Morbid obesity is adversely associated with perioperative outcomes in patients undergoing robot-assisted laparoscopic radical prostatectomy

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Abstract

Introduction: Robot-assisted laparoscopic radical prostatectomy (RALRP) may be more challenging in obese individuals. This study aimed to evaluate whether obesity had an adverse effect on perioperative outcomes following RALRP.

Methods: Hospitalized patients who underwent RALRP from 2008–2014 were identified using the National Inpatient Sample database. We grouped RALRP patients into non-obese, obesity class I–II and obesity class III (morbid obesity). Rates of blood transfusion, intraoperative and postoperative complications, in-hospital mortality, prolonged length of stay, and total costs were compared among the three groups by univariate regression, multivariate regression, and propensity score weighting analysis.

Results: Of 53 301 patients identified, 48 725 were non-obese, 3572 were diagnosed

with obesity class I–II, and 1004 were diagnosed with morbid obesity. Compared to non-obesity (7.62%), overall postoperative complications were commonly observed in obesity class I–II (10.55%) and morbid obesity (17.11%). Multivariable analyses suggested that morbid obesity was associated with increased overall postoperative (odds ratio [OR] 2.00; 95% confidence interval [CI] 1.65–2.42), cardiac (OR 1.63; 95% CI 1.03–2.58), respiratory (OR 4.03; 95% CI 3.04–5.36), genitourinary (OR 1.77; 95% CI 1.08–2.90), miscellaneous medical (OR 1.94; 95% CI 1.58–2.39) complications, prolonged hospitalization (OR 1.86; 95% CI 1.57–2.21), and 12% higher total cost. Propensity score weighting analysis yielded similar results. Adequate covariate balance was achieved for all variables after weighting.
Conclusions: Morbid obesity is adversely associated with perioperative outcomes in RALRP. Close management is required in patients undergoing RALRP with morbid obesity for potential worse prognosis.

Introduction

Obesity is a public health problem worldwide, which can lead to several morbidities, including type 2 diabetes, coronary heart disease, and cancer.[1] The WHO classifies obesity into class I (body mass index (BMI) of 30–34.99 kg/m^2), class II (BMI of 35–39.99 kg/m^2) and class III (morbid obesity; BMI of ≥ 40 kg/m^2). According to the National Health and Nutrition Examination Survey, 38.9% of US adults had obesity and 7.6% had morbid obesity during 2013-2016.[2]

Prostate cancer accounts for almost one in five newly diagnosed cancers and is projected to be the most frequent cancer amongst men in 2018 in the US. Moreover, estimated deaths of prostate cancer occupied the second place (29,430 deaths) amongst men.[3] Robotic-assisted laparoscopic radical prostatectomy (RALRP) using the da Vinci® surgical system with improved visualization and delicate control is gaining in popularity among urologic surgeons. RALRP offers several benefits over open prostatectomy, such as significantly lower blood loss, transfusion rates, traditional advantages of a minimally invasive procedure, and better short-term outcomes.[4]

The increasing prevalence of both obesity and prostate cancer often confronts the urologist with obese prostate cancer patients undergoing RALRP. However, whether urologists should be aware of the special considerations for treating obese prostate cancer patient is uncertain.[5] An extensive body of researches have previously compared the perioperative outcomes between obese and non-obese patients who underwent RALRP.[6-18] Except two studies which demonstrated significantly more complications associated with obesity ,[6, 18] all the other studies suggested null relationship between obesity and perioperative outcomes and further concluded that RALRP was a safe and effective procedure for obese prostate cancer patients. In addition, few studies have concentrated specifically on perioperative outcome in patients with morbid obesity.[7, 8, 10, 11, 19] Nevertheless, most analyses were limited to the experience of a single institution or surgeon with small sample size for morbid obesity, which could not provide accurate estimates of the association between morbid obesity and perioperative outcomes following RALRP.

As mentioned above, the outcomes of RALRP in the morbidly obese patients have not been sufficiently researched in previous studies. Therefore, we aimed at assessing the effects of obesity, particularly morbid obesity on perioperative outcomes of RALRP using the 2008-2014 National Inpatient Sample (NIS).

Methods

Data source

The NIS is a portion of the Healthcare Cost and Utilization Project. This inpatient database includes information on clinical characteristics and healthcare resource use from hospital discharge abstracts. Researchers could use the NIS sampling information to make national estimates of health care utilization, charges, quality, and outcomes. Detailed information regarding the NIS data is available at *http://www.hcup-us.ahrq.gov*. The NIS data does not have any patient-identifiable information, thus institutional review board approval and consent to participate of patients are not required

Patients and outcomes

Patients aged ≥18 years old with a primary diagnosis of prostate cancer according to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis code 185.0 were selected. We further extracted those prostate cancer patients undergoing radical prostatectomy using the ICD-9 procedure code 60.5. In October 1, 2008, a robot-assisted modifier code (17.4x) was introduced and received approval by the US Food and Drug Administration to identify robot-assisted procedures. In brief, the three codes above were employed to identify prostate cancer patients with RALRP. We further grouped patients into non-obese, obesity class I–II (V85.40-45, 278.01) and obesity class III (V85.30-39, 278, 278.0, 278.00) based on ICD-9-CM codes that indicated BMI categories or obesity status.

Demographic and hospital-related variables were identified for each record.

Elixhauser Comorbidity Index (ECI) was calculated for each admission to assess the severity of comorbidities. Data with missing part less than 5% were excluded. Blood transfusions were defined using codes 99.02 and 99.04. Intraoperative complication was defined based on code 998.2. Postoperative complications were grouped into seven groups: cardiac, respiratory, vascular events, operative wound, genitourinary complications, miscellaneous medical and surgical events. Cardiac, respiratory and vascular events were potentially life-threatening. Prolonged length of stay (PLOS) was defined as a hospitalization beyond the 75th percentile cut-off point. Total costs were derived from total charges in the database using the cost-to-charge ratio and the Consumer Price Index. All the ICD-9-CM codes used have been previously reported and validated in the NIS database.[4, 20]

Statistical analysis

The analysis of variance and Kruskal-Wallis tests were used to compare distributions of continuous variables. The chi-square test was used to compare differences in categorical variables. To further evaluate the differences in perioperative outcomes among different weight categories, we conducted multivariable logistic regression models. Total cost indicated a right skewed distribution, and we performed log-transformations for total cost before performing multivariable linear models. Variables entered into the models included age, year, race, admission type, type of insurance, median Zip code income, ECI, hospital type, hospital bedsize and hospital region.

We further conducted propensity score weighting (PSW) analysis to control for pretreatment imbalances on observed variables. To obtain better balance between treated and control groups, we used Generalized Boosted Model (GBM) for estimation of the propensity score weights.[21] Absolute standardized mean differences (ASMD) across all pairwise comparisons for each pretreatment covariate were used for balance assessment, with ASMD < 0.1 indicating adequate covariate balance. Generalized linear model accounting for both sampling weight and propensity score weight was employed to estimate difference in perioperative outcomes among different weight categories.

Statistical significance was defined as a P value <0.05 on two-tailed testing. Statistical analyses were performed using the SAS software version 9.4 (SAS Institute, Cary, NC) and R software, version 3.4.3.

Results

Of 53,301 patients identified, 48,725 (91.41%; weighted 242081) were non-obese, 3,572 (6.71%; weighted 17768) were diagnosed with obesity class I–II and 1004 (1.88%; weighted 4988) were diagnosed with morbid obesity (Table 1). Non-obese patients were younger and had higher income. Morbid obesity had the highest proportion of patients with ECI ≥2. Distribution of specific ECI conditions indicated that morbid obesity had the highest proportion of deficiency anemias, congestive heart failure, chronic pulmonary disease, diabetes, hypertension, hypothyroidism, fluid and electrolyte disorders and chronic renal failure (Supplementary table 1). From 2008 to 2014, the rate of class I–II obesity in RALRP recipients has significantly increased from 4.10% to 7.72% (P<0.0001) and the rate of morbid obesity has significantly increased from 1.32% to 2.46% (P<0.0001; Figure 1).

Tables 2 showed the rate of intraoperative and postoperative outcomes stratified according to weight category. The rates of overall postoperative complications were 7.62%, 10.55% and 17.11% in the non-obese, obesity class I–II and morbid obesity group, respectively. Univariate analysis showed that morbid obesity had significantly higher rates of overall, cardiac, respiratory, genitourinary, miscellaneous medical complications, PLOS and higher cost. Multivariable logistic regression analyses suggested that compared to non-obesity, obesity class I–II had slightly higher odds of overall postoperative (odds ratio [OR]: 1.20; 95% confidence interval [CI], 1.04-1.39), cardiac (OR: 1.36; 95% CI, 1.03-1.80) and miscellaneous medical complications (OR: 1.23; 95% CI, 1.03-1.46). Moreover, morbid obesity was associated with increased overall postoperative (OR: 2.00; 95% CI, 1.65-2.42), cardiac (OR: 1.63; 95% CI, 1.03-2.58), respiratory (OR: 4.03; 95% CI, 3.04-5.36), genitourinary (OR: 1.77; 95% CI, 1.08-2.90), miscellaneous medical (OR: 1.94; 95% CI, 1.58-2.39) complications, PLOS (OR: 1.86; 95% CI, 1.57-2.21) and 12% higher total cost.

Before PSW, most baseline variables were unbalanced across groups (Supplementary table 2). After PSW, the maximum ASMD was maximal for race (0.0972) and the minimum *P*-value was minimal for age (0.1118), which indicated good balance across all pairwise comparisons. PSW analyses produced similar results (Supplementary table 3). Compared to non-obesity, morbid obesity was associated with increased overall postoperative (OR: 2.03; 95% CI, 1.63-2.54), respiratory (OR: 4.58; 95% CI, 3.24-6.48), genitourinary (OR: 2.03; 95% CI, 1.12-3.68), miscellaneous medical (OR: 2.04; 95% CI, 1.58-2.62) complications, and PLOS (OR: 1.82; 95% CI, 1.48-2.22).

Discussion

To date, the study is the largest population-based research focusing on the temporal trend and perioperative outcomes of obesity in patients undergoing RALRP. From 2008 to 2014, both rates of class I–II obesity and morbid obesity in RALRP recipients have significantly increased. The results indicated that adverse perioperative events were observed in morbidly obese patients including overall, cardiac, respiratory, genitourinary and miscellaneous medical postoperative complications. In addition, morbid obesity was also related to more healthcare resource utilization such as PLOS and higher total cost.

Obesity has posed technical challenges and been implicated as a risk factor for unfavorable outcomes for several surgeries.[22, 23] In light of RALRP being the most frequently used minimally invasive surgical option for radical prostatectomy, technical disadvantages following RALRP in patients diagnosed with obesity have also been acknowledged. Excessive fat tissue, deeper and narrowed true pelvis induced by obesity would result in a limited working space, a long distance from the skin to operative field and difficulty in optical trocar sheath placement and suboptimal visualization.[24, 25] Also, potential exaggerated Trendelenburg positioning during RALRP is needed.[11] In addition, the enlargement of prostate size associated with obesity makes subjects more susceptible to surgical complexity.[26] Technical difficulties above in obese subjects might intuitively cause increased risk of medical events such as aggravation of impaired cardiorespiratory function, prolonged operating time and more intraoperative estimated blood loss.

Multiple studies have compared perioperative outcomes of RALRP between obese and normal weight patients since the year 2005,[17] but no consensus has ever been reached. A meta-analysis with 1821 obese patients suggested that obesity was a significant predictor for longer intraoperative operation time and increased estimated blood loss.[27] However, these findings reflected limited clinical impact for surgical efficacy following RALRP. Other clinical outcomes like LOS, positive surgical margins and complications had no significant differences between groups in the meta-analysis. Ahlering *et al.* for the first time reported significantly higher overall complications (26.3% versus 4.9%; P =0.01) in patients with obesity.[17] In fact, this result was based on only 19 obese patients and did not consider any potential confounders. Knipper et al. demonstrated that obesity predicted unfavorable perioperative complications at RALRP.[18] To date, five previous publications assessed perioperative outcomes of RALRP in morbidly obese patients.[7, 8, 10, 11, 19] Yates et al. retrospectively reviewed 15 patients undergoing RALRP with a mean BMI of 43 kg/m^2 .[11] Sundi et al. evaluated perioperative outcomes in 13 morbidly obese patients.[10] Cestari et al. created a cost-effective adequate optical trocar in 4 morbidly obese patients.[19] No perioperative complications were observed in the above mentioned studies. Abdul-Muhsin et al. performed a propensity-score matching analysis with 44 morbidly obese patients and noted that RALRP can be safely performed as perioperative complications including operative time, intraoperative complications and postoperative complication were similar between groups.[8] Another propensity-score matching analysis with 40 morbidly obese patients also failed to find significant differences in intraoperative or postoperative complications.[7] They concluded that RALRP was feasible in the morbidly obese population. However, generalization of these results was limited by insufficient statistical power with small sample sizes and data from single institution. Therefore, these results should be cautiously interpreted due to certain methodological shortcomings.

The current study suggested that the rates of intraoperative complications and blood transfusion were similar among groups, which was consistent to former publications.[8, 11] The most notable finding of our study were the potential higher risks of postoperative outcomes in severely obese patients undergoing RALRP. Higher prevalence of cardiovascular-related comorbidities and surgical obstacles in morbidly obese patients may be involved in the increased incidence of cardiac complication. We also found higher respiratory complication rate in morbidly obese patients. Arterial oxygenation insufficiency and higher peak inspiratory pressures during laparoscopic surgery may be involved.[28] Due to the higher rate of obstructive sleep apnea and obesity hypoventilation syndrome, obese patients were susceptible to pulmonary complications in the early postoperative period.[29] In addition, a steep Trendelenburg positioning may lead to pathophysiological changes such as pulmonary dysfunction with the formation of atelectasis and increased airway pressure. All the aforementioned conditions during RALRP were associated with the deterioration of pulmonary function.[30]

In the present study, the incidence of postoperative genitourinary complications is also higher in the morbidly obese population. Previous studies have examined risk of urinary leak, urethral stricture and urinary-tract infection but found no significant difference between obese and non-obese group as the sample is too small for the occurrence of complications.[9, 12] Ahlering *et al.* reported a longer LOS in obese patients [17] while the meta-analysis incorporating all available evidence did not show any differences. [27] Our study found an increased risk of prolonged hospitalization for patients with morbid obesity. Moreover, compared with non-obese patients, morbidly obese patients had 12% higher total hospitalization cost. PLOS and combined increased cost indicated more healthcare resource utilization in morbidly obese patients.

To our knowledge, this study is the largest analysis assessing the impact of obesity especially morbid obesity on perioperative outcomes after RALRP. A large sample enabled us to comprehensively evaluate and compare incidence of perioperative complications among groups. We grouped patients into three categories to test effects in different severity of obesity and the results suggested that higher obesity severity was associated with more postoperative complications. To explore robustness of results in the primary analysis, we performed GBM-based PSW analysis with three treatments. GBM estimation involved an iterative process to capture nonlinear and complex relationship between baseline covariates and treatment assignment.[21] Moreover, results from PSW were comparable with the primary analysis by logistic regression.

Limitations should also be acknowledged. First, the presence of miscoding or under-coding was common in administrative databases. However, algorithms used to determine weight category, RALRP and perioperative complications were previously validated and used in the NIS database with increased confidence.[4, 20] Second, as a retrospective observational analysis, unmeasured confounders like medications might have affected our results. In fact, unadjusted, multivariable logistic regression and PSW analyses yielded similar conclusions, which indicated the robustness of the results. Third, lack of longitudinal data after discharge impeded a comprehensive assessment of long-term complications following RALRP. Publications have reported significant worse outcomes (incontinence and impotency) in obese population. Nevertheless, these functional outcomes could usually be observed during follow-up in several months after hospitalization. Fourth, NIS data lacked information on surgeon volume, learning curve effect and tumor-related characteristics, such as tumor grade or stage.

Conclusions

The present study provides evidence that RALRP in morbidly obese patient can be challenging on account of higher risk for perioperative complications. Given the increased prevalence of obesity in RALRP, surgeons need to modify technique and familiarize themselves with considerations pertinent to their specialty for proper management and treatment of prostate cancer patients with morbid obesity. All these findings could improve preoperative risk stratification and preparation for RALRP to yield better clinical outcomes.

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Figures and Tables

Fig 1. Trend analysis for rate of obesity in patients who underwent robot-assisted laparoscopic radical prostatectomy from 2008–2014.

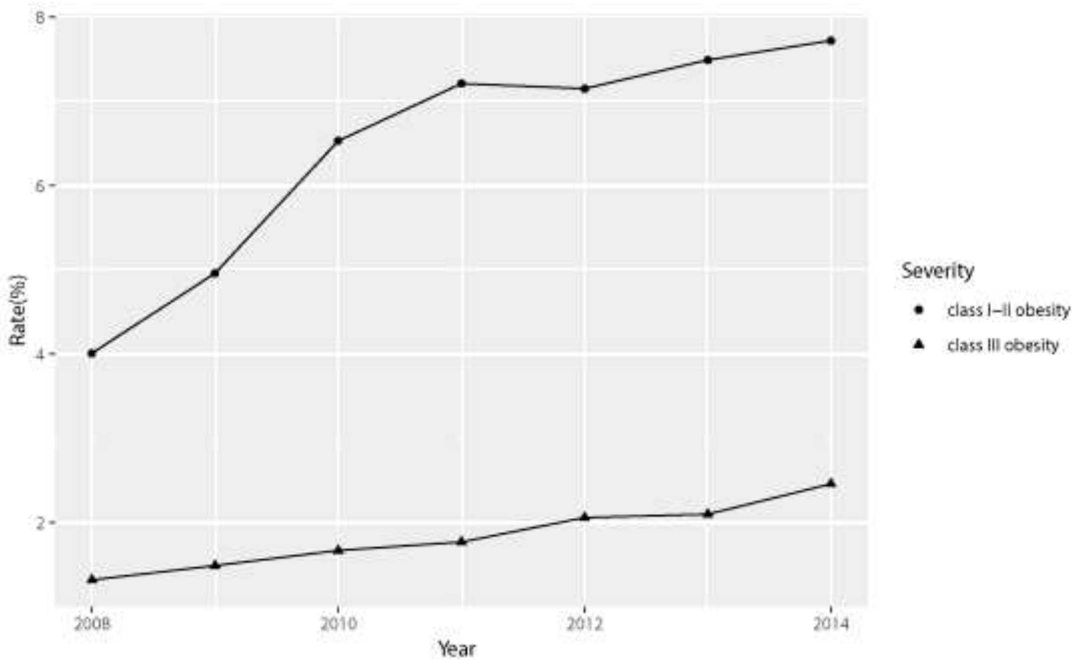

Table 1. Baseline characteristics of patients who underwent RALRP from 2008–2014 stratified by weight category

Variables	**Non-obese (n=48725)**	**Obesity class I–II (n=3572)**	**Obesity class III (n=1004)**	**p**
Mean age (SD)	61.74 (16.00)	61.21 (15.28)	59.99 (15.55)	<0.0001
Year				
2008	2080 (4.21)	88 (2.45)	29 (2.82)	0.0009
2009	8329 (17.30)	442 (12.79)	133 (13.46)	
2010	7566 (15.60)	538 (15.22)	138 (14.06)	
2011	9171 (18.32)	726 (19.50)	178 (16.94)	
2012	7542 (15.58)	594 (16.72)	171 (17.14)	
2013	7185 (14.84)	595 (16.74)	167 (16.74)	
2014	6852 (14.15)	589 (16.57)	188 (18.84)	
Race				
White	33719 (69.37)	2411 (67.75)	682 (68.07)	0.0002
Black	4972 (10.17)	443 (12.25)	139 (13.82)	
Hispanic	2564 (5.25)	200 (5.53)	44 (4.44)	
Other	2652 (5.46)	139 (3.89)	35 (3.49)	
Missing	4818 (9.76)	379 (10.58)	104 (10.18)	
Admission type				
Elective	2043 (4.27)	107 (3.04)	38 (3.80)	0.0394
Non-elective	46 682 (95.73)	3465 (96.96)	966 (96.2)	
Type of insurance				
Medicare	16 196 (33.27)	1118 (31.30)	295 (29.41)	0.0818
Medicaid	952 (1.96)	72 (2.03)	17 (1.71)	
Private	29 875 (61.29)	2256 (63.19)	658 (65.47)	
Self-pay/other	1702 (3.48)	126 (3.48)	34 (3.41)	
Median zip code income				
0–25%	8877 (18.17)	695 (19.40)	220 (21.83)	<0.0001
26–50%	11 065 (22.72)	809 (22.64)	271 (26.97)	
51–75%	12 969 (26.61)	1011 (28.45)	272 (27.11)	
76–100%	15 814 (32.50)	1057 (29.51)	241 (24.09)	
Elixhauser comorbidity index				
0	18 487 (37.89)	704 (19.73)	151 (15.11)	<0.0001
1	18 663 (38.37)	1440 (40.31)	356 (35.33)	
≥2	11 575 (23.73)	1428 (39.96)	497 (49.56)	

Hospital type				
Rural	1034 (2.08)	86(2.31)	20 (1.88)	0.1058
Urban non-teaching	12 669 (26.02)	916 (25.54)	217 (21.54)	
Urban teaching	35 022 (71.91)	2570 (72.15)	767 (76.59)	
Hospital region				
Northeast	9054 (19.01)	605 (17.41)	154 (15.53)	0.0154
Midwest	11 971 (24.36)	965 (27.03)	302 (29.80)	
South	16 888 (34.55)	1133 (31.44)	353 (34.97)	
West	10 812 (22.07)	869 (24.11)	195 (19.71)	
Hospital bed size				
Small	6731 (13.53)	479 (13.18)	131 (12.85)	0.9571
Medium	10 624 (22.27)	756 (21.47)	210 (21.34)	
Large	31 370 (64.19)	2337 (65.35)	663 (65.80)	

RALRP: robot-assisted laparoscopic radical prostatectomy; SD: standard deviation.

Table 2. Comparisons of perioperative outcomes in RALRP patients stratified by weight category

Outcomes	**Non-obese (n=48725)**	**Obesity class I–II (n=3572)**	**Obesity class III (n=1004)**	**p**
Blood transfusion	741 (1.52)	57 (1.57)	24 (2.41)	0.3175
Intraoperative complication	336 (0.69)	24 (0.67)	4 (0.40)	0.3739
Postoperative complication				
Overall	3715 (7.62)	379 (10.55)	172 (17.11)	<0.0001
Cardiac	403 (0.83)	57 (1.60)	22 (2.17)	<0.0001
Respiratory	492 (1.00)	52 (1.44)	54 (5.35)	<0.0001
Vascular	176 (0.36)	17 (0.47)	3 (0.30)	0.5893
Operative wound	159 (0.33)	14 (0.39)	8 (0.79)	0.2328
Genitourinary	398 (0.82)	45 (1.27)	18 (1.78)	0.0053
Miscellaneous medical	2193 (4.49)	233 (6.46)	105 (10.44)	<0.0001
Miscellaneous surgical	800 (1.65)	57 (1.59)	22 (2.17)	0.6620
Prolonged hospitalization	5507 (11.31)	491 (13.73)	219 (21.84)	<0.0001
In-hospital mortality	7 (0.01)	0 (0)	1 (0.10)	N/A
Total costs	115201	12897	13664	<0.0001

(median [Q1–Q3])	(8883–15332)	(9865–17014)	(10482–18116)	

RALRP: robot-assisted laparoscopic radical prostatectomy; Q1: first quartile; Q3: third quartile

Table 3. Multivariable logistic regression analysis of perioperative outcomes in RALRP patients stratified by weight category

Outcomes	**Non-obese (n=48725)**	**Obesity class I–II (n=3572)**		**Obesity class III (n=1004)**	
	Ref	**OR (95% CI)**	**p**	**OR (95%CI)**	**p**
Blood transfusion	Ref	0.86 (0.64, 1.15)	0.3073	1.27 (0.77, 2.08)	0.3517
Intraoperative complication	Ref	0.99 (0.65, 1.51)	0.9649	0.62 (0.23, 1.64)	0.3319
Postoperative complication	Ref				
Overall	Ref	1.20 (1.04, 1.39)	0.0109	2.00 (1.65, 2.42)	<0.0001
Cardiac	Ref	1.36 (1.03, 1.80)	0.0318	1.63 (1.03, 2.58)	0.0380
Respiratory	Ref	1.11 (0.81, 1.51)	0.5181	4.03 (3.04, 5.36)	<0.0001
Vascular	Ref	0.99 (0.59, 1.66)	0.9789	0.59 (0.19, 1.88)	0.3739
Operative wound	Ref	0.90 (0.51, 1.57)	0.7021	1.60 (0.76, 3.31)	0.2033
Genitourinary	Ref	1.35 (0.99, 1.84)	0.0547	1.77 (1.08, 2.90)	0.0237
Miscellaneous medical	Ref	1.23 (1.03, 1.46)	0.0233	1.94 (1.58, 2.39)	<0.0001
Miscellaneous surgical	Ref	0.90 (0.69, 1.19)	0.4617	1.21 (0.69, 2.14)	0.5048
Prolonged hospitalization	Ref	1.10 (0.95, 1.26)	0.2001	1.86 (1.57, 2.21)	<0.0001
In-hospital mortality	Ref	N/A	N/A	7.88 (0.98, 63.34)	0.0522

CI: confidence interval; OR: odds ratio; RALRP: robot-assisted laparoscopic radical prostatectomy.

Supplementary Table 1. Distribution of AHRQ-Elixhauser comorbid conditions in RALRP patients stratified by weight category

Elixhauser comorbidity Index	**Non-obese (n=48725)**	**Obesity class I–II (n=3572)**	**Obesity class III (n=1004)**	**p**
Alcohol abuse	492 (1.00)	47 (1.31)	17 (1.68)	0.0733
Deficiency anemias	963 (1.96)	102 (2.82)	42 (4.18)	0.0001
Rheumatoid arthritis/collagen vascular diseases	340 (0.70)	30 (0.83)	7 (0.68)	0.6949
Chronic blood loss anemia	102 (0.21)	2 (0.06)	4 (0.38)	0.0207
Congestive heart failure	246 (0.51)	35 (0.98)	17 (1.70)	0.0005
Chronic pulmonary disease	3595 (7.37)	342 (9.60)	113 (11.31)	<0.0001
Coagulopathy	286 (0.59)	35 (0.98)	9 (0.90)	0.0283
Depression	2077 (4.27)	244 (6.86)	62 (6.24)	<0.0001
Diabetes, uncomplicated	5462 (11.22)	811 (22.76)	305 (30.47)	<0.0001
Diabetes with chronic complications	326 (0.65)	90 (2.47)	42 (4.13)	<0.0001
Drug abuse	158 (0.33)	10 (0.29)	2 (0.19)	0.5825
Hypertension, uncomplicated and complicated	23623 (48.50)	2434 (68.08)	740 (73.63)	<0.0001
Hypothyroidism	2056 (4.24)	178 (4.98)	57 (5.69)	0.0233
Liver disease	244 (0.50)	48 (1.34)	8 (0.81)	<0.0001
Lymphoma	112 (0.23)	8 (0.22)	4 (0.41)	0.6806
Fluid and electrolyte disorders	1004 (2.06)	122 (3.38)	47 (4.64)	<0.0001
Other neurological disorders	711 (1.47)	56 (1.56)	24 (2.36)	0.1440
Paralysis	61 (0.13)	9 (0.25)	1 (0.10)	0.3978
Peripheral vascular disorders	544 (1.11)	61 (1.69)	14 (1.38)	0.0212
Psychoses	304 (0.62)	44 (1.24)	13 (1.30)	0.0023
Pulmonary circulation disorders	80 (0.16)	10 (0.28)	7 (0.71)	0.0508
Renal failure	747 (1.53)	121 (3.37)	42 (4.15)	<0.0001
Peptic ulcer disease excluding bleeding	6 (0.01)	0	0	N/A
Valvular disease	767 (1.58)	58 (1.60)	14 (1.40)	0.8839
Weight loss	62 (0.13)	4 (0.11)	3 (0.30)	0.5872

*Cancer and obesity were excluded. RALRP: robot-assisted laparoscopic radical prostatectomy.

Supplementary Table 2. Balance assessment of baseline variables across all pairwise comparisons before and after propensity score weighting				
Variables	**Unweighted**		**Weighted**	
	Maximum ASMD	**Minimum p**	**Maximum ASMD**	**Minimum p**
Age	0.2431	<0.0001	0.0582	0.1118
Year	0.1424	<0.0001	0.0655	0.6543
Race	0.1093	<0.0001	0.0972	0.2440
Admission type	0.0604	0.0001	0.0377	0.1743
Type of insurance	0.0878	0.0539	0.0300	0.6422
Median zip code oncome	0.1875	<0.0001	0.0579	0.5223
Elixhauser comorbidity index	0.5875	<0.0001	0.0540	0.2997
Hospital type	0.1017	0.0062	0.0647	0.2811
Hospital region	0.1232	<0.0001	0.0536	0.4593
Hospital bedsize	0.0337	0.4533	0.0337	0.5916

ASMD: absolute standardized mean differences.

Supplementary Table 3. Propensity score weighting analysis of perioperative outcomes in RALRP patients stratified by weight category					
Outcomes	**Non-obese (n=48725)**	**Obesity class I–II (n=3572)**		**Obesity class III (n=1004)**	
	Ref	OR (95%CI)	p	OR (95%CI)	p
Blood transfusion	Ref	0.85 (0.61,1.17)	0.3240	1.43 (0.83,2.47)	0.1990
Intraoperative complication	Ref	1.05 (0.66,1.68)	0.8300	0.47 (0.16,1.37)	0.1640
Postoperative complication	Ref				
Overall	Ref	1.24 (1.07,1.45)	0.0056	2.03 (1.63,2.54)	<0.0001
Cardiac	Ref	1.41 (1.02,1.94)	0.0352	1.41 (0.86,2.30)	0.1761
Respiratory	Ref	1.20 (0.87,1.67)	0.2620	4.58 (3.24,6.48)	<0.0001
Vascular	Ref	1.23 (0.70,2.14)	0.4740	0.70 (0.22,2.25)	0.5510
Operative wound	Ref	0.81	0.4670	1.86	0.1340

		(0.46,1.43)		(0.83,4.18)	
Genitourinary	Ref	1.38 (0.99,1.92)	0.0560	2.03 (1.12, 3.68)	0.0191
Miscellaneous medical	Ref	1.23 (1.02,1.48)	0.0322	2.04 (1.58,2.62)	<0.0001
Miscellaneous surgical	Ref	0.96 (0.71,1.30)	0.8050	1.24 (0.67,2.32)	0.4960
Prolonged hospitalization	Ref	1.13 (0.98,1.31)	0.0883	1.82 (1.48,2.22)	<0.0001
In-hospital mortality	Ref	N/A	N/A	N/A	N/A

CI: confidence interval. OR: odds ratio; RALRP: robot-assisted laparoscopic radical prostatectomy.