns persist that metabolic or bariatric surgery (MBS) may reduce glomerular filtration in patients with type 2 diabetes, and long-term data based on clinical and laboratory measurements remain limited.

Methods:

In this multicenter, prospective, observational cohort study, we compared 4-year renal, ophthalmic, and neurological outcomes between 55 patients with overweight or obesity and type 2 diabetes who underwent MBS and 380 patients who received standard medical therapy. Multiple regression adjustment, propensity score weighting, and propensity score matching was applied to adjust for baseline differences.

Results:

After 4 years of follow-up, multiple regression analyses demonstrated a greater increase in estimated glomerular filtration rate (eGFR; 2.66 ± 18.49 vs. −4.85 ± 13.14 mL/min/1.73 m², P < 0.001) and a greater reduction in urinary albumin-to-creatinine ratio (− 37.51 ± 446.75 vs. 67.13 ± 449.33 mg/g, P = 0.001) in the MBS group than in the medical therapy group, with no differences in ophthalmic or neurological complications. Propensity score-weighted analyses confirmed these findings and additionally showed a lower incidence of proliferative retinopathy in the MBS group. Consistently, propensity score-matched analyses (44 vs. 125 patients) revealed significantly improved eGFR (4.25 ± 11.88 vs. −3.18 ± 12.45 mL/min/1.73 m², P = 0.005) and reduced albuminuria (P = 0.045) in the MBS group.

Conclusion:

After 4 years of follow-up, patients with type 2 diabetes who underwent MBS had higher eGFR and lower albuminuria than patients receiving standard medical therapy. Studies using non-creatinine-based measures of kidney function are needed to confirm these findings.

Key Points

- MBS was associated with a greater 4-year rise in eGFR in type 2 diabetes.
- Albuminuria fell more after MBS than with standard medical therapy.
- Renal findings were consistent across regression, weighting, and matching.
- Non-creatinine-based GFR measures are needed to confirm these benefits.

Introduction

Metabolic bariatric surgery (MBS) improves hypertension [1], dyslipidemia [2], adverse cardiovascular events [3], glycemic control and remission of type 2 diabetes [2, 4], macrovascular and microvascular complications of type 2 diabetes [5], obstructive sleep apnea [6], metabolic dysfunction-associated steatotic liver disease [7], obesity-related cancer risk and mortality [8], and all-cause mortality [9].

Nevertheless, the impact of MBS on kidney function in patients with type 2 diabetes remains controversial. Several studies have reported a decline in estimated glomerular filtration rate (eGFR), measured GFR (mGFR) using inulin or iohexol, or creatinine clearance following surgery [10–20]. Potential explanations include postoperative acute kidney injury, resolution of obesity-related glomerular hyperfiltration, and oxalate nephropathy. However, most available studies are of short duration, and long-term prospective follow-up data remain limited.

Large-scale investigations, including the Swedish Obese Subjects (SOS) study [5], a retrospective cohort study using four U.S. health insurance databases [21], and another retrospective cohort study based on U.S. health care data [22], have consistently shown a significant reduction in microvascular complications among patients with type 2 diabetes undergoing MBS. However, these studies identified diabetic microvascular complications through diagnostic codes rather than clinical assessments or laboratory measurements.

Therefore, whether MBS preserves or improves kidney function over the long term in patients with type 2 diabetes, most of whom have normal baseline eGFR, remains unclear. In this context, we report the 4-year outcomes of the Taiwan Diabesity Study, with a particular focus on renal function, in which all outcomes were determined using standardized clinical examinations and laboratory tests.

Materials and Methods

Patient Recruitment

The Taiwan Diabesity Study (The study is registered in the ClinicalTrials.gov as [registration number blinded for review]) is a prospective, multicenter observational cohort designed to investigate end-organ damage in patients with overweight or obesity and type 2 diabetes. Patients who underwent MBS, including gastric bypass and sleeve gastrectomy, were compared with controls who received standard medical therapy. Fifty-five patients with type 2 diabetes undergoing MBS and 380 patients receiving standard medical care were recruited. The details of the study design have been described previously [23].

Data collection

The details of patient assessment have been described previously [23]. Briefly, each patient underwent standardized ophthalmic evaluations, including visual acuity and fundus examination, as well as neurological assessments consisting of inspection, the tuning fork vibration test, ankle reflex testing, and the 10-g monofilament test [24]. For the vibration test, a 128-Hz tuning fork was struck and placed on the dorsum of the interphalangeal joint of the hallux. Vibration perception was scored from 0 to 8 points, with higher scores indicating greater sensitivity to vibration. The ankle tendon reflex was scored as follows: 0 if the reflex was present, 0.5 if present only after reinforcement, and 1 if absent. The 10-g monofilament test was performed using a Semmes–Weinstein monofilament applied perpendicularly to the skin at eight sites on each foot: the plantar surfaces of the first, third, and fifth digits; the medial, central, and lateral aspects of the mid-foot; the posterior plantar surface; and the dorsal surface between the first and second toes. The filament was pressed until it bent, and patients, while blinded, were asked to indicate whether they perceived the pressure. Scores were assigned as follows: 0 if all eight sites were detected, 0.5 if seven or fewer sites were detected, and 1 if none were detected. Diabetic retinopathy was graded according to the International Classification of Diabetic Retinopathy, which categorizes disease into five stages: (1) no apparent retinopathy, (2) mild non-proliferative diabetic retinopathy (NPDR), (3) moderate NPDR, (4) severe NPDR, and (5) proliferative diabetic retinopathy. Because of the small number of cases, mild, moderate, and severe NPDR were grouped into a single category [25]. Diabetic neuropathy was evaluated using the Michigan Neuropathy Screening Instrument, with a cut-off score of 2.5 points [26, 27]. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [28].

Statistical analyses

All statistical analyses were performed using SAS version 8.0. Continuous variables with a normal distribution were compared using the independent-samples Student’s t test. Continuous variables with a skewed distribution or ordinal variables, including fasting plasma glucose, hemoglobin A1c (HbA1c), triglycerides (TG), creatinine, urinary albumin-to-creatinine ratio (ACR), tuning fork vibration test, ankle tendon reflex score, monofilament score, and visual acuity, were compared using the Wilcoxon rank-sum test.

To address baseline differences, we applied multiple regression adjustment, propensity score weighting, and propensity score matching. Multiple regression models included age, sex, baseline body mass index (BMI), HbA1c, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and duration of diabetes as covariates; for models assessing creatinine, ACR was additionally included as a covariate. Propensity score weighting was used to reduce indication bias for receiving standard medical therapy versus MBS.

For matching, we employed 1:1 fixed-ratio propensity score matching using the nearest-neighbor algorithm. Propensity scores were estimated from a non-parsimonious logistic regression model, in which the dependent variable was coded as 1 for patients receiving standard medical treatment and 0 for those undergoing MBS. Baseline covariates in the model included age, sex, and baseline BMI. The

estimated probability of treatment assignment (i.e., the propensity score) was then used to balance baseline differences between the two treatment groups.

Results

Baseline characteristics are summarized in Table 1. Compared with patients receiving standard medical therapy, those who underwent MBS were younger, more frequently female, and had a shorter duration of diabetes. The surgical group also exhibited higher body weight, waist circumference, BMI, serum TG, CKD-EPI eGFR, ACR, and better visual acuity. To account for these baseline differences, we applied multiple regression, propensity score weighting, and matching analyses to validate the results.

Table 1
Baseline characteristics (subjects followed at 48 months)

Number	**Medical Therapy**		**Bariatric surgery**		**P-value**
	380		**55**		
Variable	Mean	SD	Mean	SD	
Age (year)	51.59	9.21	43.58	9.58	**< 0.001**
Gender (male %)	63.16		36.36		
Duration of diabetes (year)	6.88	5.01	5.46	4.39	**0.039**
Weight (kg)	81.60	12.55	95.49	20.42	**< 0.001**
Waist circumference (cm)	99.46	9.80	111.47	14.38	**< 0.001**
BMI (kg/m2)	29.90	3.86	35.87	6.47	**< 0.001**
HbA1c (%)	7.84	1.37	8.57	1.40	**< 0.001**
Fasting glucose (mg/dL)	156.26	44.59	174.18	66.47	0.266
LDL-C (mg/dL)	95.79	25.78	104.07	30.67	0.055
HDL-C(mg/dL)	41.61	9.15	40.24	9.79	0.197
TG (mg/dL)	172.83	117.32	250.89	280.66	**0.014**
SBP (mmHg)	133.66	13.79	135.43	13.14	0.378
DBP (mmHg)	82.97	9.93	82.87	7.99	0.774
Creatinine (mg/dL)	0.87	0.22	0.82	0.24	**0.015**
Urine albumin creatinine ratio (mg/g)	107.13	382.73	473.60	2678.51	**0.004**
eGFR- CKD-EPI (mL/min/1.73m^2)	92.63	17.23	98.32	19.94	**0.003**
Ankle reflex score, right (0, 0.5, 1)	0.04	0.14	0.08	0.25	0.391
Ankle reflex score, left (0. 0.5, 1)	0.04	0.15	0.08	0.25	0.375
Monofilament score, right	0.00	0.04	0.00	0.00	0.512
Monofilament score, left	0.00	0.04	0.00	0.00	0.512
Visual acuity, right	0.78	0.26	0.86	0.22	**0.012**
Visual acuity, left	0.80	0.25	0.87	0.24	**0.025**
Non-proliferative retinopathy, right (%)	0.12	0.34	0.13	0.34	0.959
Non-proliferative retinopathy, left (%)	0.10	0.30	0.15	0.36	0.340

Number	Medical Therapy		Bariatric surgery		P-value
	380		55		
Proliferative retinopathy, right (%)	0.03	0.16	0.02	0.13	0.720
Proliferative retinopathy, left (%)	0.03	0.16	0.02	0.13	0.720

After 4 years of follow-up, multiple regression analyses showed that the surgical group achieved significantly greater reductions in body weight, waist circumference, BMI, HbA1c, fasting glucose, TG, systolic blood pressure (SBP), and diastolic blood pressure (DBP), along with greater increases in HDL-C levels, compared with the medical control group (Table 2). The surgical group also exhibited a significantly larger reduction in urinary ACR (-37.51 ± 446.75 vs. 67.13 ± 449.33 mg/g, P = 0.001) and a greater increase in CKD-EPI eGFR (2.66 ± 18.49 vs. -4.85 ± 13.14 mL/min/1.73 m^2, P < 0.001). In addition, there was a trend toward a lower incidence of proliferative retinopathy in the surgical group compared with the medical control group (P = 0.096).

Table 2
Changes after follow-up for 48 months adjusted by multiple regression

Number	**Medical Therapy**		**Bariatric surgery**		***P-value**
	380		**55**		
Variable	Mean	SD	Mean	SD	
Change of weight (kg)	-1.70	5.24	-21.00	15.43	**< 0.001**
Change of waist circumference (cm)	0.83	7.86	-22.60	12.17	**< 0.001**
Change of BMI (kg/m2)	-0.72	2.55	-8.31	3.65	**< 0.001**
Change of HbA1c (%)	-0.49	1.29	-2.70	1.49	**< 0.001**
Change of fasting glucose (mg/dL)	-19.26	51.57	-73.23	71.57	**< 0.001**
Change of LDL-C (mg/dL)	-6.98	30.28	-6.45	44.24	0.87
Change of HDL-C (mg/dL)	1.66	7.93	8.33	12.09	**< 0.001**
Change of TG (mg/dL)	-23.76	103.77	-127.48	140.28	**< 0.001**
Change of SBP (mmHg)	-0.71	15.45	-13.54	16.00	**< 0.001**
Change of DBP (mmHg)	-5.50	11.02	-11.97	13.33	**0.001**
Change of creatinine (mg/dL)	0.58	8.71	-0.03	0.24	**< 0.001**
Change of albumin-creatinine ratio (mg/g)	67.13	449.33	-37.51	446.75	**0.001**
Change of eGFR- CKD-EPI (mL/min/1.73m^2)	-4.85	13.14	2.66	18.49	**< 0.001**
Change of ankle reflex score, right	-0.01	0.10	-0.04	0.14	0.18
Change of ankle reflex score, left	-0.02	0.12	-0.04	0.14	0.18
Change of monofilament score, right	0.00	0.11	0.00	0.00	1.00
Change of monofilament score, left	0.00	0.11	0.00	0.00	1.00
Change of abnormal toe vibration status, right (%)	0.02	0.33	0.00	0.00	0.47
Change of abnormal toe vibration status, left (%)	0.02	0.31	-0.08	0.28	0.28
Change of visual acuity, right	-0.04	0.27	-0.06	0.36	0.81
Change of visual acuity, left	-0.02	0.26	0.04	0.19	0.42

*Adjusted for age, sex, body mass index, HbA1c, LDL-C, blood pressure, duration of diabetes

Number	Medical Therapy		Bariatric surgery		*P-value
	380		55		
Change of non-proliferative retinopathy status, right (%)	0.18	0.56	0.00	0.58	0.42
Change of non-proliferative retinopathy status, left (%)	0.18	0.53	0.00	0.58	0.37
Change of proliferative retinopathy, right (%)	0.05	0.30	0.00	0.00	0.096
Change of proliferative retinopathy, left (%)	0.05	0.29	0.00	0.00	0.096
*Adjusted for age, sex, body mass index, HbA1c, LDL-C, blood pressure, duration of diabetes					

Consistently, propensity score-weighted analyses confirmed that the surgical group experienced greater reductions in body weight, waist circumference, BMI, HbA1c, fasting glucose, TG, SBP, and DBP, as well as greater increases in HDL-C levels, compared with the medical group (Table 3). Patients in the surgical group also demonstrated a significantly larger decrease in ACR (-48.00 ± 246.97 vs. 113.14 ± 161.89 mg/g, P = 0.001) and a greater increase in CKD-EPI eGFR (0.31 ± 12.04 vs. − 5.30 ± 4.30 mL/min/1.73 m^2, P < 0.001). Moreover, the incidence of proliferative retinopathy was significantly lower in the surgical group (0.00% ± 0.001% vs. 0.14% ± 0.12%, P = 0.001).

Table 3
Changes after follow-up for 48 months weighted by propensity score

Number	**Medical Therapy**		**Bariatric surgery**		**P-value***
	380		**55**		
Variable	Mean	SD	Mean	SD	
Change of weight (kg)	-3.66	2.41	-25.25	7.97	**< 0.001**
Change of waist circumference (cm)	-0.66	3.79	-26.37	7.79	**< 0.001**
Change of BMI (kg/m2)	-1.54	1.06	-9.83	2.24	**< 0.001**
Change of HbA1c (%)	-0.63	0.43	-2.86	0.94	**< 0.001**
Change of fasting glucose (mg/dL)	-21.44	18.92	-68.76	39.59	**< 0.001**
Change of LDL-C (mg/dL)	-9.41	9.43	-5.05	22.17	0.865
Change of HDL-C (mg/dL)	1.31	2.79	7.03	6.64	**< 0.001**
Change of TG (mg/dL)	-30.19	31.57	-109.68	68.11	**< 0.001**
Change of SBP (mmHg)	-2.14	4.63	-13.70	10.92	**< 0.001**
Change of DBP (mmHg)	-5.19	3.69	-12.44	8.26	**0.001**
Change of creatinine (mg/dL)	0.41	2.25	-0.02	0.16	**< 0.001**
Change of albumin-creatinine ratio (mg/g)	113.14	161.89	-48.00	246.97	**0.001**
Change of eGFR- CKD-EPI (mL/min/1.73m^2)	-5.30	4.30	0.31	12.04	**< 0.001**
Change of ankle reflex score, right	-0.04	0.05	-0.02	0.06	0.18
Change of ankle reflex score, left	-0.05	0.06	-0.02	0.06	0.18
Change of monofilament score, right	-0.01	0.02	0.00	0.00	1.00
Change of monofilament score, left	-0.01	0.02	0.00	0.00	1.00
Change of abnormal toe vibration status, right (%)	0.03	0.10	0.00	0.00	0.18
Change of abnormal toe vibration status, left (%)	-0.02	0.09	-0.04	0.11	0.63
Change of visual acuity, right	-0.02	0.09	-0.02	0.19	0.81
Change of visual acuity, left	-0.03	0.07	0.04	0.12	0.43
* Estimated propensity scores by including age, sex, and BMI					

Number	Medical Therapy		Bariatric surgery		P-value*
	380		55		
Change of non-proliferative retinopathy status, right (%)	0.15	0.14	0.24	0.38	0.72
Change of non-proliferative retinopathy status, left (%)	0.12	0.13	0.24	0.38	0.63
Change of proliferative retinopathy, right (%)	0.14	0.12	0.00	0.00	**0.001**
Change of proliferative retinopathy, left (%)	0.14	0.12	0.00	0.00	**0.001**
* Estimated propensity scores by including age, sex, and BMI					

Furthermore, we conducted propensity score-matched analyses (matched for age, sex, and BMI) including 44 patients in the surgical group and 125 in the medical control group (Table 4). Compared with the medical group, the surgical group achieved significantly greater reductions in body weight, waist circumference, BMI, HbA1c, fasting glucose, TG, SBP, and DBP, as well as greater increases in HDL-C levels. In addition, the surgical group demonstrated a significantly larger decrease in urinary ACR (-48.00 ± 246.97 vs. 113.14 ± 161.89 mg/g, P = 0.045) and a greater increase in CKD-EPI eGFR (4.25 ± 11.88 vs. -3.18 ± 12.45 mL/min/1.73 m^2, P = 0.005).

Table 4
Changes after follow-up for 48 months matched by propensity score

Number	**Medical Therapy**		**Bariatric surgery**		**P-value**
	125		**44**		
Variable	Mean	SD	Mean	SD	
Age (year)	46.09	9.73	45.34	8.97	-
Gender (male %)	43.18		43.20		-
BMI (kg/m2)	32.59	4.17	34.29	4.54	-
Change of weight (kg)	-2.16	7.08	-18.57	15.60	**< 0.001**
Change of waist circumference (cm)	0.81	10.72	-18.25	8.87	**< 0.001**
Change of BMI (kg/m2)	-0.91	2.82	-7.46	3.03	**< 0.001**
Change of HbA1c (%)	-0.72	1.51	-2.65	1.46	**< 0.001**
Change of fasting glucose (mg/dL)	-23.77	61.89	-76.76	75.10	**< 0.001**
Change of LDL-C (mg/dL)	-9.37	34.90	-6.75	47.17	0.920
Change of HDL-C (mg/dL)	0.41	9.42	9.10	11.47	**< 0.001**
Change of TG (mg/dL)	-22.40	140.06	-135.82	146.87	**< 0.001**
Change of SBP (mmHg)	-1.41	15.23	-11.44	14.92	**< 0.001**
Change of DBP (mmHg)	-4.82	11.50	-12.23	14.41	**0.004**
Change of creatinine (mg/dL)	0.06	0.26	-0.04	0.12	**0.008**
Change of albumin-creatinine ratio (mg/g)	89.94	468.16	-3.78	474.94	**0.045**
Change of eGFR- CKD-EPI (mL/min/1.73m^2)	-3.18	12.45	4.25	11.88	**0.005**
Change of ankle reflex score, right	-0.04	0.17	-0.05	0.16	0.666
Change of ankle reflex score, left	-0.05	0.21	-0.05	0.16	0.697
Change of monofilament score, right	-0.01	0.07	0.00	0.00	0.712
* Estimated propensity scores by including age, sex, and BMI					

Number	Medical Therapy		Bariatric surgery		P-value
	125		44		
Change of monofilament score, left	-0.01	0.07	0.00	0.00	0.712
Change of abnormal toe vibration status, right (%)	0.02	0.32	0.00	0.00	0.659
Change of abnormal toe vibration status, left (%)	-0.02	0.24	-0.09	0.30	0.403
Change of visual acuity, right	-0.06	0.28	0.00	0.35	0.732
Change of visual acuity, left	-0.03	0.24	0.08	0.17	0.326
Change of non-proliferative retinopathy status, right (%)	0.14	0.55	-0.20	0.45	0.192
Change of non-proliferative retinopathy status, left (%)	0.12	0.48	-0.20	0.45	0.171
Change of proliferative retinopathy, right (%)	0.12	0.44	0.00	0.00	0.185
Change of proliferative retinopathy, left (%)	0.12	0.43	0.00	0.00	0.185
* Estimated propensity scores by including age, sex, and BMI					

Discussion

In this study, we compared long-term renal outcomes over 4 years in patients with type 2 diabetes who underwent MBS versus those receiving standard medical treatment. The surgical group demonstrated greater improvements in eGFR and larger reductions in albuminuria compared with the medical control group. Notably, most of these patients did not exhibit glomerular hyperfiltration at baseline. These findings suggest that MBS is associated with favorable long-term kidney outcomes.

Although MBS improves most obesity-related complications [1–9], its impact on renal outcomes remains controversial. While the majority of studies report reductions in albuminuria following surgery, several showed decreases in creatinine clearance or GFR.

For example, Navarro-Díaz et al. observed a decline in creatinine clearance from 139.51 ± 41.90 to 117.96 ± 33.99 mL/min in 61 patients with obesity and type 2 diabetes 24 months after surgery ($P < 0.001$) [10], and Saliba et al. demonstrated a reduction from 155 ± 37 to 131 ± 29 mL/min ($P = 0.02$) in 19 patients with obesity and diabetes 12 months after Roux-en-Y gastric bypass (RYGB) [13]. Declines of approximately 3%–24% in creatinine clearance or eGFR [11, 13, 16, 19, 20] and in mGFR measured by iohexol [12] or inulin clearance [14] have also been reported 8–24 months after surgery in other cohorts. Furthermore, in patients with obesity and end-stage kidney disease, MBS (n = 1,597) was associated with

a higher rate of kidney transplantation compared with no surgery (n = 4,750) in the United States Renal Data System registry [29]; whether this translates into net clinical benefit remains uncertain.

In contrast, several studies have reported increases in eGFR following MBS [23, 30–36]. It has been proposed that reductions in GFR or creatinine clearance observed after surgery primarily reflect the resolution of obesity-related glomerular hyperfiltration. In a detailed study, Hou et al. demonstrated that in patients with baseline eGFR > 125 mL/min (n = 31), eGFR decreased from 146.4 ± 17.1 to 133.9 ± 25.7 mL/min, whereas in those with baseline eGFR within the normal range (90–125 mL/min, n = 127), eGFR increased from 105.7 ± 9.6 to 114.2 ± 22.2 mL/min six months after RYGB. The improvement was even more pronounced in patients with chronic kidney disease (CKD). Among those with stage 2 CKD (eGFR 60–89 mL/min, n = 39), eGFR increased from 76.8 ± 16.7 to 93.3 ± 20.4 mL/min, and in stage 3 CKD patients (eGFR 30–59 mL/min, n = 6), it increased from 49.5 ± 6.6 to 66.8 ± 19.3 mL/min [15].

Similarly, Ngoh et al. found no significant change in CKD-EPI eGFR in 68 patients with obesity, whereas absolute GFR (eGFR × body surface area) and lean body weight-adjusted Cockcroft–Gault creatinine clearance declined significantly; in the 10 patients with baseline eGFR < 90 mL/min/1.73 m², eGFR and lean body weight-adjusted creatinine clearance tended to improve [17]. In another study, Nehus et al. assessed 242 adolescents with severe obesity undergoing MBS using cystatin C-based eGFR. Among patients with baseline eGFR < 90 mL/min/1.73 m², eGFR significantly improved from 76 to 102 mL/min/1.73 m² at three years post-surgery, whereas no significant change was observed in those with baseline eGFR > 90 mL/min/1.73 m² [18]. Conversely, Reid et al. reported that eGFR declined in both hyperfiltration and non-hyperfiltration groups 12 months after surgery [19].

A meta-analysis of 23 studies concluded that the overall effect of MBS on renal function, as assessed by eGFR, mGFR, or creatinine clearance, was neutral. However, subgroup analyses revealed significant reductions in patients with hyperfiltration and significant improvements in those with chronic kidney disease [37]. In our study, most patients had normal baseline eGFR, and we observed a significantly greater increase in eGFR after surgery than with medical therapy, consistent with the findings reported by Hou et al. [15].

Substantial concerns remain regarding the use of creatinine-based eGFR equations or creatinine clearance to evaluate renal function before and after MBS. This is because MBS leads to significant muscle mass loss, which reduces creatinine production and excretion, thereby confounding GFR estimation. Moreover, creatinine-based eGFR equations have not been validated in individuals with severe obesity or in those who experience substantial weight changes after surgery [37]. Notably, nearly all studies have reported reductions in serum creatinine following MBS, underscoring both the likelihood of muscle loss and the limitations of creatinine-based methods in this patient population.

Measured GFR (mGFR) using inulin or iohexol clearance is generally regarded as the reference method for assessing renal function. Friedman et al., using iohexol clearance, and Chagnac et al., using inulin and para-aminohippuric acid (PAH) clearance, both reported decreases in mGFR after surgery [12, 14]. These findings stand in stark contrast to results based on creatinine-derived estimates. Alternative, non–

creatinine-based methods such as cystatin C-based eGFR or newer biomarkers of tubular injury (e.g., neutrophil gelatinase–associated lipocalin or β2-microglobulin) may be required to clarify these discrepancies; notably, the cystatin C-based study by Nehus et al. showed improvement in patients with reduced baseline eGFR [18]. More studies employing non–creatinine-based approaches are warranted to resolve this issue.

This study has several limitations. First, treatment was chosen by the patients rather than randomly assigned; although we applied regression adjustment, propensity score weighting, and matching, residual confounding cannot be excluded. Second, the surgical group was relatively small, and analyses were not stratified by sex because of limited statistical power. Third, renal function was estimated from serum creatinine, which may be confounded by postoperative loss of muscle mass, and non-creatinine-based GFR estimates were not available. Fourth, information regarding post-surgical acute kidney injury was lacking, and it remains unclear whether any patients developed oxalate nephropathy. Finally, all participants were recruited in Taiwan, which may limit generalizability to other populations. Nevertheless, our study has several strengths: the follow-up duration was relatively long, the design was prospective and multicenter, and we relied on physical examination and laboratory test data rather than diagnostic codes, thereby enhancing the reliability of our findings.

Conclusion

We provide long-term evidence that MBS is associated with favorable renal outcomes in patients with type 2 diabetes, even in those with normal baseline GFR. However, controversy persists regarding the use of creatinine-based estimations, and further studies employing non–creatinine-based measures are needed to resolve this uncertainty.

Declarations

Ethical Approval

The Taiwan Diabesity Study was conducted across six hospitals in Taiwan and was approved by the Institutional Review Board/Research Ethics Committee of each site (approval numbers blinded for review). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study. This article does not contain any identifying information about individual participants.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contribution

Y.C.C, K.C. and C.N.H drafted the manuscript. C.N.H., Y.C.C, and W.J.L provided funding, G.T.C., W.S.Y, W.Y.L, T.S.L, and C.F.L revised the manuscript. H.L.L, S.W,H. D.L, critically reviewed the discussion , S.H.C, C.C.C., K.H.S, Y.Y.H, P.J.Y., P.C.L, and W.J.L. recruited the patients, Y.C.L, and C.C,H provided statistical consultation, Z.Y.T., and S.C.C. collected the data, W.Y.L., L.M.C., and W.J.L conceived the study and supervised the study. All authors read and approved the final manuscript.

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Data Availability

The de-identified datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Schiavon CA, Bersch-Ferreira AC, Santucci EV, et al. Effects of bariatric surgery in obese patients with hypertension: the GATEWAY randomized trial (gastric bypass to treat obese patients with steady hypertension). Circulation. 2018;137(11):1132–42.
2. Ikramuddin S, Korner J, Lee WJ, et al. Lifestyle intervention and medical management with vs without Roux-en-Y gastric bypass and control of hemoglobin A1c, LDL cholesterol, and systolic blood pressure at 5 years in the Diabetes Surgery Study. JAMA. 2018;319(3):266–78.
3. Sjöström L, Peltonen M, Jacobson P, et al. Bariatric surgery and long-term cardiovascular events. JAMA. 2012;307(1):56–65.
4. Schauer PR, Bhatt DL, Kirwan JP, et al. Bariatric surgery versus intensive medical therapy for diabetes: 5-year outcomes. N Engl J Med. 2017;376(7):641–51.
5. Sjöström L, Peltonen M, Jacobson P, et al. Association of bariatric surgery with long-term remission of type 2 diabetes and with microvascular and macrovascular complications. JAMA. 2014;311(22):2297–304.

6. Al Oweidat K, Toubasi AA, Tawileh RBA, Tawileh HBA, Hasuneh MM. Bariatric surgery and obstructive sleep apnea: a systematic review and meta-analysis. Sleep Breath. 2023;27(6):2283–94.
7. Lassailly G, Caiazzo R, Buob D, et al. Bariatric surgery reduces features of nonalcoholic steatohepatitis in morbidly obese patients. Gastroenterology. 2015;149(2):379–e8816.
8. Aminian A, Wilson R, Al-Kurd A, et al. Association of bariatric surgery with cancer risk and mortality in adults with obesity. JAMA. 2022;327(24):2423–33.
9. Sjöström L, Narbro K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. N Engl J Med. 2007;357(8):741–52.
10. Navarro-Díaz M, Serra A, Romero R, et al. Effect of drastic weight loss after bariatric surgery on renal parameters in extremely obese patients: long-term follow-up. J Am Soc Nephrol. 2006;17(12 Suppl 3):S213–7.
11. Serpa-Neto A, Bianco Rossi FM, Dal Moro Amarante R, et al. Effect of weight loss after Roux-en-Y gastric bypass on renal function and blood pressure in morbidly obese patients. J Nephrol. 2009;22(5):637–46.
12. Friedman AN, Moe S, Fadel WF, et al. Predicting the glomerular filtration rate in bariatric surgery patients. Am J Nephrol. 2014;39(1):8–15.
13. Saliba J, Kasim NR, Tamboli RA, et al. Roux-en-Y gastric bypass reverses renal glomerular but not tubular abnormalities in excessively obese diabetics. Surgery. 2010;147(2):282–7.
14. Chagnac A, Weinstein T, Herman M, et al. The effects of weight loss on renal function in patients with severe obesity. J Am Soc Nephrol. 2003;14(6):1480–6.
15. Hou CC, Shyu RS, Lee WJ, et al. Improved renal function 12 months after bariatric surgery. Surg Obes Relat Dis. 2013;9(2):202–6.
16. Getty JL, Hamdallah IN, Shamseddeen HN, et al. Changes in renal function following Roux-en-Y gastric bypass: a prospective study. Obes Surg. 2012;22(7):1055–9.
17. Ngoh CL, So JB, Tiong HE, et al. Effect of weight loss after bariatric surgery on kidney function in a multiethnic Asian population. Surg Obes Relat Dis. 2016;12(3):600–5.
18. Nehus EJ, Khoury JC, Inge TH, et al. Kidney outcomes three years after bariatric surgery in severely obese adolescents. Kidney Int. 2017;91(2):451–8.
19. Reid TJ, Saeed S, McCoy S, et al. The effect of bariatric surgery on renal function. Surg Obes Relat Dis. 2014;10(5):808–13.
20. Serra A, Granada ML, Romero R, et al. The effect of bariatric surgery on adipocytokines, renal parameters and other cardiovascular risk factors in severe and very severe obesity: 1-year follow-up. Clin Nutr. 2006;25(3):400–8.
21. O'Brien R, Johnson E, Haneuse S, et al. Microvascular outcomes in patients with diabetes after bariatric surgery versus usual care: a matched cohort study. Ann Intern Med. 2018;169(5):300–10.
22. Johnson BL, Blackhurst DW, Latham BB, et al. Bariatric surgery is associated with a reduction in major macrovascular and microvascular complications in moderately to severely obese patients

with type 2 diabetes mellitus. J Am Coll Surg. 2013;216(4):545–56.

23. Chang YC, Chao SH, Chen CC, et al. The effects of bariatric surgery on renal, neurological, and ophthalmic complications in patients with type 2 diabetes: the Taiwan Diabesity Study. Obes Surg. 2021;31(1):117–26.
24. Boulton AJ, Armstrong DG, Albert SF, et al. Comprehensive foot examination and risk assessment: a report of the task force of the foot care interest group of the American Diabetes Association. Diabetes Care. 2008;31(8):1679–85.
25. Wilkinson CP, Ferris FL, Klein RE, et al. Proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales. Ophthalmology. 2003;110(9):1677–82.
26. Moghtaderi A, Bakhshipour A, Rashidi H. Validation of Michigan neuropathy screening instrument for diabetic peripheral neuropathy. Clin Neurol Neurosurg. 2006;108(5):477–81.
27. Mete T, Aydin Y, Saka M, et al. Comparison of efficiencies of Michigan neuropathy screening instrument, neurothesiometer, and electromyography for diagnosis of diabetic neuropathy. Int J Endocrinol. 2013;2013:821745.
28. Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009;150(9):604–12.
29. Sheetz KH, Gerhardinger L, Dimick JB, Waits SA. Bariatric surgery and long-term survival in patients with obesity and end-stage kidney disease. JAMA Surg. 2020;155(7):581–8.
30. Navaneethan SD, Yehnert H. Bariatric surgery and progression of chronic kidney disease. Surg Obes Relat Dis. 2009;5(6):662–5.
31. Fenske WK, Dubb S, Bueter M, et al. Effect of bariatric surgery induced weight loss on renal and systemic inflammation and blood pressure: a 12-month prospective study. Surg Obes Relat Dis. 2013;9(4):559–68.
32. Jose B, Ford S, Super P, et al. The effect of biliopancreatic diversion surgery on renal function: a retrospective study. Obes Surg. 2013;23(5):634–7.
33. Ruiz-Tovar J, Giner L, Sarro-Sobrin F, et al. Laparoscopic sleeve gastrectomy prevents the deterioration of renal function in morbidly obese patients over 40 years. Obes Surg. 2015;25(5):796–9.
34. Imam TH, Fischer H, Jing B, et al. Estimated GFR before and after bariatric surgery in CKD. Am J Kidney Dis. 2017;69(3):380–8.
35. Chang AR, Chen Y, Still C, et al. Bariatric surgery is associated with improvement in kidney outcomes. Kidney Int. 2016;90(1):164–71.
36. Vano VK, Hatto M, Teramoto F, et al. Effects of bariatric surgery on renal function: a retrospective cohort study comparing one-year outcomes between one-anastomosis gastric bypass and Roux-en-Y gastric bypass. Sao Paulo Med J. 2024;142(5):e2023161.
37. Bilha SC, Nistor I, Nedelcu A, et al. The effects of bariatric surgery on renal outcomes: a systematic review and meta-analysis. Obes Surg. 2018;28(12):3815–33.

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