IFSO

CrossMark

ORIGINAL CONTRIBUTIONS

National Postoperative Bariatric Surgery Outcomes in Patients with Chronic Kidney Disease and End-Stage Kidney Disease

Jordana B. Cohen [1,2] · Colleen M. Tewksbury [3] · Samuel Torres Landa [4] · Noel N. Williams [3] · Kristoffel R. Dumon [3]

Abstract

Purpose Obesity is a major risk factor for end-stage kidney disease (ESKD) and is often a barrier to kidney transplantation. However, limited evidence exists evaluating postoperative bariatric surgery outcomes in patients with chronic kidney disease (CKD) and ESKD.

Materials and Methods We performed a retrospective cohort study of patients who underwent bariatric surgery in 2015–2016 using the national Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program dataset. Propensity score matching was used to balance characteristics across patients with CKD and ESKD vs. those without CKD.

Results There were 323,034 patients without CKD, 1694 patients with CKD, and 925 patients with ESKD who underwent bariatric surgery. Patients with CKD and ESKD had a significantly increased risk of 30-day reoperation (CKD odds ratio [OR] 2.25 95% confidence interval [CI] 1.45–3.51; ESKD OR 3.10, 95% CI 1.72–5.61) and readmission (CKD OR 1.98, 95% CI 1.53–2.56; ESKD OR 2.97, 95% CI 2.05–4.31) compared to patients without CKD; mortality risk was elevated in patients with ESKD (OR 11.59, 95% CI 6.71–20.04) but not in those with CKD (OR 1.00, 95% CI 0.32–3.11). Rates of adverse outcomes were < 15% across all groups. There were 12, 50, and 172 deaths per 1000 person-years among patients without CKD, with CKD, and with ESKD, respectively.

Conclusion Patients with CKD and ESKD experienced higher risk of postbariatric surgery complications compared to those without kidney disease, although absolute complication rates were low across all groups. CKD and ESKD should not be perceived as contraindications to bariatric surgery.

Keywords Bariatric surgery · Obesity · Chronic kidney disease · End-stage renal disease · Weight loss surgery

✉ Jordana B. Cohen
  jco@pennmedicine.upenn.edu

1 Renal-Electrolyte and Hypertension Division, Perelman School of Medicine, University of Pennsylvania, 831 Blockley, 423 Guardian Drive, Philadelphia, PA 19104, USA

2 Center for Clinical Epidemiology and Biostatistics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104, USA

3 Penn Metabolic and Bariatric Surgery Program, Department of Surgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA 19104, USA

4 Department of Surgery, Oregon Health and Science University, Portland, OR 97239, USA

Introduction

There is a robust and complex relationship between obesity and the development and progression of CKD. Obesity is strongly associated with several comorbidities that contribute to the deterioration of kidney function. For example, the elevated risk of CKD in obesity is likely mediated by a heightened incidence of diabetes and hypertension in patients with obesity [1–5]. Nonetheless, even after accounting for these comorbidities, there remains a strong, independent association between obesity and development of ESKD [6].

In the general population, bariatric surgery is the treatment of choice for long-standing weight loss to reduce cardiometabolic risk in patients with severe obesity [7]. In addition to improving glycemic control and blood pressure [7–10], bariatric surgery improves glomerular filtration rate and proteinuria [11], and reduces the risk of developing CKD and ESKD [12, 13]. However, there is ongoing reticence to perform

bariatric surgery in patients with CKD and ESKD [14]. This may in part be due to the presence of an "obesity paradox" in patients on dialysis; dialysis-dependent individuals with obesity have a significantly lower risk of cardiovascular morbidity and mortality compared to normal-weight patients [15, 16]. Additionally, evidence suggests an elevated risk of surgical complications among patients with kidney disease who undergo bariatric surgery [17], although this has not been consistently demonstrated [18–21]. Thus, despite the highly concomitant nature of obesity and CKD, many providers are reticent to recommend bariatric surgery in patients with obesity and CKD or ESKD. This reticence may result in compounded comorbidity burden and has been associated with reduced access to the transplant waiting list [22].

Existing studies of the perioperative risks associated with bariatric surgery in kidney disease were limited by small sample sizes of individuals with kidney disease, particularly ESKD. Additionally, while these studies highlighted stark differences in comorbidity burden between patients with vs. without CKD, they were limited by an absence of an appropriate control population. Given the significant potential cardiometabolic benefit of bariatric surgery and the importance of removing barriers to the kidney transplant waiting list, the goal of this study was to better understand the risks of short-term bariatric surgery complications in patients with CKD or ESKD compared to patients without CKD.

Methods

Study Design and Data Source

We performed a retrospective cohort study of national registry data provided by the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) 2015 and 2016 Participant Use Data Files, which encompass over 150,000 metabolic and bariatric surgery cases performed at 796 centers in the USA and Canada annually [23]. MBSAQIP collects deidentified data on preoperative risk factors, intraoperative events, and 30-day postoperative morbidity and mortality among patients undergoing metabolic and bariatric surgery. Patients were included in the study if they were at least 18 years of age at the time of undergoing bariatric surgery [23].

Exposures, Covariates, and Outcomes

The primary exposures were preoperative renal insufficiency (defined as a serum creatinine greater than 2 mg/dL without requiring dialysis, presumed to be CKD given that acute kidney injury is a contraindication to undergoing nonurgent procedures [24, 25]) and dialysis dependence, i.e.,

ESKD [26]. Covariates were selected a priori for inclusion in the multivariable models and matching algorithms based on clinical relevance and previously demonstrated associations with postoperative outcomes [27–30]. The primary outcome was 30-day postoperative mortality. The secondary outcomes were 30-day reoperation, readmission, intervention, and acute kidney injury (only among patients not on dialysis at the time of surgery) [23]. Please refer to the Supplemental Methods for additional details.

Statistical Analyses

All statistical analyses were performed using STATA version 15.1 (Statacorp LP, College Station, TX). Demographic and clinical characteristics were described using medians, means, and percentiles, with Wilcoxon rank sum test or t test for comparing continuous variables and chi-square test for comparing categorical and binary variables. Poisson regression was used to calculate event rates. Multivariable logistic regression with and without propensity score matching was used to compare patients with CKD and ESKD to patients with no CKD with regard to the risk of developing the primary and secondary 30-day outcomes.

Propensity score matching was used to balance the covariates across patients with CKD or ESKD and those with no CKD [31]. Propensity score matching is a matching technique that estimates the effect of an outcome across different exposure groups by collectively balancing risk factors across each exposure group [31, 32]. To achieve this, the technique calculates a score based on the likelihood of individuals being in each exposure group, taking into account their known risk factors. Please refer to the Supplemental Methods for additional details, including handling of missing data.

Results

Cohort Characteristics

There were 323,034 patients without CKD, 1694 patients with CKD, and 925 patients with ESKD who underwent bariatric surgery in 2015 and 2016 who met inclusion criteria. Compared to patients without CKD, those with CKD or ESKD were significantly older (Table 1; median age 44 vs. 56 vs. 49, respectively; $p < 0.001$), had clinically and statistically significantly higher rates of hypertension (49% vs. 92% vs. 80%, $p < 0.001$), diabetes mellitus (27% vs. 68% vs. 56%, $p < 0.001$), hyperlipidemia (24% vs. 64% vs. 52%, $p < 0.001$), and cardiac disease (3% vs. 19% vs. 13%, $p < 0.001$). Patients with ESKD were more likely to have sleeve gastrectomy, as opposed to gastric bypass, compared to patients without CKD or with predialysis CKD. Individuals without CKD experienced 12 deaths per 1000 person-years, individuals with

Table 1 Baseline patient demographic characteristics, preoperative comorbidities, and surgical risk factors by chronic kidney disease status

	No CKD $N = 323{,}034$	CKD $N = 1694$	ESKD $N = 925$	P value
Median age (years) (IQR)	44 (36–53)	56 (48–64)	49 (41–56)	< 0.001
Female, n (%)	256,849 (80%)	942 (56%)	515 (56%)	< 0.001
Race/ethnicity, n (%)				< 0.001
White non-Hispanic	192,010 (59%)	930 (55%)	314 (34%)	
White Hispanic	30,336 (9%)	94 (6%)	89 (10%)	
Black non-Hispanic	50,120 (16%)	439 (26%)	353 (38%)	
Black Hispanic	1364 (< 1%)	6 (< 1%)	6 (1%)	
American Indian or Alaskan Native	1256 (< 1%)	9 (1%)	7 (1%)	
Native Hawaiian or Other Pacific Islander	893 (< 1%)	893 (< 1%)	8 (1%)	
Asian	1519 (< 1%)	16 (1%)	9 (1%)	
Unknown	45,536 (14%)	194 (11%)	140 (15%)	
Median preoperative BMI closest to bariatric surgery (kg/m^2) (IQR)	43.9 (39.9–49.5)	45.3 (40.4–50.9)	44.7 (40.7–49.6)	< 0.001
Hypertension, n (%)	157,488 (49%)	1555 (92%)	740 (80%)	< 0.001
Median number of antihypertensive medications, n (%)	2 (0–3)	2 (2–3)	2 (1–3)	< 0.001
Diabetes mellitus, n (%)	85,625 (27%)	1153 (68%)	514 (56%)	< 0.001
Hyperlipidemia, n (%)	79,258 (24%)	1085 (64%)	478 (52%)	< 0.001
Myocardial infarction or cardiac stent, n (%)	8571 (3%)	320 (19%)	119 (13%)	< 0.001
Pulmonary embolism or deep vein thrombosis, n (%)	7653 (2%)	142 (8%)	66 (7%)	< 0.001
Chronic obstructive pulmonary disease, n (%)	5829 (2%)	137 (8%)	30 (3%)	< 0.001
Obstructive sleep apnea, n (%)	122,636 (38%)	1025 (61%)	495 (54%)	< 0.001
Gastroesophageal reflux disease, n (%)	102,182 (32%)	708 (42%)	370 (40%)	< 0.001
Median serum albumin (mg/dl) (IQR)	4.1 (3.8–4.3)	3.9 (3.5–4.2)	3.9 (3.6–4.2)	< 0.001
American Society of Anesthesiologists Physical Status Classification ≥ 4, n (%)	12,383 (4%)	316 (19%)	389 (42%)	< 0.001
Dependent functional status, n (%)	3211 (1%)	110 (6%)	50 (5%)	< 0.001
Active smoker within 1 year, n (%)	28,574 (9%)	119 (7%)	48 (5%)	< 0.001
Surgery type, n (%)				< 0.001
Roux-en-Y gastric bypass	93,497 (29%)	548 (32%)	150 (16%)	
Sleeve gastrectomy	229,537 (71%)	1146 (68%)	775 (84%)	

CKD chronic kidney disease (predialysis), *ESKD* end-stage kidney disease (on dialysis), *IQR* interquartile range, *BMI* body mass index

CKD experienced 50 deaths per 1000 person-years, and individuals with ESKD experienced 172 deaths per 1000 person-years of postoperative follow-up (see Table 2 for unadjusted event rates for each of the primary and secondary outcomes).

Multivariable Logistic Regression

After adjusting for important preoperative and perioperative characteristics, patients with CKD had no significant difference in 30-day mortality compared to patients without CKD (Fig. 1, Table S1; adjusted OR [aOR] 1.26, 95% CI 0.59–2.72); however, patients with ESKD had a significantly increased 30-day mortality risk (aOR 8.65, 95% CI 4.78–15.68) compared to patients without CKD. Older age, male gender, Black race, higher preoperative BMI, diabetes, hyperlipidemia, history of myocardial infarction, history of pulmonary embolism, chronic obstructive pulmonary disease, and gastric bypass (as opposed to sleeve gastrectomy) were independently associated with mortality. Patients with both CKD and ESKD had a significantly increased risk of 30-day reoperation (CKD aOR 1.72, 95% CI 1.33–2.22; ESKD aOR 2.73, 95% CI 2.01–3.72), intervention (CKD aOR 2.49, 95% CI 2.02–3.07; ESKD aOR 2.28, 95% CI 1.67–3.10), and readmission (CKD aOR 1.78, 95% CI 1.51–2.08; ESKD aOR 2.23, 95% CI 1.82–2.74). Patients with predialysis CKD also had a significantly increased odds of acute kidney injury compared to patients without CKD (aOR 7.28, 95% CI 5.46–9.69; see Tables S2–S5 for factors independently associated with each complication).

Effect Modification

There was significant interaction between diabetes and CKD status with regard to the 30-day intervention outcome (Table S6; $p < 0.001$); unlike diabetics, non-diabetics with CKD had no significant difference in 30-day intervention

Table 2 Rates of 30-day postoperative outcomes by chronic kidney disease status

	No CKD $N = 323{,}034$	CKD $N = 1694$	ESKD $N = 925$	P value
Mortality, n (%)	322 (0.1%)	7 (0.4%)	13 (1.4%)	< 0.001
Reoperation, n (%)	5389 (1.7%)	64 (3.8%)	45 (4.9%)	< 0.001
Intervention, n (%)	6266 (1.9%)	102 (6%)	45 (4.9%)	< 0.001
Readmission, n (%)	15,677 (4.9%)	182 (10.7%)	113 (12.2%)	< 0.001
Acute kidney injury, n (%)	552 (0.2%)	63 (3.7%)		< 0.001

Analyses were not performed evaluating acute kidney injury in ESKD because these patients were already on dialysis at the time of surgery

CKD chronic kidney disease (predialysis), *ESKD* end-stage kidney disease (on dialysis)

risk compared to non-diabetics without CKD (diabetic with CKD aOR 2.98, 95% CI 2.36–3.77; non-diabetic with CKD aOR 1.42, 95% CI 0.87–2.31). There was also significant interaction between sex and CKD status with regard to 30-day reoperation ($p = 0.003$); males with CKD had a significantly increased risk of 30-day reoperation compared to males without CKD (aOR 2.10, 95% CI 1.49–2.95), while females with CKD had no significantly increased risk of 30-day reoperation compared to females without CKD (aOR 1.32, 95% CI 0.89–1.97). There was no effect modification of the association between CKD status and age ≥ 60 years, hypertension, and type of bariatric surgery ($p > 0.05$). There was insufficient statistical power to assess for effect modification in ESKD.

Propensity Score Matching

Three thousand three hundred seventy-two patients without CKD and with predialytic CKD were able to achieve 1:1 propensity score matching (1686 from each group; see Table S7 for balance table). Similar to the multivariable logistic regression models, there was no significant difference in mortality between patients with CKD and those without CKD (Table 3; OR 1.00, 95% CI 0.32–3.11). Compared to patients without CKD, patient with predialytic CKD had significantly higher risk of 30-day reoperation (OR 2.25, 95% CI 1.45–3.51), intervention (OR 4.82, 95% CI 3.02–7.68), readmission (OR 1.98, 95% CI 1.53–2.56), and acute kidney injury (OR 7.23, 95% CI 3.59–14.59).

Fig. 1 Thirty-day postoperative risk by chronic kidney disease status. The figure represents odds ratios (enclosed circles) with 95% confidence intervals (lines) using multivariable logistic regression of all patients in the cohort (no CKD $N = 323{,}034$ [red]; CKD $N = 1694$ [blue]; ESKD $N = 925$ [green]). Models were adjusted for age, sex, race/ethnicity, closest preoperative BMI to surgery, history of hypertension, diabetes, hyperlipidemia, coronary artery disease, pulmonary embolism or deep vein thrombosis, chronic obstructive pulmonary disease, obstructive sleep apnea, gastroesophageal reflux disease, American Society of Anesthesiologists physical status classification, smoking status, functional dependence, and type of bariatric surgery; missing variables were addressed using multiple imputation. CKD chronic kidney disease (predialysis), ESKD end-stage kidney disease (on dialysis).
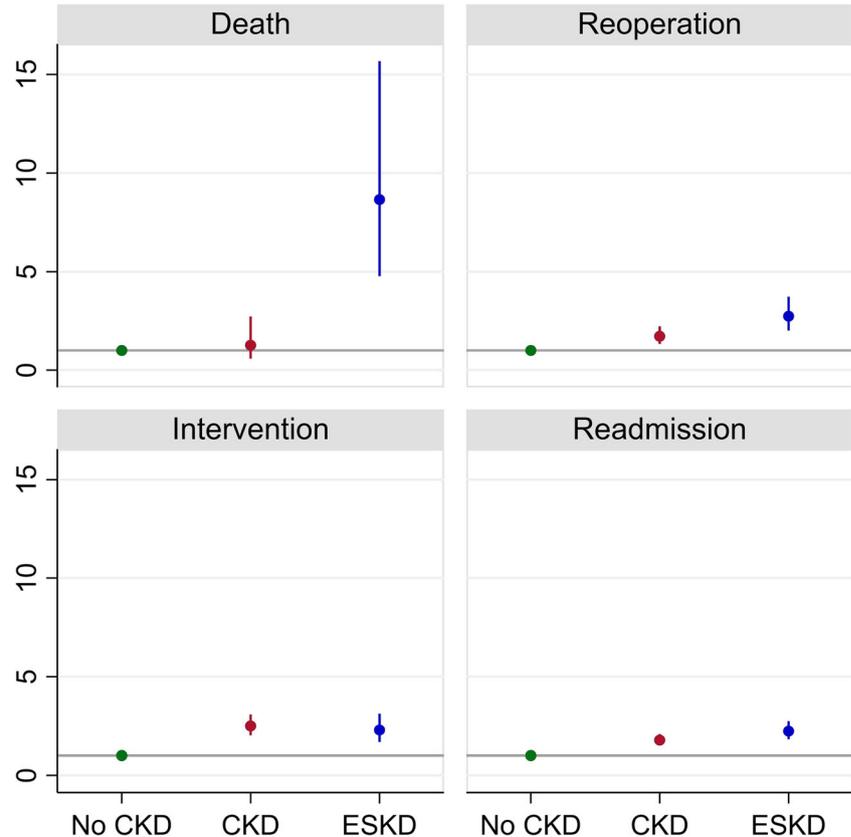
Table 3 Thirty-day postoperative risk by kidney disease status, using 1:1 propensity score matching

No CKD vs. CKD (N = 3372)				No CKD vs. ESKD (N = 1834)			
	Odds ratio	95% CI	P value		Odds ratio	95% CI	P value
Mortality				Mortality			
No CKD	–	–	–	No CKD	–	–	–
CKD	1.00	0.32–3.11	1.000	ESKD	11.59	6.71–20.04	< 0.001
Reoperation				Reoperation			
No CKD	–	–	–	No CKD	–	–	–
CKD	2.25	1.45–3.51	< 0.001	ESKD	3.10	1.72–5.61	< 0.001
Intervention				Intervention			
No CKD	–	–	–	No CKD	–	–	–
CKD	4.82	3.02–7.68	< 0.001	ESKD	3.59	1.92–6.70	< 0.001
Readmission				Readmission			
No CKD	–	–	–	No CKD	–	–	–
CKD	1.98	1.53–2.56	< 0.001	ESKD	2.97	2.05–4.31	< 0.001
Acute kidney injury							
No CKD	–	–	–				
CKD	7.23	3.59–14.59	< 0.001				

CKD chronic kidney disease (predialysis), *ESKD* end-stage kidney disease (on dialysis), *CI* confidence interval

No CKD was the reference group for all analyses. Analyses were not performed evaluating acute kidney injury in ESKD because these patients were already on dialysis at the time of surgery. All individuals were matched on age, sex, race, closest preoperative BMI to surgery, history of hypertension, diabetes, hyperlipidemia, coronary artery disease, pulmonary embolism or deep vein thrombosis, chronic obstructive pulmonary disease, obstructive sleep apnea, gastroesophageal reflux disease, American Society of Anesthesiologists physical status classification, smoking status, functional dependence, and type of bariatric surgery; multiple imputation was used to address missing covariates

One thousand eight hundred thirty-four patients without CKD and with ESKD achieved 1:1 propensity score matching (917 from each group; see Table S8 for balance table). Patients with ESKD continued to have a significantly increased risk of 30-day mortality (Table 3; OR 11.59, 95% CI 6.71–20.04), reoperation (1.72–5.61), intervention (OR 3.59, 95% CI 1.92–6.70), and readmission (OR 2.97, 95% CI 2.05–4.31) compared to patients without CKD.

Discussion

Understanding that ESKD is described as a relative contraindication to bariatric surgery [14], this is the largest study to date of postoperative bariatric surgery outcomes in patients with CKD and ESKD. Using national registry data, we demonstrated that patients with CKD and ESKD were more likely to experience postoperative complications compared to individuals with normal kidney function. Nonetheless, rates of 30-day complications and readmissions across all groups were < 15%. While patients with ESKD had an increased risk of 30-day mortality, there was no difference in mortality risk among patients with CKD compared to patients without CKD; the mortality rates were comparable to the non-bariatric surgery CKD and ESKD population [33, 34]. Reflective of current national trends [35, 36], the overwhelming majority of

patients in the cohort underwent sleeve gastrectomy, with a minority undergoing Roux-en-Y gastric bypass.

Our study was strengthened by the use of an expansive, contemporary cohort that is highly generalizable to bariatric surgery practices across the USA and Canada. In order to provide less biased evidence regarding postbariatric surgical outcomes in patients with CKD or ESKD, we also employed matching techniques to address differences in medical morbidities and surgical risk factors across patients with vs. without CKD and ESKD. Existing studies have demonstrated mixed findings with regard to postoperative bariatric surgery outcomes in patients with kidney disease [17–21]. We suspect the discrepancy in outcomes across studies is at least somewhat attributable to small sample sizes, as several studies included < 40 dialysis patients [17, 20]. These studies also occurred in an era when more invasive bariatric surgery was common, whereas there has more recently been a shift to laparoscopic and minimally invasive surgeries, particularly sleeve gastrectomy [35, 36]. To the best of our knowledge, previous studies have not evaluated postoperative outcomes in a nationwide cohort. Understanding the substantial differences in comorbidity burden across patients with and without CKD, previous studies were also limited by the absence of a carefully matched control group to compare outcomes of patients with CKD and ESKD to patients without CKD.

We reported that individuals without CKD, with CKD, and with ESKD experienced 12, 50, and 172 deaths per 1000 person-years of postbariatric surgery follow-up, respectively. Among patients with CKD, the mortality rate we observed is markedly lower than that reported nationally in (non-bariatric surgery) Medicare patients with CKD (110 per 1000 person-years) [33]; this difference is likely somewhat attributable to the fact that the average age of our cohort is much lower than the average age in the Medicare population. Patients with ESKD had a similar mortality rate compared to the nationally reported (non-bariatric surgery) mortality rate in dialysis patients during the same time period (166 per 1000 person-years) [33]. Additionally, the mortality rate in our cohort was lower than 30-day postoperative mortality rates reported in dialysis patients who underwent other non-emergent surgeries (1.4% in our cohort, compared to 12.6% reported for non-emergent surgeries in the American College of Surgeons (ACS) National Surgical Quality Improvement Program database) [34].

In sensitivity analyses, our study demonstrated that non-diabetic patients with CKD had no increased risk of 30-day non-operative interventions following bariatric surgery compared to non-diabetic patients without CKD, although diabetics with CKD had markedly increased risk of interventions. These results corroborate previous evidence that diabetics have a greater risk of postoperative infection compared to non-diabetics in the 1 month after bariatric surgery [37]. Additionally, in non-emergent surgeries, diabetics are at a greater risk of surgical site infection [38] and cardiovascular complications [27] compared to non-diabetics. Our study also demonstrated that men with CKD had a higher risk of readmission after bariatric surgery compared to men without CKD, while women with CKD had similar rates of readmission as women without CKD. There is existing evidence of greater risk of postbariatric surgical adverse outcomes among men compared to women [39, 40], although this is not consistent across all studies [41]. The reason for worse outcomes among men is speculated to be, in part, due to larger relative body habitus at the time of bariatric surgery [39]. Given similar mortality risk and risk of other complications across men and women in our study, we conclude that the increased risk of readmission is likely not clinically significant with regard to more serious adverse events.

Our study has several important limitations to consider. While we had access to robust, comprehensive data on comorbidities, demographics, and 30-day outcomes, more granular information regarding degree of renal dysfunction was not available. The MBSAQIP dataset relies on center-level reporting of risk factors and outcomes, and does not collect creatinine or proteinuria data. As a result, patients with mild CKD (e.g., creatinine < 2 mg/dL but

low-grade proteinuria) may have been misclassified as not having CKD. Correspondingly, we were unable to explore the relationship between severity of predialysis CKD and adverse outcomes, although existing evidence suggests that patients with CKD experience similar postbariatric surgery outcomes across all categories of CKD severity [18]. Additionally, we were unable to validate the outcome of 30-day acute kidney injury or to apply more widely accepted definitions of acute kidney injury [42, 43]. It is not surprising that CKD patients would be more prone to postoperative acute kidney injury than non-CKD patients [44–46]; however, we urge cautious interpretation of the results of this outcome. Given that the MBSAQIP dataset uses a conservative definition of acute kidney injury, patients who truly had acute kidney injury, particularly those with normal baseline kidney function, may have been misclassified as not experiencing this outcome. We also did not have sufficient statistical power to assess for effect modification in ESKD. Finally, the dataset does not provide information on key longitudinal outcomes, such as mortality beyond 30 days or sustained weight loss; these are important areas for future investigation.

Conclusion

Patients with CKD and ESKD experience higher relative risk of postbariatric surgery complications compared to patients without CKD; however, the overall rates of complications are quite low across all patients. Furthermore, after matching on important comorbidities, patients with CKD have similar postoperative mortality risk compared to patients without CKD. Although patients with ESKD have higher mortality risk compared to patients without CKD, this is comparable to the expected increased mortality rates in the non-surgical ESKD population, and substantially lower than postoperative ESKD mortality rates previously reported in other non-emergent surgeries. Our results reinforce that CKD and ESKD should not be contraindications to undergoing bariatric surgery. Among patients who have not yet started dialysis, bariatric surgery can help reduce the risk of progression to ESKD [13]. In patients who are already on dialysis, bariatric surgery can be an important bridge to life-saving transplantation [22]. Nonetheless, acknowledging the elevated risk of complications, the effect of bariatric surgery on longitudinal survival in patients with ESKD (particularly those who are not transplant candidates) remains unknown. Taking into account ongoing reticence to refer patients with CKD and ESKD for bariatric surgery, future research should focus on exploring the long-term survival impact of bariatric surgery and on ways to mitigate short-term adverse postoperative outcomes in this patient population.

Compliance with Ethical Standards

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. For this type of study, formal consent is not required.

Conflict of Interest The authors declare that they have no conflicts of interest.

Informed Consent Does not apply.

References

1. Franceschini N, Gouskova NA, Reiner AP, et al. Adiposity patterns and the risk for ESRD in postmenopausal women. Clin J Am Soc Nephrol. 2015;10(2):241–50.
2. Kramer H, Gutierrez OM, Judd SE, et al. Waist circumference, body mass index, and ESRD in the REGARDS (Reasons for Geographic and Racial Differences in Stroke) study. Am J Kidney Dis. 2016;67(1):62–9.
3. Guh DP, Zhang W, Bansback N, et al. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC Public Health. 2009;9:88.
4. Vazquez G, Duval S, Jacobs Jr DR, et al. Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. Epidemiol Rev. 2007;29:115–28.
5. Wormser D, Kaptoge S, Di Angelantonio E, et al. Separate and combined associations of body-mass index and abdominal adiposity with cardiovascular disease: collaborative analysis of 58 prospective studies. Lancet. 2011;377(9771):1085–95.
6. Hsu CY, McCulloch CE, Iribarren C, et al. Body mass index and risk for end-stage renal disease. Ann Intern Med. 2006;144(1):21–8.
7. Cohen JB, Cohen DL. Cardiovascular and renal effects of weight reduction in obesity and the metabolic syndrome. Curr Hypertens Rep. 2015;17(5):34.
8. Cohen JB. Hypertension in obesity and the impact of weight loss. Curr Cardiol Rep. 2017;19(10):98.
9. 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.
10. Sjostrom L, Peltonen M, Jacobson P, et al. Bariatric surgery and long-term cardiovascular events. JAMA. 2012;307(1):56–65.
11. Navaneethan SD, Yehnert H, Moustarah F, et al. Weight loss interventions in chronic kidney disease: a systematic review and meta-analysis. Clin J Am Soc Nephrol. 2009;4(10):1565–74.
12. Friedman AN, Wahed AS, Wang J, et al. Effect of bariatric surgery on CKD risk. J Am Soc Nephrol. 2018;29(4):1289–300.
13. Chang AR, Chen Y, Still C, et al. Bariatric surgery is associated with improvement in kidney outcomes. Kidney Int. 2016;90(1):164–71.
14. Nguyen NT, Blackstone RP, Morton JM, et al. The ASMBS textbook of bariatric surgery: volume 1: bariatric surgery. New York: Springer; 2014.
15. Kalantar-Zadeh K, Streja E, Molnar MZ, et al. Mortality prediction by surrogates of body composition: an examination of the obesity paradox in hemodialysis patients using composite ranking score analysis. Am J Epidemiol. 2012;175(8):793–803.
16. Johansen KL, Young B, Kaysen GA, et al. Association of body size with outcomes among patients beginning dialysis. Am J Clin Nutr. 2004;80(2):324–32.
17. Turgeon NA, Perez S, Mondestin M, et al. The impact of renal function on outcomes of bariatric surgery. J Am Soc Nephrol. 2012;23(5):885–94.
18. Saleh F, Kim SJ, Okrainec A, et al. Bariatric surgery in patients with reduced kidney function: an analysis of short-term outcomes. Surg Obes Relat Dis. 2015;11(4):828–35.
19. Mozer AB, Pender JR, Chapman WH, et al. Bariatric surgery in patients with dialysis-dependent renal failure. Obes Surg. 2015;25(11):2088–92.
20. Jamal MH, Corcelles R, Daigle CR, et al. Safety and effectiveness of bariatric surgery in dialysis patients and kidney transplantation candidates. Surg Obes Relat Dis. 2015;11(2):419–23.
21. Andalib A, Aminian A, Khorgami Z, et al. Safety analysis of primary bariatric surgery in patients on chronic dialysis. Surg Endosc. 2016;30(6):2583–91.
22. Segev DL, Simpkins CE, Thompson RE, et al. Obesity impacts access to kidney transplantation. J Am Soc Nephrol. 2008;19(2):349–55.
23. American College of Surgeons and American Society of Metabolic and Bariatric Surgery. Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) User Guide for the 2016 Participant Use Data File. (2017).
24. Levy EM, Viscoli CM, Horwitz RI. The effect of acute renal failure on mortality. A cohort analysis. JAMA. 1996;275(19):1489–94.
25. Lassnigg A, Schmidlin D, Mouhieddine M, et al. Minimal changes of serum creatinine predict prognosis in patients after cardiothoracic surgery: a prospective cohort study. J Am Soc Nephrol. 2004;15(6):1597–605.
26. United States Renal Data System. Annual data report: atlas of chronic kidney disease and end-stage renal disease in the United States. Bethesda: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2016.
27. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation. 1999;100(10):1043–9.
28. Gupta PK, Gupta H, Sundaram A, et al. Development and validation of a risk calculator for prediction of cardiac risk after surgery. Circulation. 2011;124(4):381–7.
29. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. J Am Coll Cardiol. 2014;64(22):e77–137.
30. Chang SH, Stoll CR, Song J, et al. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. JAMA Surg. 2014;149(3):275–87.
31. Abadie A, Drukker D, Herr JL, et al. Implementing matching estimators for average treatment effects in Stata. Stata J. 2004;4:290–311.
32. Weitzen S, Lapane KL, Toledano AY, et al. Principles for modeling propensity scores in medical research: a systematic literature review. Pharmacoepidemiol Drug Saf. 2004;13(12):841–53.

33. United States Renal Data System. 2017 USRDS annual data report: epidemiology of kidney disease in the United States. Bethesda: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2017.

34. Gajdos C, Hawn MT, Kile D, et al. Risk of major nonemergent inpatient general surgical procedures in patients on long-term dialysis. JAMA Surg. 2013;148(2):137–43.

35. English WJ, DeMaria EJ, Brethauer SA, et al. American Society for Metabolic and Bariatric Surgery estimation of metabolic and bariatric procedures performed in the United States in 2016. Surg Obes Relat Dis. 2018;14(3):259–63.

36. Varela JE, Nguyen NT. Laparoscopic sleeve gastrectomy leads the U.S. utilization of bariatric surgery at academic medical centers. Surg Obes Relat Dis. 2015;11(5):987–90.

37. Steele KE, Prokopowicz GP, Chang HY, et al. Risk of complications after bariatric surgery among individuals with and without type 2 diabetes mellitus. Surg Obes Relat Dis. 2012;8(3):305–30.

38. Zhang Y, Zheng QJ, Wang S, et al. Diabetes mellitus is associated with increased risk of surgical site infections: a meta-analysis of prospective cohort studies. Am J Infect Control. 2015;43(8):810–5.

39. Livingston EH, Huerta S, Arthur D, et al. Male gender is a predictor of morbidity and age a predictor of mortality for patients undergoing gastric bypass surgery. Ann Surg. 2002;236(5):576–82.

40. Flum DR, Salem L, Elrod JA, et al. Early mortality among Medicare beneficiaries undergoing bariatric surgical procedures. JAMA. 2005;294(15):1903–8.

41. Flum DR, Belle SH, King WC, et al. Perioperative safety in the longitudinal assessment of bariatric surgery. N Engl J Med. 2009;361(5):445–54.

42. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 2013;3(1):1–150.

43. Mehta RL, Kellum JA, Shah SV, et al. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care. 2007;11(2):R31.

44. Huang TM, Wu VC, Young GH, et al. Preoperative proteinuria predicts adverse renal outcomes after coronary artery bypass grafting. J Am Soc Nephrol. 2011;22(1):156–63.

45. Mehta RH, Grab JD, O'Brien SM, et al. Bedside tool for predicting the risk of postoperative dialysis in patients undergoing cardiac surgery. Circulation. 2006;114(21):2208–16. quiz 2208

46. Thakar CV, Arrigain S, Worley S, et al. A clinical score to predict acute renal failure after cardiac surgery. J Am Soc Nephrol. 2005;16(1):162–8.