

Research Report

Nutritional Predictors of Perioperative Complications and Mortality Following Nephrectomy for Renal Malignancies: A Population-Based Analysis

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Abstract.

Introduction and Objective: Conflicting data exists regarding the impact of body mass index (BMI) on postoperative outcomes following surgery for renal malignancies (RM). Herein, we investigated associations between obesity, hypoalbuminemia, and/or significant weight loss in the preoperative period, and risk complications and mortality within 30 days of radical (RN) or partial nephrectomy (PN).

Materials and Methods: Review of the American College of Surgeons National Surgical Quality Improvement Program database identified 8,618 patients treated with PN or RN for RM between 2005 and 2012. Univariate and multivariable logistic regression models were developed to assess associations between hypoalbuminemia (<3.5 g/dl), >10% weight loss within 6 months of surgery, obesity (BMI >30 kg/m²), and 30-day major complications and mortality.

Results: Median BMI was 29.2 kg/m² with 24.9%, 11.9%, and 8.2% having class I, II, and III obesity, respectively. Weight loss of >10% was observed in 2.6% and 15.4% had preoperative albumin <3.5 g/dl. There were 1,802 complications (20.9%) and 88 deaths within 30 days (1.0%). On multivariable analysis, BMI ≥40 kg/m² (OR 1.3, *p*=0.04), >10% weight loss (OR 1.9, *p*<0.001) and hypoalbuminemia (OR 1.5, *p*<0.001) were independently associated with 30-day complications, while only >10% weight loss was independently associated with 30-day mortality (OR 2.4, *p*=0.03).

Conclusions: Extreme obesity, hypoalbuminemia, and significant weight loss were independently associated with risk of significant complications following PN or RN while only significant preoperative weight loss was associated with early mortality, underscoring the need to further understand the utility of moderating these risk factors in the perioperative period.

Keywords: Nutrition, albumin, renal malignancy, nephrectomy, body mass index

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INTRODUCTION

In 2017, over 40,000 men and 23,000 women in the United States will receive a diagnosis of cancer involving the kidney and renal pelvis [1]. Surgical resection is the cornerstone of treatment for localized renal malignancy (RM) [2]. Nephron-sparing surgery or partial nephrectomy (PN) is the standard of care in small, localized RM, while larger, central, or endophytic tumors often warrant radical nephrectomy (RN). Extirpation of RM via either PN or RN can be approached using either an open or minimally invasive approach [2].

Preoperative nutritional status is increasingly acknowledged to be of critical importance with respect to postoperative outcomes and perioperative risk stratification. Indeed, malnutrition has been associated with an increased risk of postoperative complications and mortality in the pediatric, cardiac, orthopedic, and general surgery literature [3–8]. Malnutrition may be characterized using variable definitions, including unintentional weight loss, low body mass index (BMI) according to the World Health Organization criteria ($\text{BMI} < 18.5 \text{ kg/m}^2$) as well as hypoalbuminemia ($< 3.5 \text{ g/dl}$) [9]. The Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) define malnutrition on the basis of 6 characteristics: insufficient energy intake, weight loss, loss of muscle mass, loss of subcutaneous fat, localized or generalized fluid accumulation, and diminished functional status, of which 2 must be present to diagnose malnutrition [10]. Regarding serum albumin, A.S.P.E.N. demonstrated that this acute phase protein does not consistently change with weight loss or caloric restriction and may not be a reliable indicator of malnutrition [10–13]. Therefore, we present albumin as a possible limitation in our discussion.

In the urologic literature, poor preoperative nutritional status appears to be strongly associated with oncologic outcomes following surgery, including cancer-specific and overall survival [9, 14–18]. Additionally, among patients with metastatic RM undergoing cytoreductive nephrectomy, malnutrition as defined by hypoalbuminemia has been associated with perioperative mortality [15]. However, beyond this report, the association between preoperative nutritional status and early postoperative morbidity and mortality following PN and RN across stages of RM remains inadequately characterized. Furthermore, there is conflicting data regarding associations

between obesity, as defined by $\text{BMI} > 30 \text{ kg/m}^2$, and perioperative outcomes after PN and RN, as some authors have reported increased perioperative morbidity among patients with obesity [16, 17], while other reports have failed to find any such association [16, 19, 20].

Understanding potentially modifiable risk factors for perioperative complications is of the utmost importance. Therefore, the objective of this study was to test the hypothesis that malnutrition, as defined by BMI-based criteria for underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$), hypoalbuminemia, and/or significant weight loss in the preoperative period is associated with increased risk of complications and mortality within 30 days following surgery, using a population-based cohort of patients with RM treated with either PN or RN. Additionally, a secondary objective was to assess how these perioperative outcomes were associated with increasing severity of obesity, according to BMI.

MATERIALS AND METHODS

We performed a retrospective review of the American College of Surgeons National Quality Improvement Program (ACS-NSQIP) database from 2005–2012. This is a nationally validated, prospectively maintained dataset that includes 135 patient-level clinical and surgical variables and tracks 30-day complications and mortality for major surgical procedures.

PN and RN cases performed for RM were extracted from the database using ICD-9 codes for RM and Current Procedure Terminology codes for RN (50545, 50230, 50220, 50225, 50234, 50236, 50543, 50546, 50548, 50549) and PN (50240). To minimize the risk of confounding related to coincident procedures that may have increased the complexity of the surgery, and therefore the potential risk for complications, cases were excluded for concurrent procedures that were likely to be unrelated to a primary diagnosis of RM.

Preoperative nutritional factors extracted included preoperative albumin ($< 3.5 \text{ g/dl}$ vs. $> 3.5 \text{ g/dl}$), documented weight loss $> 10\%$ within 6 months prior to surgery and preoperative BMI (categorized as underweight, normal weight, overweight, class I, II, and III obesity as ≤ 18.5 , $18.5\text{--}24.9$, $25\text{--}29.9$, $30\text{--}34.9$, $35\text{--}39.9$, and $\geq 40 \text{ kg/m}^2$ respectively).

Statistical analysis

Clinical, tumor, demographic, and treatment-related factors were compared between patients

Table 1
Demographic, clinical, and treatment-related factors

Feature (N available)	Number (%) or Median (Interquartile Range, IQR)
Age (N = 8618)	62 (53,71)
Sex (N = 8604)	
Male	5254 (61.1)
Female	3350 (38.9)
Race/Ethnicity (N = 8618)	
Non-Hispanic White	6384 (74.1)
Hispanic White	411 (4.8)
Black or African American	714 (8.3)
Asian, Native Hawaiian, or Pacific Islander	172 (2.0)
American Indian or Alaska Native	28 (0.3)
Other or Unknown	909 (10.5)
Year of Operation (N = 8618)	
2005	8 (0.1)
2006	48 (0.6)
2007	173 (2.0)
2008	474 (5.5)
2009	792 (9.2)
2010	1100 (12.8)
2011	2661 (30.9)
2012	3362 (39.0)
Surgical Approach (N = 8618)	
Laparoscopic	4929 (57.2)
Open	3689 (42.8)
Concurrent Lymphadenectomy (N = 8618)	
No	8410 (97.6)
Yes	208 (2.4)
Partial Nephrectomy (N = 8618)	1435 (16.7)
ASA Class (N = 8610)	
I/II	3256 (37.8)
III/IV/V	5354 (62.2)
Concurrent procedures (N = 8618)	
Thoracic procedure	13 (0.2)
Chest tube	7 (0.1)
Vascular repair/reconstruction	125 (1.5)
Removal of thrombus	42 (0.5)
Spleneectomy	44 (0.5)
Resection/repair of diaphragm	17 (0.2)
Bowel resection	107 (1.2)
Lysis of adhesions	92 (1.1)
Bowel repair	4 (0.0)
Liver biopsy/resection	62 (0.7)
Cholecystectomy	134 (1.6)
Pancreatic resection	25 (0.3)
Hernia repair	93 (1.1)
Adrenalectomy	104 (1.2)
Current smoker within 1 year (N = 8618)	1732 (20.1)
Diabetes mellitus (N = 8618)	
Insulin	526 (6.1)
Non-insulin (oral)	1141 (13.2)
Hypertension (N = 8618)	5617 (65.2)
Preoperative hematocrit (N = 8312)	40.2 (36.7, 43.3)
Preoperative creatinine (N = 8329)	1.0 (0.8, 1.21)
Preoperative GFR (N = 8227)	71.9 (54.8, 86.9)
Preoperative GFR Category (N = 8227)	
Normal (≥ 90 ml/min/1.73 ²)	1735 (21.1)
CKD 2 (eGFR 60–89 ml/min/1.73 ²)	3883 (47.2)
CKD 3 (eGFR 30–59 ml/min/1.73 ²)	2081 (25.3)
CKD 4 (eGFR 15–29 ml/min/1.73 ²)	200 (2.4)
CKD 5 (eGFR <15 ml/min/1.73 ²)	328 (4.0)

(Continued)

Table 1
(Continued)

Feature (N available)	Number (%) or Median (Interquartile Range, IQR)
Preoperative chemotherapy/systemic therapy (N = 4706)	69 (1.5)
Preoperative radiotherapy (N = 4668)	23 (0.5)
Paralysis (hemiplegia, paraplegia, quadriplegia) (N = 4706)	49 (1.0)
Disseminated Cancer/Metastatic disease (N = 8618)	374 (4.3)
Steroid use for chronic condition (N = 8618)	379 (4.4)
Stroke (CVA, stroke with/without neurological deficits) (N = 4705)	181 (3.8)
History of revascularization/amputation for peripheral vascular disease (N = 4706)	63 (1.3)
Alcohol consumption >2 drinks/day in the 2 weeks prior to admission (N = 4725)	162 (3.4)
Dyspnea (N = 8618)	
At rest	43 (0.5)
With moderate exertion	818 (9.5)
No	7757 (90.0)
Functional status (N = 8590)	
Independent	8416 (98.0)
Partially Dependent	154 (1.8)
Totally Dependent	20 (0.2)
Pulmonary comorbidity (dyspnea or chronic obstructive pulmonary disease) (N = 8618)	1132 (13.1)
Heart disease (congestive heart failure, myocardial infarction, previous percutaneous coronary intervention, cardiac surgery, angina) (N = 4732)	588 (12.4)
Angina in the 1 month prior to surgery (N = 4706)	36 (0.8)

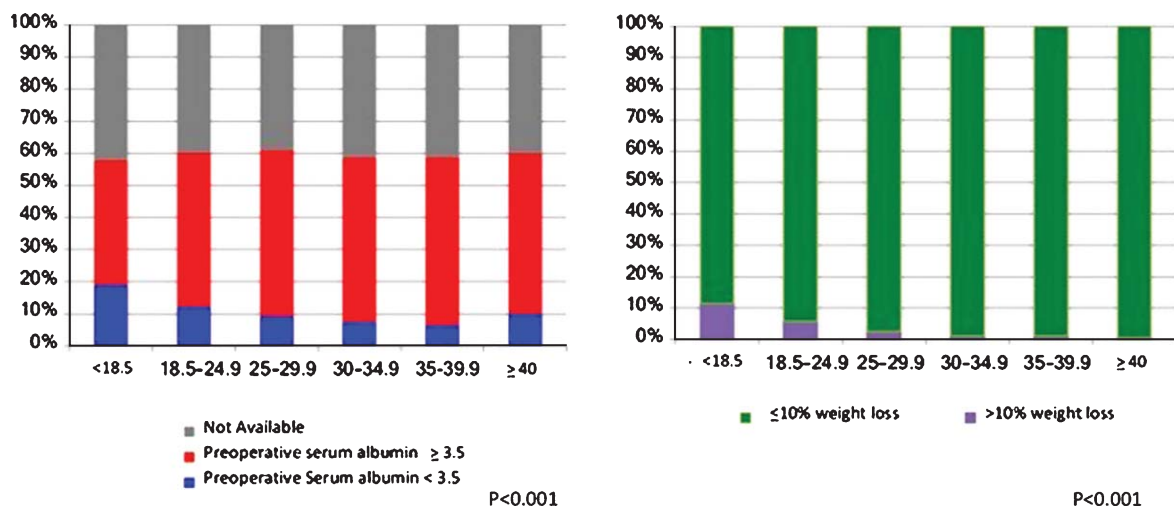


Fig. 1. Preoperative Serum Albumin and Weight loss >10% within the 6 months prior to surgery according to body mass index group.

across the three variables related to nutritional status, including age, sex, race/ethnicity, medical comorbidities (including pulmonary comorbidity [dyspnea or chronic obstructive pulmonary disease], heart disease [congestive heart failure, history of myocardial infarction (MI), prior percutaneous catheterization, previous cardiac surgery, history of angina], baseline paralysis, steroid use, requirement for dialysis, history of stroke, peripheral vascular disease requiring revascularization or amputation, presence of ascites, American Society of Anesthesia (ASA)

classification, history of substance abuse, functional status, exposure to preoperative chemotherapy or radiotherapy, and whether or not the patient had disseminated cancer at the time of surgery. Surgical factors included PN vs. RN, laparoscopic vs. open approach, and whether or not the patient underwent a concurrent lymphadenectomy.

Continuous features were described with means (standard deviation [SD]) and categorical data was described with numbers (percentages). A subset of the medical comorbidities included in the analysis

Table 2

Distribution of Nutritional Factors and Obesity across the cohort	
Nutritional Characteristic	Median (IQR; range) or N (%)
Body Mass Index (kg/m ² ; N = 8552)	29.2 (25.7, 33.7; 10.9 – 86.9)
BMI Category (WHO Classification) (N = 8552)	
<18.5	95 (1.1)
18.5–24.9	1673 (19.6)
25.0–29.9	2936 (34.3)
30.0–34.9	2126 (24.9)
35.0–39.9	1018 (11.9)
≥40	704 (8.2)
>10% loss of body weight in the last 6 months (N = 8617)	223 (2.6)
Preoperative serum albumin (g/dL; N = 5163)	4.0 (3.7, 4.3; 1.0–7.1)
Preoperative albumin category	
<3.5 g/dL	796 (15.4)
≥3.5 g/dL	4367 (84.6)

(history of MI, prior percutaneous catheterization, previous cardiac surgery, history of angina, paralysis, history of stroke, peripheral vascular disease, alcohol use, and chemotherapy or radiotherapy) were phased out from collection by NSQIP in 2011 and as therefore only available for a subset of our cohort. Missing values were handled as follows: for descriptive continuous statistics, only the patients for whom the variable was available were included in that variable’s distribution. In the univariate and multivariable modeling, for features with a significant number of patients with unknown values, missing data was included as a separate “unknown” category, or if only missing for a small number, was collapsed with the normal category and or excluded for continuous data, as specified in the multivariable tables. In total, 29 patients were excluded from the final multivariable modeling due to missing data.

The outcomes of interest included major and minor complications and mortality within 30 days of surgery. Complications included cardiac arrest, MI, pneumonia, ventilator >48 hours, reintubation, deep surgical site infection (SSI), organ space SSI, superficial SSI, sepsis or septic shock, deep vein thrombosis, pulmonary embolism, renal insufficiency or failure, return to the operating room, intraoperative or postoperative transfusion with 72 hours, wound disruption, cerebrovascular accident/stroke, coma >24 hours, peripheral nerve injury, 30-day mortality, and urinary tract infection. The proportion of patients who required transfusion were assessed but not included in the final models. Univariate and multivariable logistic regression were performed to evaluate associations

Table 3

Operative details and 30-day Complications and Mortality (N = 8618)

Operative Detail	Mean (SD) or N(%)
Total Operative Time (minutes)	184.0 (85.1)
Transfusion	1170 (13.6)
Return to the Operative Room (N = 8617)	253 (2.9)
Days from Principal Operative Procedure to Unplanned Reoperation	9.9 (8.3; range 0–30)
Post-operative Length of Stay	4.4 (4.01; range 0–82)
Readmissions (Available 2011 – 2012 only; N = 5758)	370 (6.4)
Complications	
	N(%)
Cardiac Arrest requiring CPR	46 (0.5)
Myocardial Infarction	58 (0.7)
Pneumonia	121 (1.4)
Requirement for ventilation >48 hours	91 (1.1)
Unplanned intubation	124 (1.4)
Deep Incision Surgical Site Infection	25 (0.3)
Organ Space Surgical Site Infection	46 (0.5)
Sepsis or Septic Shock	142 (1.6)
Deep Vein Thrombosis/Thrombophlebitis/DVT Requiring Therapy	67 (0.8)
Pulmonary Embolism	42 (0.5)
DVT or PE	100 (1.2)
Progressive Renal Insufficiency	86 (1.0)
Superficial Surgical Site Infection	105 (1.2)
Wound disruption	35 (0.4)
Urinary Tract Infection	146 (1.7)
Stroke/CVA with neurological deficit	28 (0.3)
Coma >24 hours	1 (0.0)
Peripheral nerve injury	3 (0.0)
Death within 30 days	88 (1.0)
Multiple complications (excluding bleeding/transfusion)	
0	7676 (89.1)
1	626 (7.3)
2	153 (1.8)
3	76 (0.9)
4	37 (0.4)
5	23 (0.3)
6	19 (0.2)
7	7 (0.1)
8	1 (0.0)

between clinical, demographic, and surgical factors and the outcomes of interest. The final multivariable models were developed using forward selection of variables independently associated with the outcomes of interest, at the 5% level of significance. Due to the low prevalence of 30-day mortality, variables for

Table 4A
Univariate and Multivariable Logistic Regression Models for Postoperative Complications within 30 days of surgery

Feature	Univariate Models		Multivariable Model	
	Odds Ratio (95% Confidence Interval)	p-value	Odds Ratio (95% Confidence Interval)	p-value
BMI Category (ref = normal)				
Underweight (<18.5)	0.94 (0.57–1.55)	0.82	0.64 (0.37–1.12)	0.12
Overweight (25.0 – 29.9)	0.83 (0.72–0.96)	0.01	0.92 (0.78–1.08)	0.29
Obese Class I (30.0 – 34.9)	0.81 (0.70–0.95)	0.009	0.92 (0.77–1.10)	0.35
Obese Class II (35.0 – 39.9)	0.79 (0.65–0.96)	0.02	0.88 (0.71–1.09)	0.25
Obese Class III (>40.0)	1.09 (0.89–1.34)	0.41	1.28 (1.01–1.62)	0.04
Unknown	1.25 (0.72–2.17)	0.44	0.85 (0.44–1.64)	0.62
>10% loss of body weight within 6 months (ref = no)	3.32 (2.54–4.34)	<0.001	1.87 (1.37–2.55)	<0.001
Preoperative Serum Albumin (ref>3.5)				
<3.5	3.21 (2.73–3.76)	<0.001	1.47 (1.22–1.78)	<0.001
Unknown	1.00 (0.89–1.12)	0.98	0.99 (0.87–1.13)	0.90
Preoperative Serum Albumin (continuous)	0.38 (0.35–0.44)	<0.001		
Partial Nephrectomy (ref = Radical Nephrectomy)	1.09 (0.95–1.25)	0.23	0.72 (0.61–0.84)	<0.001
Laparoscopic Nephrectomy (ref = Lap)	3.14 (2.82–3.50)	<0.001	3.38 (2.97–3.85)	<0.001
Lymphadenectomy (ref = no)	2.53 (1.91–3.36)	<0.001	1.78 (1.30–2.44)	<0.001
Age (per 5-year increase)	1.12 (1.09–1.14)	<0.001		
Sex (ref = female)				
Male	1.07 (0.96–1.19)	0.20		
Unknown	2.20 (0.74–6.59)	0.16		
Race (ref = Non-Hispanic White)				
American Indian/Alaska Native	1.50 (0.66–3.40)	0.34		
Asian/Native Hawaiian/Pacific Islander	0.95 (0.66–1.39)	0.81		
Black or African American	1.09 (0.90–1.31)	0.37		
Hispanic White	0.79 (0.61–1.03)	0.08		
Other/Unknown	0.91 (0.76–1.08)	0.29		
Year of Operation	0.91 (0.87–0.94)	<0.001	0.96 (0.93–1.00)	0.08
ASA Class 3–5 (ref = 1-2 or unknown)	2.27 (2.02–2.56)	<0.001	1.50 (1.31–1.72)	<0.001
Current smoker within 1 year of surgery (ref = no)	0.85 (0.74–0.97)	0.01		
Diabetes Mellitus (ref = no)				
Insulin-dependent	2.16 (1.78–2.61)	<0.001	1.54 (1.24–1.92)	<0.001
Treated with oral agents	1.29 (1.11–1.50)	<0.001	1.07 (0.91–1.26)	0.43
Hypertension requiring medication (ref = no)	1.48 (1.32–1.66)	<0.001		
Preoperative Hematocrit (ref = normal or unknown: male 42+, female 38+)				
Very low (male<32, female<28)	9.48 (7.67–11.72)	<0.001	4.65 (3.64–5.95)	<0.001
Low (male 32–41.9, female 28–37.9)	2.09 (1.87–2.34)	<0.001	1.51 (1.33–1.71)	<0.001
Preoperative eGFR (ref = eGFR>90 ml/min/1.73 m²)				
CKD 2 (60–89)	0.97 (0.83–1.13)	0.66	0.93 (0.79–1.10)	0.42
CKD 3 (30–59)	2.09 (1.79–2.45)	<0.001	1.46 (1.22–1.75)	<0.001
CKD 4 (15–29)	4.88 (3.60–6.62)	<0.001	2.70 (1.88–3.88)	<0.001
CKD 5 (<15)	2.12 (1.62–2.78)	<0.001	1.82 (1.10–3.01)	0.02
Unknown	1.07 (0.80–1.43)	0.66	1.14 (0.83–1.57)	0.42
Disseminated Cancer (ref = no)	2.49 (2.01–3.08)	<0.001	1.54 (1.20–1.97)	<0.001
Functional Status (ref = independent)				
Partially dependent	2.63 (1.90–3.64)	<0.001	1.53 (1.06–2.21)	0.02
Totally dependent	9.10 (3.49–23.72)	<0.001	3.74 (1.28–10.90)	0.02
Dyspnea (ref = no)				
At rest	4.62 (2.53–8.43)	<0.001		
With moderate exertion	1.50 (1.36–1.88)	<0.001		
History of severe COPD (ref = no)	1.62 (1.32–1.99)	<0.001		
Pulmonary comorbidity dyspnea or COPD (ref = no)	1.66 (1.44–1.91)	<0.001	1.18 (1.00–1.38)	0.048
Heart disease (ref = no)				
Yes	1.55 (1.28–1.88)	<0.001		
Unknown	0.84 (0.75–0.94)	0.002		

(Continued)

Table 4A
(Continued)

Feature	Univariate Models		Multivariable Model	
	Odds Ratio (95% Confidence Interval)	<i>p</i> -value	Odds Ratio (95% Confidence Interval)	<i>p</i> -value
Paralysis (ref = no)				
Hemiplegia/paraplegia/quadruplegia	2.19 (1.23–3.91)	0.008		
Unknown	0.81 (0.73–0.90)	<0.001		
Steroid use for a chronic condition (ref = no)	1.44 (1.14–1.81)	0.002		
Stroke (CVA/stroke with or without neurological deficit) (ref = no)				
Yes	1.65 (1.20–2.28)	0.002		
Unknown	0.82 (0.74–0.91)	<0.001		
Currently on dialysis (ref = no)	1.62 (1.28–2.03)	<0.001	0.65 (0.41–1.04)	0.07
History of revascularization/amputation for peripheral vascular disease (ref = no)				
Yes	2.61 (1.58–4.32)	<0.001		
Unknown	0.81 (0.73–0.90)	<0.001		
Ascites (ref = no)	8.17 (3.32–20.06)	<0.001	2.83 (0.98–8.14)	0.05
History of angina within 1 month before surgery (ref = no)				
Yes	1.32 (0.64–2.75)	0.46		
Unknown	0.80 (0.72–0.89)	<0.001		

The multivariable model was developed with forward selection. The C-index for the multivariable model is 0.75.

the model of 30-day mortality were further selected based on clinical significance to avoid over-fitting. Statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary NC).

RESULTS

A total of 8,618 patients who underwent PN or RN for RM between 2005–2012 were identified, with a median age of 62 (interquartile range [IQR]: 53–71). The study cohort included 5,254 (61.1%) males and 6,384 (74.1%) non-Hispanic white patients. An open surgical approach was utilized in 3,689 patients (42.8%), and 208 patients (2.4%) underwent concurrent lymphadenectomy. Cytoreductive surgery was performed in 374 patients (4.3%, coded as “disseminated cancer” in the NSQIP dataset). PN was undertaken in 1,435 (16.7%) patients. In total, 5,354 patients (62.2%) met criteria for ASA Class III–V, and 174 (2.0%) of patients were either partially or totally dependent with respect to functional status. Preoperative demographic, clinical, and comorbidity data is summarized in Table 1.

The prevalence of the nutritional features of interest (BMI, preoperative albumin level and preoperative weight loss) are summarized in Table 2. The median BMI of the study cohort was 29.2 kg/m², with 2,126 (24.9%), 1,018 (11.9%), and 704 (8.2%) with class I, II, and III obesity respectively. Thus, the overall prevalence of obesity in the study cohort

was 45.0% (*n* = 3,848) while 2,936 (34.0%) of the population were overweight, and 95 (1.1%) were underweight. Significant (>10%) weight loss in the 6 months preceding surgery was observed in 223 (2.6%) patients. Serum albumin was available in 5,163 patients (59.9%). Median preoperative albumin was 4 g/dL (IQR: 3.7, 4.3; range 1–7.1). Of patients with available serum albumin, 796 (15.4%) had albumin <3.5 g/dL. Figure 1 demonstrates the distribution of the two nutritional features of interest according to BMI category. Patients who were underweight according to BMI category (BMI <18.5 kg/m²) had the highest proportion of hypoalbuminemia and significant weight loss as a percentage of their total body weight in the 6 months preoperatively (*p* < 0.001 for both).

Complications occurred in 1,802 of 8,618 patients (20.9%) within 30 days postoperatively and there were 88 deaths (1.0%). Mean post-operative length of stay was 4.4 days (SD 4.0, range 0–82). Complications necessitating reoperation were observed in 253 patients (2.9%) within an average of 9.9 days (SD 8.3, range 0–30). Readmission within 30 days was available for 5,758 patients (2011–2012 only) and was observed in 370 patients treated in that time period (6.4%). Respiratory complications (pneumonia, use of ventilator >48 hours, and reintubation) occurred in 237 patients (2.8%). The prevalence of specific complications by type are detailed in Table 3. Blood transfusions were administered in 1,170 (13.6%). In

Table 4B
Univariable and Multivariable Logistic Regressions for Death within 30 days

Feature	Univariate Models		Multivariable Model	
	Odds Ratio (95% Confidence Interval)	p-value	Odds Ratio (95% Confidence Interval)	p-value
BMI Category (ref = normal)				
Underweight (<18.5)	1.31 (0.31–5.60)	0.71	1.11 (0.25–4.92)	0.89
Overweight (25.0 – 29.9)	0.46 (0.26–0.81)	0.007	0.56 (0.31–1.01)	0.05
Obese Class I (30.0 – 34.9)	0.43 (0.23–0.82)	0.01	0.64 (0.33–1.24)	0.19
Obese Class II (35.0 – 39.9)	0.91 (0.48–1.72)	0.78	1.55 (0.78–3.07)	0.21
Obese Class III (>40.0)	0.52 (0.22–1.28)	0.15	0.98 (0.38–2.50)	0.96
Unknown	0.94 (0.13–7.01)	0.95	0.44 (0.05–3.94)	0.46
>10% loss of body weight within 6 months (ref = no)	4.43 (2.19–8.94)	<0.001	2.39 (1.11–5.14)	0.03
Preoperative Serum Albumin (ref>3.5)				
<3.5	3.39 (2.01–5.72)	<0.001	1.72 (0.98–3.00)	0.06
Unknown	0.90 (0.55–1.47)	0.67	0.94 (0.56–1.57)	0.80
Preoperative Serum Albumin (continuous)				
Partial Nephrectomy (ref = Radical Nephrectomy)	0.71 (0.38–1.34)	0.30		
Laparoscopic Nephrectomy (ref = Open)	2.36 (1.53–3.65)	<0.001	2.30 (1.47–3.60)	<0.001
Lymphadenectomy (ref = no)	2.47 (0.99–6.16)	0.05		
Age (per 5-year increase)	1.34 (1.22–1.47)	<0.001	1.38 (1.23–1.55)	<0.001
Male Sex (ref = female)	1.53 (0.96–2.42)	0.07		
Race (ref = Non-Hispanic White)				
Asian/Native Hawaiian/Pacific Islander	1.11 (0.27–4.57)	0.89		
Black or African American	0.80 (0.35–1.85)	0.60		
Hispanic White	0.93 (0.34–2.55)	0.88		
Other/Unknown	0.94 (0.47–1.90)	0.87		
Year of Operation	0.88 (0.76–1.01)	0.07		
ASA Class 3–5 (ref = 1-2 or unknown)	7.15 (3.30–15.48)	<0.001	3.64 (1.64–8.07)	0.002
Current smoker within 1 year of surgery (ref = no)	1.17 (0.71–1.93)	<0.001	1.76 (1.03–3.02)	0.04
Diabetes Mellitus (ref = no)				
Insulin-dependent				
Treated with oral agents	1.93 (0.96–3.91)	0.07		
Hypertension requiring medication (ref = no)	1.68 (0.98–2.89)	0.06		
Preoperative Hematocrit (continuous)	1.71 (1.05–2.80)	0.03		
Preoperative Hematocrit (continuous)	0.90 (0.87–0.93)	<0.001		
Preoperative eGFR (ref = eGFR>90 ml/min/1.73 m²)				
CKD 2 (60–89)	0.82 (0.42–1.62)	0.57	0.69 (0.34–1.38)	0.29
CKD 3 (30–59)	2.13 (1.12–4.07)	0.02	1.12 (0.56–2.24)	0.74
CKD 4 (15–29)	5.52 (2.26–13.48)	0.002	2.31 (0.90–5.99)	0.08
CKD 5 (<15)	3.31 (1.36–8.05)	0.008	3.06 (1.22–7.70)	0.02
Unknown	0.68 (0.15–3.03)	0.61	0.67 (0.14–3.15)	0.62
Disseminated Cancer (ref = no)	5.90 (3.48–10.02)	<0.001	5.33 (3.02–9.41)	<0.001
Functional Status (ref = independent)				
Partially dependent	6.81 (3.35–13.86)	<0.001		
Totally dependent	12.20 (2.78–53.47)	<0.001		
Dyspnea (ref = no)				
At rest	5.07 (1.20–21.33)	0.03		
Moderate exertion	1.55 (0.84–2.86)	0.16		
Heart disease (ref = no)				
Yes	4.48 (2.58–7.77)	<0.001		
Unknown	1.04 (0.64–1.68)	0.89		
Paralysis (ref = no)				
Hemiplegia/paraplegia/quadruplegia	1.78 (0.24–13.1)	0.57		
Unknown	0.73 (0.47–1.12)	0.15		
Steroid use for a chronic condition (ref = no)	2.84 (1.46–5.52)	0.002		
Stroke (CVA/stroke with or without neurological deficit) (ref = no)				
Yes	2.02 (0.72–5.66)	0.18		
Unknown	0.78 (0.51–1.22)	0.28		

(Continued)

Table 4B
(Continued)

Feature	Univariate Models		Multivariable Model	
	Odds Ratio (95% Confidence Interval)	<i>p</i> -value	Odds Ratio (95% Confidence Interval)	<i>p</i> -value
Currently on dialysis (ref = no)	1.92 (0.88–4.19)	0.10		
History of revascularization/amputation for peripheral vascular disease (ref = no)				
Yes	7.92 (3.05–20.58)	<0.001		
Unknown	0.78 (0.50–1.22)	0.27		
Ascites (ref = no)	9.90 (2.28–42.99)	0.002		
History of angina within 1 month before surgery (ref = no)				
Yes	5.12 (1.20–21.88)	0.03		
Unknown	0.74 (0.48–1.15)	0.18		

The C-index for the multivariable model is 0.83.

total, excluding bleeding or transfusion-related complications, 626 (7.3%) patients experienced a single complication, 153 (1.8%) of patients experienced two complications, and 163 (1.9%) experienced three or more complications after PN or RN.

Univariate and multivariable logistic regression models detailing associations between the nutritional and clinical factors of interest with the outcomes of 30-day complications (excluding transfusions) and 30-day mortality are presented in Table 4a and 4b, respectively. On multivariable analysis, class III obesity compared to normal weight (Odds Ratio [OR] 1.28, 95% Confidence Interval [CI] 1.01–1.62; $p=0.04$), >10% weight loss within 6 months (OR 1.87, 95%CI 1.27–2.55; $p<0.0001$), and serum albumin<3.5 g/dL (OR 1.47, 95%CI 1.22–1.78; $p<0.0001$) were independently associated with increased risk of moderate-to-severe complications within 30 days of surgery (Table 4A). The final multivariable model was adjusted for laparoscopic vs. open approach, PN vs. RN, age, concurrent lymphadenectomy, ASA class, year of operation, preoperative hematocrit and eGFR, and preoperative comorbidities (DM, metastatic disease, functional status, pulmonary comorbidity, dialysis treatment, and presence of ascites). The c-index for the model was 0.75.

Regarding mortality within 30 days of surgery, only >10% weight loss in the 6 months prior to surgery (OR 2.39, 95%CI 1.11–5.14; $p=0.03$) was statistically significantly associated with the outcome of interest, while preoperative serum albumin<3.5 g/dL (OR 1.72, 95%CI 0.98–3.00; $p=0.06$) did not demonstrate a complete association with 30-day mortality. Conversely, there were no significant associations between obesity or underweight

and 30-day mortality, after adjusting for surgical approach, age, ASA class, eGFR, metastatic disease burden, and smoking (Table 4B). The c-index for this model was 0.83.

To better characterize patients with a BMI >40 kg/m², >10% preoperative weight loss, and a preoperative albumin <3.5 g/dl, contingency tables were included to compare groups based on age, sex, race, smoking status, preoperative comorbidities, laparoscopic vs. open approach, ASA class, metastatic vs. non-metastatic disease, and PN vs. RN. Patients with a BMI >40 kg/m² were more likely to be aged 50–59 ($n=226$; $p<0.001$), received a radical nephrectomy ($n=570$; $p<0.001$), and had a history of hypertension requiring medication ($n=549$; $p<0.001$; Table 5). Significant preoperative weight loss was associated with receipt of radical nephrectomy ($n=212$; $p<0.001$), an open surgical approach ($n=133$; $p<0.001$), and ASA class 3–5 ($n=157$; $p=0.010$; Table 6). Preoperative hypoalbuminemia was associated with age 60–69 ($n=247$; $p<0.001$), ASA class 3–5 ($n=656$; $p<0.001$), and history of hypertension requiring medication ($n=555$; $p=0.002$; Table 7).

DISCUSSION

Postoperative complications have been reported to affect up to one quarter of patients following surgery for RM and are associated with both in-hospital mortality and total hospitalization costs [21]. In this study, we assessed the association of BMI and malnutrition with major complications and mortality within 30 days of surgery in 8,618 patients undergoing PN or RN for RM. In this study cohort, the median BMI was 29.2 kg/m², with an overall prevalence of class I–III obesity of 45% while only 1.1% were

underweight. Significant weight loss (>10%) was observed in 2.6% of patients and 15.4% of patients for whom albumin was available had a preoperative albumin of <3.5 g/dl. As for our outcomes of interest, a total of 1,802 complications (20.9%) and 88 deaths (1.0%) were observed within 30 days after surgery. Additionally, we observed an increased risk of complications with RN compared to PN on multivariable modeling. This may be due to an increased risk of chronic kidney disease with RN compared to PN [22] or due to lower complexity related to smaller tumors. Unfortunately, we were unable to account for tumor size, stage, or surgical complexity due to limitations of tumor-specific covariates in the dataset.

We observed that morbid obesity, significant weight loss within 6 months, and serum albumin <3.5 g/dl were independently associated with an increased risk of complications 30 days of surgery. However, significant weight loss was the only nutritional factor independently significantly associated with an increased rate of mortality within 30 days of surgery while there appeared to be a trend with respect to preoperative hypoalbuminemia and early postoperative death. These results highlight the importance of assessing preoperative factors of malnutrition in patients undergoing PN or RN for RM.

The relationship between nutritional status and surgical outcomes has been previously described in patients treated for cancers of the kidney. Morgan and colleagues reported that nutritional deficiency was independently associated with overall mortality (Hazard Ratio [HR] 2.41, 95%CI 1.40–4.18) and disease-specific mortality (HR 2.76, 95%CI 1.17–6.50) in 369 patients undergoing surgical treatment for kidney cancer [14]. Nutritional deficiency was defined as a BMI of <18.5 kg/m², serum albumin <3.5 g/dl, or preoperative weight loss >5%. Overall survival was 58.5% in the nutritionally deficient cohort vs. 85.4% in controls ($p < 0.001$). Disease-specific survival was 80.4% and 94.7%, respectively ($p < 0.001$).

Similarly, Abel and colleagues described that a preoperative serum albumin <3.4 g/dl was a predictor of 90-day mortality on univariate analysis in 162 patients undergoing surgical treatment for kidney cancer with concomitant IVC thrombus above the hepatic veins (OR 8.61, 95%CI 1.81–40.94; $p = 0.01$) [15]. On multivariable analysis serum albumin <3.4 g/dl was an independent predictor of 90-day mortality (OR 10.13, 95%CI 1.56–65.64; $p = 0.02$). Within this cohort, 17 patients (10.5%) underwent surgical treatment with a preoperative serum albumin

<3.4 g/dl. The authors recommended delaying surgical treatment until serum albumin levels were within normal limits.

The association between preoperative nutritional status and surgical complications for other genitourinary malignancies have also been described in the literature. Johnson and colleagues reported that poor preoperative nutritional status, defined by serum albumin <3.5 g/dl, was an independent predictor of having a postoperative complication in 1,213 patients who underwent radical cystectomy for bladder cancer on multivariable analysis ($p = 0.03$) [9]. Respiratory complications were most significantly associated with a serum albumin <3.5 g/dl (19% vs. 6%; $p < 0.01$). BMI was not found to be an independent predictor of increased overall complication rate on multivariable analysis; however, an increased BMI was significantly associated with developing a superficial wound infection ($p < 0.001$), wound dehiscence ($p = 0.01$), renal insufficiency ($p = 0.01$), and returning to the OR ($p = 0.05$) on univariate analysis.

Our study has certain limitations related to its retrospective study design that must be addressed. The use of registry data may be limited due to abstractor accuracy and limited variables or granularity of the data [23]. Importantly, the NSQIP database does not provide tumor stage, grade, and size data, which is a limitation when using this database. The NSQIP database also provides only 30-day outcomes, and not 90-day outcomes. Furthermore, we observed that serum albumin data was only available in 60% of the cohort, which may introduce bias into the study results. As noted, those patients for whom albumin was missing were included in the overall models as a separate category, however, this likely represents a heterogeneous group. Furthermore, albumin is an acute phase reactant that can fluctuate with inflammation and as a single measurement may be an unreliable indicator of nutritional status [24]. Additionally, when assessing true body composition, BMI is nonspecific and does not differentiate excessive adipose tissue from lean muscle mass, which may have implications for both oncologic outcomes as well as perioperative morbidity [25–27]. For example, BMI has been demonstrated to mask sarcopenia, which has been associated with both increased mortality and postoperative complications in kidney cancer [28], as well as in breast, rectal, esophageal, and head and neck malignancies [29–32].

Despite these limitations, to our knowledge this is the first study that demonstrated the association

Table 5
Relationship of body mass index by category and variables of interest

Characteristic/ feature	BMI Category (WHO classification) (with unknown)								P-value
	All (n = 8618)	<18.5 (n = 95)	18.5–4.9 (n = 1673)	25.0–29.9 (n = 2936)	30.0–34.9 (n = 2126)	35.0–39.9 (n = 1018)	40+ (n = 704)	Unknown (n = 66)	
Age									<0.001
No. (%) used	8618 (100.0%)	95 (100.0%)	1673 (100.0%)	2936 (100.0%)	2126 (100.0%)	1018 (100.0%)	704 (100.0%)	66 (100.0%)	
Mean (SD)	61.53 (12.88)	60.71 (15.58)	63.19 (14.65)	62.78 (12.84)	61.36 (11.67)	58.78 (11.58)	56.74 (11.43)	63.76 (13.49)	
Median (IQR)	62 (53,71)	62 (51,73)	64 (54,74)	63 (55,72)	62 (54,70)	59.5 (52,67)	57 (49,65)	62.5 (52,75)	
Range	17 to 90	19 to 90	17 to 90	18 to 90	22 to 90	19 to 88	22 to 89	36 to 90	
Age Category, no. (row %)									<0.001
<40	457	7 (1.5)	114 (24.9)	131 (28.7)	82 (17.9)	63 (13.8)	57 (12.5)	3 (0.7)	
40–49	1039	14 (1.3)	172 (16.6)	324 (31.2)	255 (24.5)	142 (13.7)	126 (12.1)	6 (0.6)	
50–59	2136	20 (0.9)	349 (16.3)	673 (31.5)	545 (25.5)	304 (14.2)	226 (10.6)	19 (0.9)	
60–69	2564	24 (0.9)	418 (16.3)	866 (33.8)	708 (27.6)	331 (12.9)	205 (8.0)	12 (0.5)	
70–79	1764	21 (1.2)	397 (22.5)	661 (37.5)	432 (24.5)	157 (8.9)	78 (4.4)	18 (1.0)	
80+	658	9 (1.4)	223 (33.9)	281 (42.7)	104 (15.8)	21 (3.2)	12 (1.8)	8 (1.2)	
Gender, no. (row %)									<0.001
Not available	14	1	4	5	3		1		
Male	5254	36 (0.7)	904 (17.2)	1994 (38.0)	1390 (26.5)	588 (11.2)	303 (5.8)	39 (0.7)	
Female	3350	58 (1.7)	765 (22.8)	937 (28.0)	733 (21.9)	430 (12.8)	400 (11.9)	27 (0.8)	
Race/ethnicity (all years), no. (row %)									<0.001
Non-Hispanic White	6384	66 (1.0)	1225 (19.2)	2134 (33.4)	1615 (25.3)	773 (12.1)	528 (8.3)	43 (0.7)	
Hispanic White	411	3 (0.7)	67 (16.3)	165 (40.1)	97 (23.6)	39 (9.5)	36 (8.8)	4 (1.0)	
Black or African American	714	13 (1.8)	121 (16.9)	225 (31.5)	168 (23.5)	114 (16.0)	67 (9.4)	6 (0.8)	
Asian, Native Hawaiian or Pacific Islander	172	3 (1.7)	65 (37.8)	70 (40.7)	23 (13.4)	5 (2.9)	5 (2.9)	1 (0.6)	
American Indian or Alaska Native	28	0 (0.0)	6 (21.4)	8 (28.6)	10 (35.7)	3 (10.7)	1 (3.6)	0 (0.0)	
Other or Unknown	909	10 (1.1)	189 (20.8)	334 (36.7)	213 (23.4)	84 (9.2)	67 (7.4)	12 (1.3)	

(Continued)

Table 5
(Continued)

Characteristic/ feature	BMI Category (WHO classification) (with unknown)								P-value
	All (n = 8618)	<18.5 (n = 95)	18.5–4.9 (n = 1673)	25.0–29.9 (n = 2936)	30.0–34.9 (n = 2126)	35.0–39.9 (n = 1018)	40+ (n = 704)	Unknown (n = 66)	
Year of Operation, no. (row %)									0.017
2005	8	0 (0.0)	1 (12.5)	4 (50.0)	2 (25.0)	0 (0.0)	1 (12.5)	0 (0.0)	
2006	48	1 (2.1)	18 (37.5)	15 (31.3)	3 (6.3)	7 (14.6)	3 (6.3)	1 (2.1)	
2007	173	2 (1.2)	40 (23.1)	56 (32.4)	34 (19.7)	25 (14.5)	15 (8.7)	1 (0.6)	
2008	474	8 (1.7)	110 (23.2)	156 (32.9)	124 (26.2)	39 (8.2)	32 (6.8)	5 (1.1)	
2009	792	13 (1.6)	147 (18.6)	278 (35.1)	183 (23.1)	94 (11.9)	66 (8.3)	11 (1.4)	
2010	1100	10 (0.9)	216 (19.6)	347 (31.5)	298 (27.1)	131 (11.9)	93 (8.5)	5 (0.5)	
2011	2661	27 (1.0)	530 (19.9)	921 (34.6)	652 (24.5)	319 (12.0)	188 (7.1)	24 (0.9)	
2012	3362	34 (1.0)	611 (18.2)	1159 (34.5)	830 (24.7)	403 (12.0)	306 (9.1)	19 (0.6)	
Lap vs Open (nephrectomy cohort only), no. (row %)									0.49
Lap	4929	46 (0.9)	973 (19.7)	1682 (34.1)	1213 (24.6)	565 (11.5)	410 (8.3)	40 (0.8)	
Open	3689	49 (1.3)	700 (19.0)	1254 (34.0)	913 (24.7)	453 (12.3)	294 (8.0)	26 (0.7)	
Lymphadenectomy, no. (row %)									0.035
No	8410	92 (1.1)	1639 (19.5)	2859 (34.0)	2059 (24.5)	1002 (11.9)	693 (8.2)	66 (0.8)	
Yes	208	3 (1.4)	34 (16.3)	77 (37.0)	67 (32.2)	16 (7.7)	11 (5.3)	0 (0.0)	
Partial nephrectomy, no. (row %)									<0.001
No	7183	87 (1.2)	1447 (20.1)	2449 (34.1)	1747 (24.3)	820 (11.4)	570 (7.9)	63 (0.9)	
Yes	1435	8 (0.6)	226 (15.7)	487 (33.9)	379 (26.4)	198 (13.8)	134 (9.3)	3 (0.2)	
ASA class, no. (row %)									<0.001
Not available	8		1	5	1	1			
1-No Disturb	156	2 (1.3)	51 (32.7)	77 (49.4)	19 (12.2)	5 (3.2)	1 (0.6)	1 (0.6)	
2-Mild Disturb	3100	22 (0.7)	656 (21.2)	1189 (38.4)	803 (25.9)	286 (9.2)	125 (4.0)	19 (0.6)	
3-Severe Disturb	4836	64 (1.3)	855 (17.7)	1503 (31.1)	1195 (24.7)	664 (13.7)	519 (10.7)	36 (0.7)	
4-Life Threat	517	7 (1.4)	109 (21.1)	162 (31.3)	108 (20.9)	62 (12.0)	59 (11.4)	10 (1.9)	
5-Moribund	1	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
ASA class (1-2 vs 3-4), no. (row %)									<0.001
Not available	8		1	5	1	1			
1 or 2-No or Mild Disturb	3256	24 (0.7)	707 (21.7)	1266 (38.9)	822 (25.2)	291 (8.9)	126 (3.9)	20 (0.6)	
3, 4, or 5-Severe Disturb, Life Threat, or Moribund	5354	71 (1.3)	965 (18.0)	1665 (31.1)	1303 (24.3)	726 (13.6)	578 (10.8)	46 (0.9)	

BMI									<0.001
No. (%) used	8552 (99.2%)	95 (100.0%)	1673 (100.0%)	2936 (100.0%)	2126 (100.0%)	1018 (100.0%)	704 (100.0%)	0 (0.0%)	
Mean (SD)	30.26 (6.87)	16.98 (1.55)	22.75 (1.61)	27.47 (1.41)	32.21 (1.43)	37.12 (1.42)	45.68 (6.42)	()	
Median (IQR)	29.18 (25.68,33.71)	17.33 (16.72,18.11)	23.01 (21.67,24.14)	27.49 (26.23,28.68)	32.02 (30.98,33.37)	36.89 (35.96,38.19)	43.59 (41.36,47.67)	(,)	
Range	10.93 to 86.85	10.93 to 18.50	18.51 to 24.99	25.01 to 30.00	30.01 to 35.00	35.01 to 39.97	40.02 to 86.85		
BMI Category (WHO classification), no. (row %)									<0.001
Not available	66							66	
<18.5	95	95 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
18.5–24.9	1673	0 (0.0)	1673 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
25.0–29.9	2936	0 (0.0)	0 (0.0)	2936 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
30.0–34.9	2126	0 (0.0)	0 (0.0)	0 (0.0)	2126 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	
35.0–39.9	1018	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1018 (100.0)	0 (0.0)	0 (0.0)	
40+	704	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	704 (100.0)	0 (0.0)	
>10% loss body weight in last 6 months, no. (row %)									<0.001
Not available	1		1						
No	8394	84 (1.0)	1576 (18.8)	2861 (34.1)	2102 (25.0)	1007 (12.0)	700 (8.3)	64 (0.8)	
Yes	223	11 (4.9)	96 (43.0)	75 (33.6)	24 (10.8)	11 (4.9)	4 (1.8)	2 (0.9)	
Current smoker within one year, no. (row %)									<0.001
No	6886	60 (0.9)	1264 (18.4)	2336 (33.9)	1749 (25.4)	831 (12.1)	592 (8.6)	54 (0.8)	
Yes	1732	35 (2.0)	409 (23.6)	600 (34.6)	377 (21.8)	187 (10.8)	112 (6.5)	12 (0.7)	
Diabetes mellitus with oral agents or insulin, no. (row %)									<0.001
Insulin	526	1 (0.2)	40 (7.6)	130 (24.7)	148 (28.1)	109 (20.7)	93 (17.7)	5 (1.0)	
Non-Insulin/Oral	1141	7 (0.6)	122 (10.7)	319 (28.0)	331 (29.0)	186 (16.3)	169 (14.8)	7 (0.6)	
None	6951	87 (1.3)	1511 (21.7)	2487 (35.8)	1647 (23.7)	723 (10.4)	442 (6.4)	54 (0.8)	
Hypertension requiring medication, no. (row %)									<0.001
No	3001	51 (1.7)	829 (27.6)	1073 (35.8)	609 (20.3)	264 (8.8)	155 (5.2)	20 (0.7)	
Yes	5617	44 (0.8)	844 (15.0)	1863 (33.2)	1517 (27.0)	754 (13.4)	549 (9.8)	46 (0.8)	

(Continued)

Table 5
(Continued)

Characteristic/ feature	BMI Category (WHO classification) (with unknown)								P-value
	All (n = 8618)	<18.5 (n = 95)	18.5–4.9 (n = 1673)	25.0–29.9 (n = 2936)	30.0–34.9 (n = 2126)	35.0–39.9 (n = 1018)	40+ (n = 704)	Unknown (n = 66)	
Surgical Specialty, no. (row %)									<0.001
General Surgery	535	11 (2.1)	148 (27.7)	164 (30.7)	104 (19.4)	64 (12.0)	37 (6.9)	7 (1.3)	
Cardiac Surgery	1	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Gynecology	1	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Neurosurgery	4	0 (0.0)	0 (0.0)	2 (50.0)	1 (25.0)	1 (25.0)	0 (0.0)	0 (0.0)	
Orthopedics	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
ENT	1	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Plastics	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Thoracic	6	0 (0.0)	0 (0.0)	3 (50.0)	1 (16.7)	2 (33.3)	0 (0.0)	0 (0.0)	
Urology	8010	83 (1.0)	1506 (18.8)	2749 (34.3)	2004 (25.0)	943 (11.8)	666 (8.3)	59 (0.7)	
Vascular	59	0 (0.0)	18 (30.5)	17 (28.8)	15 (25.4)	8 (13.6)	1 (1.7)	0 (0.0)	
Ophthalmology	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Oral Surgery	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Podiatry	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Other	1	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Pre-operative serum albumin									<0.001
No. (%) used	5163 (59.9%)	55 (57.9%)	1007 (60.2%)	1790 (61.0%)	1248 (58.7%)	598 (58.7%)	422 (59.9%)	43 (65.2%)	
Mean (SD)	3.95 (0.56)	3.69 (0.75)	3.89 (0.63)	3.98 (0.57)	4.00 (0.54)	3.99 (0.48)	3.85 (0.50)	3.76 (0.67)	
Median (IQR)	4 (3.7,4.3)	3.9 (3.2,4.2)	4 (3.6,4.3)	4.1 (3.7,4.4)	4.1 (3.7,4.4)	4 (3.7,4.3)	3.9 (3.6,4.2)	3.9 (3.5,4.2)	
Range	1 to 7.1	1.6 to 5	1 to 6.3	1.2 to 5.9	1.3 to 7.1	1.8 to 6.4	1.6 to 4.9	2.3 to 4.9	
Pre-operative serum albumin category, no. (row %)									<0.001
Not available	3455	40	666	1146	878	420	282	23	
<3.5	796	18 (2.3)	205 (25.8)	269 (33.8)	159 (20.0)	66 (8.3)	70 (8.8)	9 (1.1)	
3.5+	4367	37 (0.8)	802 (18.4)	1521 (34.8)	1089 (24.9)	532 (12.2)	352 (8.1)	34 (0.8)	
Pre-operative hematocrit									<0.001
No. (%) used	8312 (96.4%)	89 (93.7%)	1619 (96.8%)	2827 (96.3%)	2055 (96.7%)	982 (96.5%)	676 (96.0%)	64 (97.0%)	
Mean (SD)	39.73 (5.26)	36.66 (5.76)	38.70 (5.35)	39.98 (5.23)	40.22 (5.25)	40.32 (4.94)	39.46 (4.85)	36.68 (6.63)	
Median (IQR)	40.2 (36.7,43.3)	36.7 (32.6,39.6)	39.1 (35.6,42.2)	40.5 (37,43.5)	40.8 (37.4,43.7)	40.65 (37.4,43.6)	39.7 (36.4,43)	37.55 (32.6,41.85)	
Range	11.8 to 59	21.8 to 52	13.8 to 57.3	12.1 to 58.2	11.8 to 59	14.8 to 55.5	23 to 52.8	12.8 to 46.5	

Pre-operative hematocrit category, no. (row %)									<0.001
Not available	318	7	58	113	73	36	29	2	
Very low (Male<32; Female<28)	425	10 (2.4)	119 (28.0)	140 (32.9)	88 (20.7)	35 (8.2)	22 (5.2)	11 (2.6)	
Low (Male 32–41.9; Female 28–37.9)	3701	47 (1.3)	771 (20.8)	1259 (34.0)	876 (23.7)	418 (11.3)	296 (8.0)	34 (0.9)	
Normal (Male 42+; Female 38+)	4174	31 (0.7)	725 (17.4)	1424 (34.1)	1089 (26.1)	529 (12.7)	357 (8.6)	19 (0.5)	
Pre-operative serum creatinine									<0.001
No. (%) used	8239 (95.6%)	90 (94.7%)	1601 (95.7%)	2796 (95.2%)	2034 (95.7%)	982 (96.5%)	672 (95.5%)	64 (97.0%)	
Mean (SD)	1.30 (1.42)	1.24 (1.34)	1.37 (1.66)	1.32 (1.43)	1.32 (1.38)	1.26 (1.30)	1.10 (0.82)	1.67 (2.04)	
Median (IQR)	1 (0.8,1.21)	0.805 (0.7,1.1)	0.94 (0.8,1.2)	1 (0.81,1.24)	1 (0.82,1.22)	0.95 (0.8,1.2)	0.94 (0.79,1.195)	1.01 (0.8129,1.32)	
Range	0.2 to 15	0.23 to 8.39	0.3 to 15	0.3 to 14.69	0.2 to 14.13	0.3 to 15	0.47 to 13.31	0.37 to 9.7	
Pre-operative GFR									0.003
No. (%) used	8227 (95.5%)	89 (93.7%)	1597 (95.5%)	2792 (95.1%)	2032 (95.6%)	982 (96.5%)	671 (95.3%)	64 (97.0%)	
Mean (SD)	71.31 (28.70)	83.85 (49.37)	71.38 (29.77)	70.33 (26.02)	70.80 (30.85)	73.04 (27.73)	72.79 (26.02)	69.20 (38.50)	
Median (IQR)	71.90 (54.80,86.88)	78.16 (60.04,100.46)	72.65 (54.25,88.27)	71.28 (55.23,85.51)	71.04 (54.97,85.65)	74.41 (55.47,90.06)	72.03 (54.73,89.69)	70.65 (44.56,83.02)	
Range	3.13 to 595.90	6.27 to 359.94	3.72 to 298.15	3.30 to 316.08	3.13 to 595.90	3.37 to 226.92	4.20 to 186.09	5.00 to 192.20	
Pre-operative GFR category, no. (row %)									<0.001
Not available	391	6	76	144	94	36	33	2	
Normal: eGFR>= 90 mL/min/1.73 m ²	1735	25 (1.4)	369 (21.3)	527 (30.4)	391 (22.5)	246 (14.2)	165 (9.5)	12 (0.7)	
CKD 2: eGFR 60–89 mL/min/1.73 m ²	3883	42 (1.1)	715 (18.4)	1369 (35.3)	998 (25.7)	437 (11.3)	294 (7.6)	28 (0.7)	
CKD 3: eGFR 30–59 mL/min/1.73 m ²	2081	13 (0.6)	377 (18.1)	734 (35.3)	519 (24.9)	239 (11.5)	183 (8.8)	16 (0.8)	
CKD 4: eGFR 15–29 mL/min/1.73 m ²	200	4 (2.0)	50 (25.0)	55 (27.5)	42 (21.0)	28 (14.0)	19 (9.5)	2 (1.0)	
CKD 5: eGFR<15 mL/min/1.73 m ²	328	5 (1.5)	86 (26.2)	107 (32.6)	82 (25.0)	32 (9.8)	10 (3.0)	6 (1.8)	

(Continued)

Table 5
(Continued)

Characteristic/ feature	BMI Category (WHO classification) (with unknown)								P-value
	All (n = 8618)	<18.5 (n = 95)	18.5–4.9 (n = 1673)	25.0–29.9 (n = 2936)	30.0–34.9 (n = 2126)	35.0–39.9 (n = 1018)	40+ (n = 704)	Unknown (n = 66)	
Chemotherapy for malignancy in <= 30 days pre-op, no. (row %)									0.12
Not available	3912	46	722	1399	965	442	319	19	
No	4637	48 (1.0)	934 (20.1)	1508 (32.5)	1150 (24.8)	573 (12.4)	377 (8.1)	47 (1.0)	
Yes	69	1 (1.4)	17 (24.6)	29 (42.0)	11 (15.9)	3 (4.3)	8 (11.6)	0 (0.0)	
Radiotherapy for malignancy in last 90 days, no. (row %)									0.70
Not available	3950	46	733	1413	973	444	322	19	
No	4645	49 (1.1)	935 (20.1)	1512 (32.6)	1150 (24.8)	571 (12.3)	381 (8.2)	47 (1.0)	
Yes	23	0 (0.0)	5 (21.7)	11 (47.8)	3 (13.0)	3 (13.0)	1 (4.3)	0 (0.0)	
Paralysis (hemiplegia, paraplegia, quadriplegia), no. (row %)									0.081
Not available	3912	46	722	1399	965	442	319	19	
No	4657	48 (1.0)	934 (20.1)	1522 (32.7)	1153 (24.8)	574 (12.3)	379 (8.1)	47 (1.0)	
Yes	49	1 (2.0)	17 (34.7)	15 (30.6)	8 (16.3)	2 (4.1)	6 (12.2)	0 (0.0)	
Disseminated cancer, no. (row %)									<0.001
No	8244	89 (1.1)	1591 (19.3)	2798 (33.9)	2046 (24.8)	980 (11.9)	683 (8.3)	57 (0.7)	
Yes	374	6 (1.6)	82 (21.9)	138 (36.9)	80 (21.4)	38 (10.2)	21 (5.6)	9 (2.4)	
Steroid use for chronic condition, no. (row %)									<0.001
No	8239	90 (1.1)	1563 (19.0)	2821 (34.2)	2055 (24.9)	969 (11.8)	678 (8.2)	63 (0.8)	
Yes	379	5 (1.3)	110 (29.0)	115 (30.3)	71 (18.7)	49 (12.9)	26 (6.9)	3 (0.8)	
Stroke (CVA/stroke with or without neurological deficit), no. (row %)									0.18
Not available	3913	46	722	1400	965	442	319	19	
No	4524	47 (1.0)	899 (19.9)	1484 (32.8)	1122 (24.8)	555 (12.3)	371 (8.2)	46 (1.0)	
Yes	181	2 (1.1)	52 (28.7)	52 (28.7)	39 (21.5)	21 (11.6)	14 (7.7)	1 (0.6)	

Currently on dialysis (pre-op), no. (row %)									<0.001
No	8244	88 (1.1)	1578 (19.1)	2808 (34.1)	2043 (24.8)	978 (11.9)	690 (8.4)	59 (0.7)	
Yes	374	7 (1.9)	95 (25.4)	128 (34.2)	83 (22.2)	40 (10.7)	14 (3.7)	7 (1.9)	
History of revascularization/amputation for periph. vascular disease, no. (row %)									0.85
Not available	3912	46	722	1399	965	442	319	19	
No	4643	49 (1.1)	936 (20.2)	1514 (32.6)	1149 (24.7)	568 (12.2)	381 (8.2)	46 (1.0)	
Yes	63	0 (0.0)	15 (23.8)	23 (36.5)	12 (19.0)	8 (12.7)	4 (6.3)	1 (1.6)	
EtOH>2 drinks/day in 2 wks before admission, no. (row %)									0.19
Not available	3893	46	721	1389	962	440	316	19	
No	4563	48 (1.1)	912 (20.0)	1485 (32.5)	1127 (24.7)	566 (12.4)	379 (8.3)	46 (1.0)	
Yes	162	1 (0.6)	40 (24.7)	62 (38.3)	37 (22.8)	12 (7.4)	9 (5.6)	1 (0.6)	
Dyspnea, no. (row %)									<0.001
At rest	43	1 (2.3)	10 (23.3)	12 (27.9)	8 (18.6)	6 (14.0)	6 (14.0)	0 (0.0)	
Moderate exertion	818	11 (1.3)	126 (15.4)	221 (27.0)	205 (25.1)	121 (14.8)	129 (15.8)	5 (0.6)	
No	7757	83 (1.1)	1537 (19.8)	2703 (34.8)	1913 (24.7)	891 (11.5)	569 (7.3)	61 (0.8)	
Functional Status, no. (row %)									<0.001
Not available	28	1	8	5	9	2	3		
Independent	8416	87 (1.0)	1621 (19.3)	2876 (34.2)	2087 (24.8)	1002 (11.9)	682 (8.1)	61 (0.7)	
Partially Dependent	154	5 (3.2)	38 (24.7)	50 (32.5)	27 (17.5)	12 (7.8)	19 (12.3)	3 (1.9)	
Totally Dependent	20	2 (10.0)	6 (30.0)	5 (25.0)	3 (15.0)	2 (10.0)	0 (0.0)	2 (10.0)	
History of severe COPD, no. (row %)									0.012
No	8141	82 (1.0)	1568 (19.3)	2776 (34.1)	2023 (24.8)	966 (11.9)	663 (8.1)	63 (0.8)	
Yes	477	13 (2.7)	105 (22.0)	160 (33.5)	103 (21.6)	52 (10.9)	41 (8.6)	3 (0.6)	

(Continued)

Table 5
(Continued)

Characteristic/ feature	All (n = 8618)	BMI Category (WHO classification) (with unknown)							P-value
		<18.5 (n = 95)	18.5–4.9 (n = 1673)	25.0–29.9 (n = 2936)	30.0–34.9 (n = 2126)	35.0–39.9 (n = 1018)	40+ (n = 704)	Unknown (n = 66)	
Pulmonary comorbidity (dyspnea or COPD), no. (row %)									<0.001
No	7486	75 (1.0)	1478 (19.7)	2604 (34.8)	1855 (24.8)	862 (11.5)	552 (7.4)	60 (0.8)	
Yes	1132	20 (1.8)	195 (17.2)	332 (29.3)	271 (23.9)	156 (13.8)	152 (13.4)	6 (0.5)	
Ascites, no. (row %)									0.28
No	8596	94 (1.1)	1665 (19.4)	2929 (34.1)	2123 (24.7)	1016 (11.8)	703 (8.2)	66 (0.8)	
Yes	22	1 (4.5)	8 (36.4)	7 (31.8)	3 (13.6)	2 (9.1)	1 (4.5)	0 (0.0)	
Heart disease (CHF, MI, previous PCI, previous cardiac surgery, angina), no. (row %)									0.11
Not available	3886	46	716	1392	959	439	316	18	
No	4144	47 (1.1)	846 (20.4)	1346 (32.5)	1017 (24.5)	494 (11.9)	352 (8.5)	42 (1.0)	
Yes	588	2 (0.3)	111 (18.9)	198 (33.7)	150 (25.5)	85 (14.5)	36 (6.1)	6 (1.0)	
History of angina in 1 month before surgery, no. (row %)									0.83
Not available	3912	46	722	1399	965	442	319	19	
No	4670	49 (1.0)	943 (20.2)	1528 (32.7)	1150 (24.6)	570 (12.2)	383 (8.2)	47 (1.0)	
Yes	36	0 (0.0)	8 (22.2)	9 (25.0)	11 (30.6)	6 (16.7)	2 (5.6)	0 (0.0)	

Table 6
Relationship of weight loss >10% within the 6 months prior to surgery and variables of interest

Characteristic/feature	All (n = 8618)	>10% loss body weight in last 6 months		P-value
		No (n = 8394)	Yes (n = 223)	
Age				0.080
No. (%) used	8618 (100.0%)	8394 (100.0%)	223 (100.0%)	
Mean (SD)	61.53 (12.88)	61.49 (12.88)	63.02 (12.90)	
Median (IQR)	62 (53,71)	62 (53,71)	63 (55,73)	
Range	17 to 90	17 to 90	26 to 88	
Age Category, no. (row %)				0.012
<40	457	446 (97.6)	11 (2.4)	
40–49	1039	1019 (98.1)	20 (1.9)	
50–59	2136	2075 (97.1)	61 (2.9)	
60–69	2564	2509 (97.9)	55 (2.1)	
70–79	1764	1717 (97.3)	46 (2.6)	
80+	658	628 (95.4)	30 (4.6)	
Gender, no. (row %)				0.83
Not available	14	13	1	
Male	5254	5120 (97.4)	134 (2.6)	
Female	3350	3261 (97.3)	88 (2.6)	
Race/ethnicity (all years), no. (row %)				0.38
Non-Hispanic White	6384	6219 (97.4)	164 (2.6)	
Hispanic White	411	404 (98.3)	7 (1.7)	
Black or African American	714	698 (97.8)	16 (2.2)	
Asian, Native Hawaiian or Pacific Islander	172	167 (97.1)	5 (2.9)	
American Indian or Alaska Native	28	26 (92.9)	2 (7.1)	
Other or Unknown	909	880 (96.8)	29 (3.2)	
Year of Operation, no. (row %)				0.55
2005	8	8 (100.0)	0 (0.0)	
2006	48	47 (97.9)	1 (2.1)	
2007	173	165 (95.4)	8 (4.6)	
2008	474	459 (96.8)	15 (3.2)	
2009	792	773 (97.6)	19 (2.4)	
2010	1100	1065 (96.8)	34 (3.1)	
2011	2661	2593 (97.4)	68 (2.6)	
2012	3362	3284 (97.7)	78 (2.3)	
Lap vs Open (nephrectomy cohort only), no. (row %)				<0.001
Lap	4929	4838 (98.2)	90 (1.8)	
Open	3689	3556 (96.4)	133 (3.6)	
Lymphadenectomy, no. (row %)				<0.001
No	8410	8200 (97.5)	209 (2.5)	
Yes	208	194 (93.3)	14 (6.7)	
Partial nephrectomy, no. (row %)				<0.001
No	7183	6970 (97.0)	212 (3.0)	
Yes	1435	1424 (99.2)	11 (0.8)	
ASA class, no. (row %)				0.090
Not available	8	8		
1-No Disturb	156	152 (97.4)	4 (2.6)	
2-Mild Disturb	3100	3038 (98.0)	62 (2.0)	
3-Severe Disturb	4836	4693 (97.0)	142 (2.9)	
4-Life Threat	517	502 (97.1)	15 (2.9)	
5-Moribund	1	1 (100.0)	0 (0.0)	
ASA class (1-2 vs 3-4), no. (row %)				0.010
Not available	8	8		
1 or 2-No or Mild Disturb	3256	3190 (98.0)	66 (2.0)	
3, 4, or 5-Severe Disturb, Life Threat, or Moribund	5354	5196 (97.0)	157 (2.9)	
BMI				<0.001
No. (%) used	8552 (99.2%)	8330 (99.2%)	221 (99.1%)	
Mean (SD)	30.26 (6.87)	30.38 (6.86)	25.77 (5.37)	
Median (IQR)	29.18 (25.68,33.71)	29.33 (25.78,33.83)	25.27 (21.99,28.41)	
Range	10.93 to 86.85	10.93 to 86.85	11.94 to 49.48	

(Continued)

Table 6
(Continued)

Characteristic/feature	All (n = 8618)	>10% loss body weight in last 6 months		P-value
		No (n = 8394)	Yes (n = 223)	
BMI Category (WHO classification), no. (row %)				<0.001
Not available	66	64	2	
<18.5	95	84 (88.4)	11 (11.6)	
18.5–24.9	1673	1576 (94.2)	96 (5.7)	
25.0–29.9	2936	2861 (97.4)	75 (2.6)	
30.0–34.9	2126	2102 (98.9)	24 (1.1)	
35.0–39.9	1018	1007 (98.9)	11 (1.1)	
40+	704	700 (99.4)	4 (0.6)	
>10% loss body weight in last 6 months, no. (row %)				<0.001
Not available	1			
No	8394	8394 (100.0)	0 (0.0)	
Yes	223	0 (0.0)	223 (100.0)	
Current smoker within one year, no. (row %)				0.010
No	6886	6723 (97.6)	163 (2.4)	
Yes	1732	1671 (96.5)	60 (3.5)	
Diabetes mellitus with oral agents or insulin, no. (row %)				0.99
Insulin	526	512 (97.3)	14 (2.7)	
Non-Insulin/Oral	1141	1112 (97.5)	29 (2.5)	
None	6951	6770 (97.4)	180 (2.6)	
Hypertension requiring medication, no. (row %)				0.029
No	3001	2908 (96.9)	93 (3.1)	
Yes	5617	5486 (97.7)	130 (2.3)	
Surgical Specialty, no. (row %)				0.030
General Surgery	535	515 (96.3)	20 (3.7)	
Cardiac Surgery	1	1 (100.0)	0 (0.0)	
Gynecology	1	1 (100.0)	0 (0.0)	
Neurosurgery	4	4 (100.0)	0 (0.0)	
Orthopedics	0	0 (0.0)	0 (0.0)	
ENT	1	1 (100.0)	0 (0.0)	
Plastics	0	0 (0.0)	0 (0.0)	
Thoracic	6	6 (100.0)	0 (0.0)	
Urology	8010	7812 (97.5)	197 (2.5)	
Vascular	59	53 (89.8)	6 (10.2)	
Ophthalmology	0	0 (0.0)	0 (0.0)	
Oral Surgery	0	0 (0.0)	0 (0.0)	
Podiatry	0	0 (0.0)	0 (0.0)	
Other	1	1 (100.0)	0 (0.0)	
Pre-operative serum albumin				<0.001
No. (%) used	5163 (59.9%)	5003 (59.6%)	159 (71.3%)	
Mean (SD)	3.95 (0.56)	3.97 (0.55)	3.42 (0.76)	
Median (IQR)	4 (3.7,4.3)	4.03 (3.7,4.3)	3.5 (2.9,4)	
Range	1 to 7.1	1 to 7.1	1.5 to 5.9	
Pre-operative serum albumin category, no. (row %)				<0.001
Not available	3455	3391	64	
<3.5	796	718 (90.2)	78 (9.8)	
3.5+	4367	4285 (98.1)	81 (1.9)	
Pre-operative hematocrit				<0.001
No. (%) used	8312 (96.4%)	8095 (96.4%)	216 (96.9%)	
Mean (SD)	39.73 (5.26)	39.84 (5.21)	35.64 (5.35)	
Median (IQR)	40.2 (36.7,43.3)	40.3 (36.9,43.3)	35.95 (32,39.6)	
Range	11.8 to 59	11.8 to 59	18.8 to 49.2	

(Continued)

Table 6
(Continued)

Characteristic/feature	All (n = 8618)	>10% loss body weight in last 6 months		P-value
		No (n = 8394)	Yes (n = 223)	
Pre-operative hematocrit category, no. (row %)				<0.001
Not available	318	310	8	
Very low (Male<32; Female<28)	425	391 (92.0)	34 (8.0)	
Low (Male 32–41.9; Female 28–37.9)	3701	3566 (96.4)	135 (3.6)	
Normal (Male 42+; Female 38+)	4174	4127 (98.9)	46 (1.1)	
Pre-operative serum creatinine				0.61
No. (%) used	8239 (95.6%)	8027 (95.6%)	211 (94.6%)	
Mean (SD)	1.30 (1.42)	1.31 (1.42)	1.26 (1.39)	
Median (IQR)	1 (0.8,1.21)	1 (0.8,1.21)	0.96 (0.77,1.21)	
Range	0.2 to 15	0.2 to 15	0.3 to 13.25	
Pre-operative GFR				0.061
No. (%) used	8227 (95.5%)	8016 (95.5%)	210 (94.2%)	
Mean (SD)	71.31 (28.70)	71.22 (28.57)	74.97 (32.95)	
Median (IQR)	71.90 (54.80,86.88)	71.90 (54.85,86.72)	72.13 (54.31,94.16)	
Range	3.13 to 595.90	3.13 to 595.90	4.65 to 298.15	
Pre-operative GFR category, no. (row %)				0.13
Not available	391	378	13	
Normal: eGFR>= 90 mL/min/1.73 m ²	1735	1677 (96.7)	58 (3.3)	
CKD 2: eGFR 60–89 mL/min/1.73 m ²	3883	3798 (97.8)	84 (2.2)	
CKD 3: eGFR 30–59 mL/min/1.73 m ²	2081	2025 (97.3)	56 (2.7)	
CKD 4: eGFR 15–29 mL/min/1.73 m ²	200	195 (97.5)	5 (2.5)	
CKD 5: eGFR<15 mL/min/1.73 m ²	328	321 (97.9)	7 (2.1)	
Chemotherapy for malignancy in<= 30 days pre-op, no. (row %)				0.002
Not available	3912	3809	103	
No	4637	4523 (97.5)	113 (2.4)	
Yes	69	62 (89.9)	7 (10.1)	
Radiotherapy for malignancy in last 90 days, no. (row %)				0.12
Not available	3950	3847	103	
No	4645	4526 (97.4)	118 (2.5)	
Yes	23	21 (91.3)	2 (8.7)	
Paralysis (hemiplegia, paraplegia, quadriplegia), no. (row %)				1.00
Not available	3912	3809	103	
No	4657	4537 (97.4)	119 (2.6)	
Yes	49	48 (98.0)	1 (2.0)	
Disseminated cancer, no. (row %)				<0.001
No	8244	8059 (97.8)	184 (2.2)	
Yes	374	335 (89.6)	39 (10.4)	
Steroid use for chronic condition, no. (row %)				0.17
No	8239	8029 (97.5)	209 (2.5)	
Yes	379	365 (96.3)	14 (3.7)	
Stroke (CVA/stroke with or without neurological deficit), no. (row %)				0.47
Not available	3913	3810	103	
No	4524	4410 (97.5)	114 (2.5)	
Yes	181	174 (96.1)	6 (3.3)	
Currently on dialysis (pre-op), no. (row %)				0.82
No	8244	8029 (97.4)	214 (2.6)	
Yes	374	365 (97.6)	9 (2.4)	
History of revascularization/amputation for periph. vascular disease, no. (row %)				0.68
Not available	3912	3809	103	
No	4643	4524 (97.4)	118 (2.5)	
Yes	63	61 (96.8)	2 (3.2)	

(Continued)

Table 6
(Continued)

Characteristic/feature	All (n = 8618)	>10% loss body weight in last 6 months		P-value
		No (n = 8394)	Yes (n = 223)	
EtOH>2 drinks/day in 2 wks before admission, no. (row %)				0.61
Not available	3893	3790	103	
No	4563	4447 (97.5)	115 (2.5)	
Yes	162	157 (96.9)	5 (3.1)	
Dyspnea, no. (row %)				<0.001
At rest	43	40 (93.0)	3 (7.0)	
Moderate exertion	818	774 (94.6)	44 (5.4)	
No	7757	7580 (97.7)	176 (2.3)	
Functional Status, no. (row %)				<0.001
Not available	28	28		
Independent	8416	8206 (97.5)	209 (2.5)	
Partially Dependent	154	140 (90.9)	14 (9.1)	
Totally Dependent	20	20 (100.0)	0 (0.0)	
History of severe COPD, no. (row %)				0.17
No	8141	7934 (97.5)	206 (2.5)	
Yes	477	460 (96.4)	17 (3.6)	
Pulmonary comorbidity (dyspnea or COPD), no. (row %)				<0.001
No	7486	7317 (97.7)	168 (2.2)	
Yes	1132	1077 (95.1)	55 (4.9)	
Ascites, no. (row %)				0.11
No	8596	8374 (97.4)	221 (2.6)	
Yes	22	20 (90.9)	2 (9.1)	
Heart disease (CHF, MI, previous PCI, previous cardiac surgery, angina), no. (row %)				0.25
Not available	3886	3783	103	
No	4144	4042 (97.5)	101 (2.4)	
Yes	588	569 (96.8)	19 (3.2)	
History of angina in 1 month before surgery, no. (row %)				0.23
Not available	3912	3809	103	
No	4670	4551 (97.5)	118 (2.5)	
Yes	36	34 (94.4)	2 (5.6)	

of morbid obesity, hypoalbuminemia and significant weight loss with 30-day complications and/or mortality in a large population-based cohort undergoing PN or RN for RM. This data demonstrates implications for preoperative risk stratification based upon a patient's nutritional status. To better characterize patients at risk for postoperative complications, we recommend assessing preoperative serum albumin as a marker of malnutrition. Furthermore, patients at risk for adverse outcomes may potentially be identified preoperatively permitting prehabilitative and perioperative nutritional interventions to be implemented accordingly. Surgical rehabilitation includes the use of aerobic and resistant exercises and nutritional optimization to a preoperative albumin of >4 g/dl to improve postoperative outcomes [33, 34]. In a recent randomized control trial, preoperative nutritional interventions were compared in patients undergoing colorectal resection [35]. Patients that

received immunonutrient-enriched supplementation 7 days preoperatively and 5 days postoperatively had reduced postoperative complications compared to patients that received standard high-caloric supplementation. Herein, we suggest including nutritional optimization preoperatively into the medical management of all oncologic patients undergoing surgical treatment for RM.

Preoperative nutritional status appears to be an important aspect when assessing and treating oncologic patients, particularly when surgery is the primary treatment. Morbid obesity and poor nutritional status, measured by serum albumin level and significant preoperative weight loss, were all significantly associated with increased moderate-to-severe postoperative complications and/or mortality. Finally, these findings suggest the importance of preoperative risk stratification and counseling prior to surgical treatment of RM. Future work is necessary

Table 7
Relationship of preoperative serum albumin and variables of interest

Characteristic/feature	All (n = 8618)	Preoperative serum albumin category (with unknown)			P-value
		<3.5 (n = 796)	3.5+ (n = 4367)	Unknown (n = 3455)	
Age					<0.001
No. (%) used	8618 (100.0%)	796 (100.0%)	4367 (100.0%)	3455 (100.0%)	
Mean (SD)	61.53 (12.88)	63.36 (12.93)	61.37 (12.73)	61.30 (13.01)	
Median (IQR)	62 (53,71)	64 (55,72.5)	62 (53,70)	62 (53,71)	
Range	17 to 90	22 to 90	17 to 90	18 to 90	
Age Category, no. (row %)					<0.001
<40	457	31 (6.8)	233 (51.0)	193 (42.2)	
40–49	1039	77 (7.4)	535 (51.5)	427 (41.1)	
50–59	2136	192 (9.0)	1080 (50.6)	864 (40.4)	
60–69	2564	247 (9.6)	1314 (51.2)	1003 (39.1)	
70–79	1764	156 (8.8)	908 (51.5)	700 (39.7)	
80+	658	93 (14.1)	297 (45.1)	268 (40.7)	
Gender, no. (row %)					0.11
Not available	14		7	7	
Male	5254	462 (8.8)	2654 (50.5)	2138 (40.7)	
Female	3350	334 (10.0)	1706 (50.9)	1310 (39.1)	
Race/ethnicity (all years), no. (row %)					<0.001
Non-Hispanic White	6384	588 (9.2)	3315 (51.9)	2481 (38.9)	
Hispanic White	411	33 (8.0)	209 (50.9)	169 (41.1)	
Black or African American	714	97 (13.6)	352 (49.3)	265 (37.1)	
Asian, Native Hawaiian or Pacific Islander	172	14 (8.1)	106 (61.6)	52 (30.2)	
American Indian or Alaska Native	28	4 (14.3)	16 (57.1)	8 (28.6)	
Other or Unknown	909	60 (6.6)	369 (40.6)	480 (52.8)	
Year of Operation, no. (row %)					<0.001
2005	8	3 (37.5)	4 (50.0)	1 (12.5)	
2006	48	3 (6.3)	26 (54.2)	19 (39.6)	
2007	173	28 (16.2)	87 (50.3)	58 (33.5)	
2008	474	40 (8.4)	254 (53.6)	180 (38.0)	
2009	792	61 (7.7)	374 (47.2)	357 (45.1)	
2010	1100	90 (8.2)	529 (48.1)	481 (43.7)	
2011	2661	270 (10.1)	1429 (53.7)	962 (36.2)	
2012	3362	301 (9.0)	1664 (49.5)	1397 (41.6)	
Lap vs Open (nephrectomy cohort only), no. (row %)					<0.001
Lap	4929	363 (7.4)	2612 (53.0)	1954 (39.6)	
Open	3689	433 (11.7)	1755 (47.6)	1501 (40.7)	
Lymphadenectomy, no. (row %)					<0.001
No	8410	779 (9.3)	4288 (51.0)	3343 (39.8)	
Yes	208	17 (8.2)	79 (38.0)	112 (53.8)	
Partial nephrectomy, no. (row %)					<0.001
No	7183	728 (10.1)	3601 (50.1)	2854 (39.7)	
Yes	1435	68 (4.7)	766 (53.4)	601 (41.9)	
ASA class, no. (row %)					<0.001
Not available	8		4	4	
1-No Disturb	156	5 (3.2)	85 (54.5)	66 (42.3)	
2-Mild Disturb	3100	135 (4.4)	1545 (49.8)	1420 (45.8)	
3-Severe Disturb	4836	546 (11.3)	2511 (51.9)	1779 (36.8)	
4-Life Threat	517	109 (21.1)	222 (42.9)	186 (36.0)	
5-Moribund	1	1 (100.0)	0 (0.0)	0 (0.0)	
ASA class (1-2 vs 3-4), no. (row %)					<0.001
Not available	8		4	4	
1 or 2-No or Mild Disturb	3256	140 (4.3)	1630 (50.1)	1486 (45.6)	
3, 4, or 5-Severe Disturb, Life Threat, or Moribund	5354	656 (12.3)	2733 (51.0)	1965 (36.7)	
BMI					<0.001
No. (%) used	8552 (99.2%)	787 (98.9%)	4333 (99.2%)	3432 (99.3%)	
Mean (SD)	30.26 (6.87)	29.23 (7.24)	30.36 (6.75)	30.36 (6.90)	

(Continued)

Table 7
(Continued)

Characteristic/feature	All (n = 8618)	Preoperative serum albumin category (with unknown)			P-value
		<3.5 (n = 796)	3.5+ (n = 4367)	Unknown (n = 3455)	
Median (IQR)	29.18 (25.68,33.71)	27.82 (24.43,32.80)	29.35 (25.88,33.71)	29.26 (25.74,33.89)	
Range	10.93 to 86.85	16.09 to 61.14	10.93 to 86.85	13.71 to 79.88	
BMI Category (WHO classification), no. (row %)					<0.001
Not available	66	9	34	23	
<18.5	95	18 (18.9)	37 (38.9)	40 (42.1)	
18.5–24.9	1673	205 (12.3)	802 (47.9)	666 (39.8)	
25.0–29.9	2936	269 (9.2)	1521 (51.8)	1146 (39.0)	
30.0–34.9	2126	159 (7.5)	1089 (51.2)	878 (41.3)	
35.0–39.9	1018	66 (6.5)	532 (52.3)	420 (41.3)	
40+	704	70 (9.9)	352 (50.0)	282 (40.1)	
>10% loss body weight in last 6 months, no. (row %)					<0.001
Not available	1		1		
No	8394	718 (8.6)	4285 (51.0)	3391 (40.4)	
Yes	223	78 (35.0)	81 (36.3)	64 (28.7)	
Current smoker within one year, no. (row %)					0.11
No	6886	629 (9.1)	3458 (50.2)	2799 (40.6)	
Yes	1732	167 (9.6)	909 (52.5)	656 (37.9)	
Diabetes mellitus with oral agents or insulin, no. (row %)					<0.001
Insulin	526	88 (16.7)	254 (48.3)	184 (35.0)	
Non-Insulin/Oral	1141	106 (9.3)	610 (53.5)	425 (37.2)	
None	6951	602 (8.7)	3503 (50.4)	2846 (40.9)	
Hypertension requiring medication, no. (row %)					0.002
No	3001	241 (8.0)	1496 (49.9)	1264 (42.1)	
Yes	5617	555 (9.9)	2871 (51.1)	2191 (39.0)	
Surgical Specialty, no. (row %)					
General Surgery	535	94 (17.6)	266 (49.7)	175 (32.7)	
Cardiac Surgery	1	0 (0.0)	0 (0.0)	1 (100.0)	
Gynecology	1	0 (0.0)	0 (0.0)	1 (100.0)	
Neurosurgery	4	0 (0.0)	2 (50.0)	2 (50.0)	
Orthopedics	0	0 (0.0)	0 (0.0)	0 (0.0)	
ENT	1	0 (0.0)	1 (100.0)	0 (0.0)	
Plastics	0	0 (0.0)	0 (0.0)	0 (0.0)	
Thoracic	6	0 (0.0)	6 (100.0)	0 (0.0)	
Urology	8010	691 (8.6)	4058 (50.7)	3261 (40.7)	
Vascular	59	10 (16.9)	34 (57.6)	15 (25.4)	
Ophthalmology	0	0 (0.0)	0 (0.0)	0 (0.0)	
Oral Surgery	0	0 (0.0)	0 (0.0)	0 (0.0)	
Podiatry	0	0 (0.0)	0 (0.0)	0 (0.0)	
Other	1	1 (100.0)	0 (0.0)	0 (0.0)	
Pre-operative serum albumin					<0.001
No. (%) used	5163 (59.9%)	796 (100.0%)	4367 (100.0%)	0 (0.0%)	
Mean (SD)	3.95 (0.56)	2.95 (0.44)	4.14 (0.36)	()	
Median (IQR)	4 (3.7,4.3)	3.1 (2.7,3.3)	4.1 (3.9,4.4)	(,)	
Range	1 to 7.1	1 to 3.4	3.5 to 7.1		
Pre-operative serum albumin category, no. (row %)					<0.001
Not available	3455			3455	
<3.5	796	796 (100.0)	0 (0.0)	0 (0.0)	
3.5+	4367	0 (0.0)	4367 (100.0)	0 (0.0)	
Pre-operative hematocrit					<0.001
No. (%) used	8312 (96.4%)	792 (99.5%)	4340 (99.4%)	3180 (92.0%)	
Mean (SD)	39.73 (5.26)	34.35 (5.81)	40.40 (4.79)	40.14 (4.97)	
Median (IQR)	40.2 (36.7,43.3)	34 (30.3,38.3)	40.7 (37.5,43.5)	40.6 (37.4,43.5)	
Range	11.8 to 59	13.8 to 57.3	11.8 to 59	12.1 to 56.3	

(Continued)

Table 7
(Continued)

Characteristic/feature	All (n = 8618)	Preoperative serum albumin category (with unknown)			P-value
		<3.5 (n = 796)	3.5+ (n = 4367)	Unknown (n = 3455)	
Pre-operative hematocrit category, no. (row %)					<0.001
Not available	318	4	34	280	
Very low (Male<32; Female<28)	425	194 (45.6)	115 (27.1)	116 (27.3)	
Low (Male 32–41.9; Female 28–37.9)	3701	471 (12.7)	1864 (50.4)	1366 (36.9)	
Normal (Male 42+; Female 38+)	4174	127 (3.0)	2354 (56.4)	1693 (40.6)	
Pre-operative serum creatinine					<0.001
No. (%) used	8239 (95.6%)	788 (99.0%)	4355 (99.7%)	3096 (89.6%)	
Mean (SD)	1.30 (1.42)	1.70 (1.93)	1.24 (1.23)	1.30 (1.50)	
Median (IQR)	1 (0.8,1.21)	1.045 (0.8,1.5)	0.98 (0.8,1.2)	0.99275 (0.8,1.2)	
Range	0.2 to 15	0.3 to 13.9	0.2 to 15	0.23 to 15	
Pre-operative GFR					<0.001
No. (%) used	8227 (95.5%)	788 (99.0%)	4348 (99.6%)	3091 (89.5%)	
Mean (SD)	71.31 (28.70)	65.07 (34.70)	72.19 (28.57)	71.67 (26.94)	
Median (IQR)	71.90 (54.80,86.88)	64.09 (43.75,84.25)	72.85 (55.64,87.20)	71.96 (56.16,86.88)	
Range	3.13 to 595.90	3.74 to 298.15	3.30 to 595.90	3.13 to 359.94	
Pre-operative GFR category, no. (row %)					<0.001
Not available	391	8	19	364	
Normal: eGFR>= 90 mL/min/1.73 m ²	1735	161 (9.3)	930 (53.6)	644 (37.1)	
CKD 2: eGFR 60–89 mL/min/1.73 m ²	3883	275 (7.1)	2092 (53.9)	1516 (39.0)	
CKD 3: eGFR 30–59 mL/min/1.73 m ²	2081	230 (11.1)	1093 (52.5)	758 (36.4)	
CKD 4: eGFR 15–29 mL/min/1.73 m ²	200	50 (25.0)	96 (48.0)	54 (27.0)	
CKD 5: eGFR<15 mL/min/1.73 m ²	328	72 (22.0)	137 (41.8)	119 (36.3)	
Chemotherapy for malignancy in<= 30 days pre-op, no. (row %)					0.003
Not available	3912	392	2172	1348	
No	4637	393 (8.5)	2155 (46.5)	2089 (45.1)	
Yes	69	11 (15.9)	40 (58.0)	18 (26.1)	
Radiotherapy for malignancy in last 90 days, no. (row %)					0.96
Not available	3950	397	2198	1355	
No	4645	397 (8.5)	2159 (46.5)	2089 (45.0)	
Yes	23	2 (8.7)	10 (43.5)	11 (47.8)	
Paralysis (hemiplegia, paraplegia, quadriplegia), no. (row %)					0.55
Not available	3912	392	2172	1348	
No	4657	398 (8.5)	2175 (46.7)	2084 (44.7)	
Yes	49	6 (12.2)	20 (40.8)	23 (46.9)	
Disseminated cancer, no. (row %)					<0.001
No	8244	712 (8.6)	4200 (50.9)	3332 (40.4)	
Yes	374	84 (22.5)	167 (44.7)	123 (32.9)	
Steroid use for chronic condition, no. (row %)					<0.001
No	8239	735 (8.9)	4178 (50.7)	3326 (40.4)	
Yes	379	61 (16.1)	189 (49.9)	129 (34.0)	
Stroke (CVA/stroke with or without neurological deficit), no. (row %)					0.30
Not available	3913	392	2172	1349	
No	4524	386 (8.5)	2103 (46.5)	2035 (45.0)	
Yes	181	18 (9.9)	92 (50.8)	71 (39.2)	
Currently on dialysis (pre-op), no. (row %)					<0.001
No	8244	706 (8.6)	4218 (51.2)	3320 (40.3)	
Yes	374	90 (24.1)	149 (39.8)	135 (36.1)	
History of revascularization/amputation for periph. vascular disease, no. (row %)					0.007
Not available	3912	392	2172	1348	
No	4643	392 (8.4)	2173 (46.8)	2078 (44.8)	
Yes	63	12 (19.0)	22 (34.9)	29 (46.0)	

(Continued)

Table 7
(Continued)

Characteristic/feature	All (n = 8618)	Preoperative serum albumin category (with unknown)			P-value
		<3.5 (n = 796)	3.5+ (n = 4367)	Unknown (n = 3455)	
EtOH>2 drinks/day in 2 wks before admission, no. (row %)					0.65
Not available	3893	392	2153	1348	
No	4563	391 (8.6)	2143 (47.0)	2029 (44.5)	
Yes	162	13 (8.0)	71 (43.8)	78 (48.1)	
Dyspnea, no. (row %)					<0.001
At rest	43	10 (23.3)	20 (46.5)	13 (30.2)	
Moderate exertion	818	120 (14.7)	409 (50.0)	289 (35.3)	
No	7757	666 (8.6)	3938 (50.8)	3153 (40.6)	
Functional Status, no. (row %)					<0.001
Not available	28	3	13	12	
Independent	8416	744 (8.8)	4291 (51.0)	3381 (40.2)	
Partially Dependent	154	37 (24.0)	60 (39.0)	57 (37.0)	
Totally Dependent	20	12 (60.0)	3 (15.0)	5 (25.0)	
History of severe COPD, no. (row %)					0.014
No	8141	735 (9.0)	4125 (50.7)	3281 (40.3)	
Yes	477	61 (12.8)	242 (50.7)	174 (36.5)	
Pulmonary comorbidity (dyspnea or COPD), no. (row %)					<0.001
No	7486	632 (8.4)	3792 (50.7)	3062 (40.9)	
Yes	1132	164 (14.5)	575 (50.8)	393 (34.7)	
Ascites, no. (row %)					<0.001
No	8596	782 (9.1)	4363 (50.8)	3451 (40.1)	
Yes	22	14 (63.6)	4 (18.2)	4 (18.2)	
Heart disease (CHF, MI, previous PCI, previous cardiac surgery, angina), no. (row %)					<0.001
Not available	3886	384	2161	1341	
No	4144	336 (8.1)	1958 (47.2)	1850 (44.6)	
Yes	588	76 (12.9)	248 (42.2)	264 (44.9)	
History of angina in 1 month before surgery, no. (row %)					0.11
Not available	3912	392	2172	1348	
No	4670	398 (8.5)	2183 (46.7)	2089 (44.7)	
Yes	36	6 (16.7)	12 (33.3)	18 (50.0)	

to better evaluate the correlation of nutritional status and surgical complications in patients undergoing surgical treatment for kidney cancer in a prospective study design.

AUTHORS' CONTRIBUTION

Karan Arora: Manuscript writing/editing

Kristine T. Hanson: Protocol/project development, Data collection, Data analysis, Manuscript writing/editing

Elizabeth B. Habermann: Protocol/project development, Data collection, Data analysis, Manuscript writing/editing

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CONFLICT OF INTEREST DISCLOSURES

The authors declare that they have no conflict of interest.

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