



# The role of body mass index on quality indicators following minimally-invasive radical prostatectomy

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**Purpose:** We sought to determine the role of body mass index (BMI) on quality indicators, such as length of stay and readmission. The National Surgical Quality Improvement Program (NSQIP) database was queried to examine the effect of obesity, defined as BMI >30, on outcomes after Minimally Invasive Radical Retropubic Prostatectomy (MI-RRP).

**Materials and Methods:** Utilizing the NSQIP database, patient records were identified using the Current Procedural Terminology (CPT) code 55866 (laparoscopy, surgical prostatectomy, radical retropubic) during a 10-year period (2007–2017). Obesity was classified according to the CDC classification. Chi-square tests were utilized to evaluate BMI distribution by surgery year. Logistic regression was used to evaluate the relationship of BMI with length of stay (LOS) and hospital readmission within 30 days, after controlling for preoperative variables.

**Results:** Records of 49,238 patients who have undergone MI-RRP during 2007–2017 were evaluated. Mean yearly BMI rose from 28.5 to 29.2, while the percentage of surgical patients with BMI >30 rose by 5% (33% to 38%;  $p < 0.0001$ ) over the study period. Obese patients demonstrated higher morbidity, prolonged LOS, and increased readmission rates after MI-RRP. Obesity severity correlated negatively with quality indicators in a graded fashion.

**Conclusions:** Obesity rates in patients undergoing MI-RRP increased from 2007–2017. Obese patients are at increased risk of morbidity, prolonged LOS, and readmission within 30 days, following MI-RRP. These patients should not be excluded from MI-RRP; rather, physicians should discuss these increased risks with their patients. Proper weight loss strategies should be instituted preoperatively to mitigate these risks.

**Keywords:** Body mass index; Laparoscopy; Patient readmission; Postoperative complications; Prostatectomy

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## INTRODUCTION

Obesity is currently a growing health concern both globally and within the United States. Per the World Health Organization, obesity is defined as the accumulation of excess

body fat and is quantified by a body mass index (BMI)  $\geq 30$  kg/m<sup>2</sup> [1]. The Centers for Disease Control further subclassifies obesity into Class I (30 < BMI < 35), Class II (35 < BMI < 40), and Class III (BMI  $\geq 40$ ) [2]. Globally, obesity rates have increased from 26.5% in 1980 to 39.0% in 2015, with the Ameri-

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cas and Europe showing the highest prevalence of obesity [3]. Concerning the United States obesity rates, in particular, 39.8% of adults in 2017 met the criteria to be considered 'obese.' Further analysis reveals adults aged 40–59 years had the highest prevalence of obesity at 42.9% compared with the 20–39 years (37.5%) and the ≥60 years (41.0%) age groups [4].

Obesity places a considerable burden on the physical health of patients and a financial strain on healthcare systems. In a recent meta-analysis within the United States, obesity was estimated to increase the mean cost of care by US dollar (USD) 1,910 per person, per year [5]. Additionally, obesity can cost the US health system a staggering USD 149.4 billion per year [5], and the percentage of healthcare dollars being spent on obesity-related complications and comorbidities continues to rise [6]. Obese patients experience increased rates of cardiovascular disease (CVD) [7] and Type 2 diabetes (T2DM) [7] and are at increased risk of postoperative complications, including wound infection and dehiscence [8].

Prostate cancer is the third most common male cancer in the United States and the second most common cause of male cancer-related deaths. Mostly targeting middle age to older men, 12% of men will be diagnosed with prostate cancer at some point in their life [9]. Additionally, 2.4% of men will die from prostate cancer-related disease [10,11]. Minimally Invasive Radical Retropubic Prostatectomy (MI-RRP) has seen a rise in popularity due to more favorable perioperative outcomes and shorter mean postoperative lengths of stay, as compared to its open-technique counterpart [12]. In this study, we define MI-RRP as any radical retropubic prostatectomy performed utilizing either a laparoscopic or robot-assisted approach.

Given that obesity is associated with higher rates of complications and can negatively influence quality metrics, we utilized the National Surgical Quality Improvement Program database (NSQIP) to examine the relationship between BMI and quality health indicators following MI-RRP.

## MATERIALS AND METHODS

### 1. Data acquisition

The American College of Surgeons (ACS) NSQIP database is a standardized registry of surgical procedures performed at participating US hospitals since 2004. Details regarding data collection and quality control can be found in the ACS NSQIP users guide [13]. Briefly, the NSQIP database includes individual patient data collected on selected surgical procedures performed, including many preopera-

tive patient characteristics, inter-operative details, and early postoperative outcomes. At participating hospitals, data collection is performed per a standard protocol, undergoes rigorous quality checks, and is then submitted for inclusion in the national registry which releases the full, de-identified database back to participating investigators with approved access.

Before accessing the data, the plan for this investigation was submitted for review to the Wake Forest School of Medicine Investigational Review Board (IRB) and determined to be exempt. Data for years 2007 through 2017 were obtained by direct download from the ACS NSQIP website. Information on patient demographics, risk factors, and outcomes was assembled for all encounters with Current Procedural Terminology (CPT) code 55866: laparoscopy, surgical prostatectomy, retropubic radical, including nerve-sparing, including robotic-assisted when utilized. In other words, the CPT code 55866 is defined as radical retropubic prostatectomy, performed via laparoscopic or robotic approach, with or without nerve-sparing techniques. For purposes of analysis, ethnicity was coded as Hispanic or non-Hispanic while race was independently coded as white, African American, Asian, or unknown/other. To ensure patient anonymity, ACS NSQIP truncates age at 90 years. BMI was calculated in kg/m<sup>2</sup> for patients with complete information on weight and height. Other preoperative characteristics examined included diabetes, smoking status (current vs. former/never), dyspnea, history of severe chronic obstructive pulmonary disease, congestive heart failure within 30 days, hypertension requiring medication, steroid use, bleeding disorders, open wound or wound infection, >10% loss of body weight in last six months, emergent case, transfusion within last 72 hours, non-elective surgery (this procedure), renal failure or dialysis dependence, systemic sepsis, functional status (partially/totally dependent vs. others), contaminated or dirty wound, American Society of Anesthesiologists (ASA) classification score (severe systemic disease or worse vs. other). Only those factors with total occurrence greater than 500 over the observation period are presented.

In the years 2012 and later, ACS NSQIP included model-based predicted probabilities of morbidity and mortality on all cases estimated using hierarchical logistic regression analysis and based only on patient-level predictors. They represent the probability (0 to 1) that a case will experience a morbidity or mortality event based on pre-existing factors included in the database. These probabilities are updated every six months for the previous 12 months of data, thus the parameters used to generate the predicted values change over time as do observed values of the predictor variables.

A secondary analysis was performed including these probabilities as predictors in the subsample where they were observed.

As we utilized the NSQIP database primarily consisting of patients within North America, we sought to define prolonged length of stay as greater than 2 days as defined in another North America-centric population study [14]. In another population database, the Nationwide Inpatient Sample, comprised of similar hospital-driven data points, prolonged length of stay was defined as greater than 2 days. Readmission to the hospital within 30 days of surgery for any reason was examined as a secondary outcome; however, readmission data were only available for surgery years 2011 or later. Patients without complete data for length of stay and BMI (i.e., height and weight) were excluded from our analysis.

## 2. Statistical methods

Patient demographics and preoperative characteristics were examined overall and by presence/absence of obesity,

defined as BMI  $>30$  kg/m<sup>2</sup> vs.  $\leq 30$  kg/m<sup>2</sup>. Descriptive statistics included means and standard deviations of continuous factors or frequencies and percentages of categorical factors. Univariable comparisons between obese and non-obese groups were compared for continuous factors using t-tests with Satterthwaite's adjustment for unequal variances, and chi-square tests for categorical factors. Distribution of BMI by year of surgery was examined graphically using box-and-whisker plots. Logistic regression models for length of stay (LOS)  $>2$  days, and separately for hospital readmission within 30 days, were fitted to examine relationships between obesity and those outcomes after controlling for other preoperative characteristics. A p-values  $\leq 0.05$  were determined to be statistically significant. All analyses were performed using SAS software, versions 9.4 (BASE) and 15.4 (STAT), SAS Institute, Cary, NC, USA.

**Table 1.** Descriptive statistics of selected factors overall and by obesity (BMI  $\geq 30$  kg/m<sup>2</sup> vs. BMI  $< 30$  kg/m<sup>2</sup>)

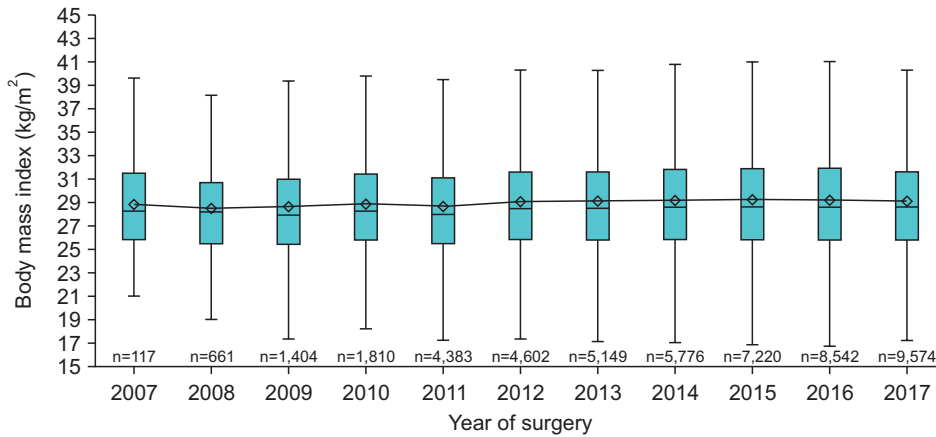
Factor	Overall (n=49,238)	BMI $\geq 30$ kg/m <sup>2</sup> (n=18,350)	BMI $< 30$ kg/m <sup>2</sup> (n=30,888)	p-value
Age (y)	62.4 $\pm$ 7.2	61.7 $\pm$ 7.0	62.9 $\pm$ 7.2	<0.0001
BMI (kg/m <sup>2</sup> )	29.1 $\pm$ 4.8	33.9 $\pm$ 3.8	26.2 $\pm$ 2.5	-
Surgery year				<0.0001
2007–2008	778 (1.6)	263 (33.8)	515 (66.2)	
2009–2010	3,214 (6.5)	1,106 (34.4)	2,108 (65.6)	
2011–2014	19,910 (40.4)	7,291 (36.6)	12,619 (63.4)	
2015–2017	25,336 (51.5)	9,690 (38.3)	15,646 (61.8)	
Hispanic ethnicity	2,196 (4.5)	761 (4.1)	1,435 (4.6)	0.0100
White or Caucasian race	37,163 (75.5)	13,902 (75.8)	23,261 (75.3)	<0.0001
African American race	5,830 (11.8)	2,641 (14.4)	3,189 (10.3)	
Asian race	1,224 (2.5)	165 (0.9)	1,059 (3.4)	
Other race	5,021 (10.20)	1,642 (8.9)	3,379 (10.9)	
Diabetes mellitus with oral agents or insulin	6,100 (12.4)	3,286 (17.9)	2,814 (9.1)	<0.0001
Current smoker within one year	5,969 (12.1)	1,936 (10.6)	4,033 (13.1)	<0.0001
Dyspnea	1,155 (2.4)	588 (3.2)	567 (1.8)	<0.0001
History of severe COPD	908 (1.8)	341 (1.9)	567 (1.8)	0.8600
Hypertension requiring medication	25,452 (51.7)	11,658 (63.5)	13,794 (44.7)	<0.0001
Steroid use for chronic condition	662 (1.3)	257 (1.4)	405 (1.3)	0.4100
Bleeding disorder	511 (1.0)	240 (1.3)	271 (0.9)	<0.0001
ASA classification: severe disturbance	17,891 (36.3)	8,323 (45.4)	9,568 (31.0)	<0.0001
Estimated probability of morbidity <sup>a</sup>	4.23 $\pm$ 1.48	4.80 $\pm$ 1.61	3.89 $\pm$ 1.27	<0.0001
Estimated probability of mortality <sup>a</sup>	0.14 $\pm$ 0.16	0.15 $\pm$ 0.14	0.13 $\pm$ 0.17	<0.0001
Hospital length of stay $>2$ days	5,915 (12.0)	2,410 (13.1)	3,505 (11.3)	<0.0001
Readmission to hospital $<30$ days <sup>b</sup>	1,610 (3.9)	740 (4.8)	870 (3.4)	<0.0001

Values are presented as mean $\pm$ standard deviation for continuous factors and frequency (%) for categorical factors.

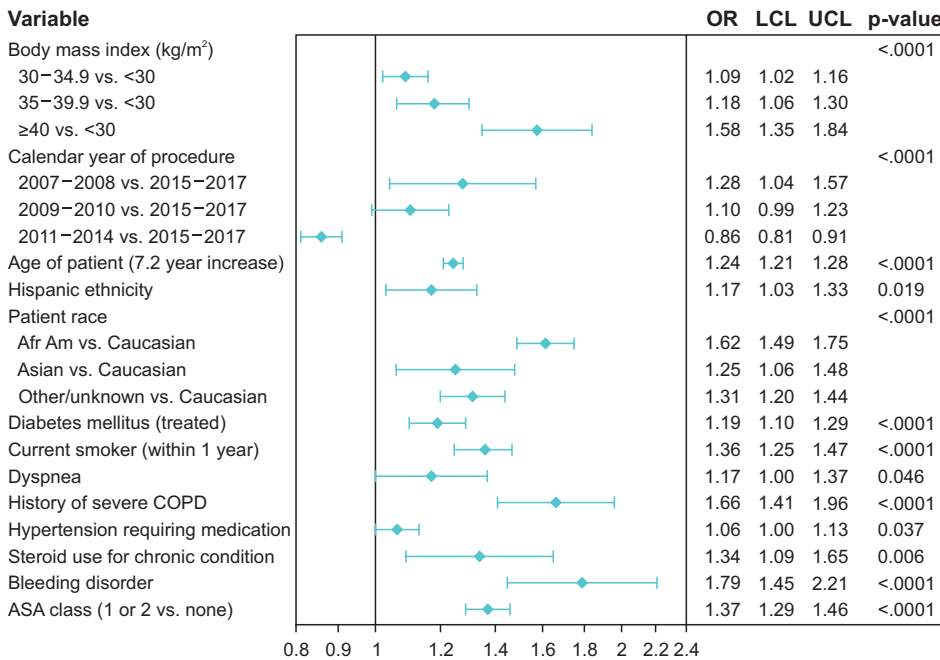
BMI, body mass index; COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists.

<sup>a</sup>:n=40,887 for estimated probabilities of morbidity and mortality (n=15,503 with BMI  $\geq 30$  kg/m<sup>2</sup>, n=25,384 with BMI  $< 30$  kg/m<sup>2</sup>).

<sup>b</sup>:n=40,764 for readmission data (n=15,463 with BMI  $\geq 30$  kg/m<sup>2</sup>, n=25,301 with BMI  $< 30$  kg/m<sup>2</sup>).



**Fig. 1.** Box-and-whisker plots showing the distribution of body mass index by calendar year of surgery. Lower and upper edges of rectangles represent the 25th and 75th percentiles, horizontal line the median, whiskers extend to  $\pm 3$  times the inner-quartile range, diamonds depict the mean values and are joined by horizontal lines.



**Fig. 2.** Graphical depiction of odds ratios, 95% confidence limits, and p-values for multivariable logistic regression model to predict extended length of stay >2 days in patients undergoing robotic prostatectomy. OR, odds ratio; LCL, lower 95% confidence limit; UCL, upper 95% confidence limit; Afr Am, African Americans; COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists.

**RESULTS**

A total of 6,485,915 case records were downloaded from ACS NSQIP corresponding to years of surgery from 2007 through 2017. Of those, 49,405 (0.8%) had CPT code 55866 indicating MI-RRP was performed. After excluding cases without data for LOS or BMI, 49,238 remained available for analysis. Data were completely observed for all covariates except as noted in Table 1. Fig. 1 shows the distribution of BMI by year of surgery performed. There was a rise in the mean BMI from a low of 28.5 kg/m<sup>2</sup> for 668 MI-RRPs in 2008 to 29.2 kg/m<sup>2</sup> for 8,542 performed in 2016. Likewise, the upper quartile increased from 30.7 in 2008 to 31.9 in 2016. The proportion of obese patients (BMI  $\geq 30$  kg/m<sup>2</sup>) grew from 33.8% in surgery years 2007–2008 to 38.3% in years 2015–2017 (p<0.0001, Table 1).

Table 1 shows other factors and comorbidities associated with the presence of obesity, much of that significance is attributable to the large sample size. The mean estimated probability of morbidity was considerably higher in obese patients. Finally, both hospital LOS >2 days and readmission to the were associated with BMI >30 kg/m<sup>2</sup>. All had p-values <0.0001.

The risk of prolonged LOS increased with increases in BMI. The proportion of patients with LOS >2 days increased with obesity severity, from 11.4% in non-obese to 12.5% among 13,130 patients with BMI 30–34.9 kg/m<sup>2</sup>, to 13.9% among 4,040 patients with BMI 35–39.9 kg/m<sup>2</sup>, and 18.4% among 1,068 with BMI  $\geq 40$  kg/m<sup>2</sup> (p<0.0001; not tabled).

Fig. 2 shows the results of multivariable logistic regression analysis for risk of LOS >2 days including the preoperative factors listed in Table 1 except probabilities of morbidity

and mortality. BMI is broken into four categories with BMI <30 kg/m<sup>2</sup> as the referent. The odds ratio for BMI goes from 1.09 (95% confidence interval [CI] 1.02, 1.16) in BMI 30–34.9 kg/m<sup>2</sup>, to 1.18 (95% CI 1.06, 1.30) in BMI 35–39.9 kg/m<sup>2</sup>, to 1.58 (95% CI 1.35, 1.84) in BMI ≥40 kg/m<sup>2</sup> when compared to non-obese (p-value<0.0001). This strong relationship is depicted in Fig. 3, which shows estimated odds ratios for the risk of prolonged LOS in both unadjusted and the adjusted model from Fig. 2.

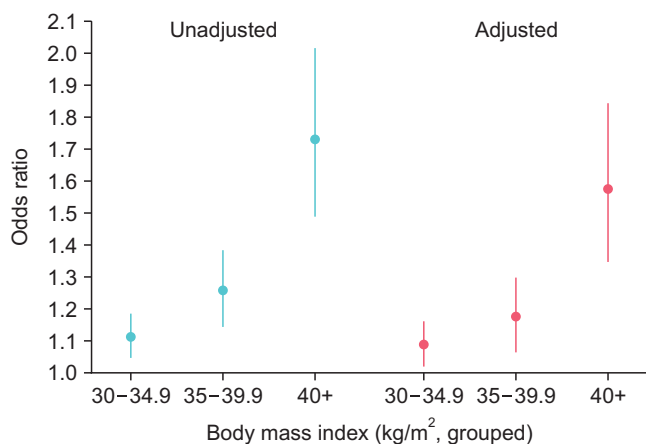
A multivariable logistic regression model to predict readmission within 30 days for any reason was constructed for the subgroup of patients in years 2011 or later where read-

mission data were collected. Increased obesity was associated with an increased risk of readmission. The odds ratio for BMI increased from 1.29 (95% CI 1.15, 1.44) in BMI 30–34.9 kg/m<sup>2</sup>, to 1.33 (95% CI 1.23, 1.57) in BMI 35–39.9 kg/m<sup>2</sup>, to 1.54 (95% CI 1.18, 2.01) in BMI ≥40 kg/m<sup>2</sup> when compared to BMI <30 kg/m<sup>2</sup> (p-value<0.0001). This relationship held after controlling for other preoperative characteristics and risk factors, as well as prolonged LOS, which has an odds ratio for readmission of 2.38 (95% CI 2.13, 2.67; p-value<0.0001; Fig. 4).

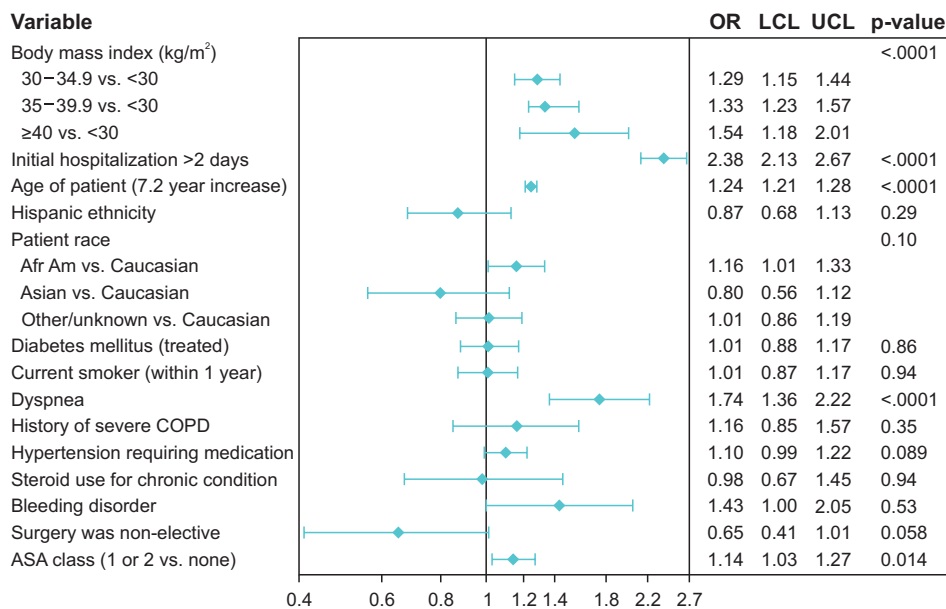
## DISCUSSION

Obesity is a significant public health issue in the United States, with 93.3 million (39.8%) Americans meeting obesity criteria [15], and continuing to increase in prevalence globally [1]. This disease places an extra physical and financial strain on patients and health systems alike. Hypertension, CVD, T2DM, and a variety of malignancies have been shown to have an increased prevalence in patients who are obese [7,16,17]. A recent meta-analysis indicated that prostate-cancer specific mortality in obese patients (BMI ≤30 kg/m<sup>2</sup>) was almost twice that of patients with normal BMI [18].

In addition to increasing the risk of multiple different medical comorbidities, studies have shown obesity to be an independent risk factor of postoperative complications and poor postoperative outcomes. A meta-analysis including 2,890 patients was performed evaluating obesity as a primary risk factor for urinary incontinence following robotic-assisted laparoscopic radical prostatectomy [19]. Results from this study demonstrated an increased risk of urinary incontinence in obese patients at 12 (odds ratio 2.43, p=0.01) and 24



**Fig. 3.** Odds ratio (OR) and 95% confidence limits depicting increased risk of length of stay >2 days by body mass index (BMI) in categories. Dots show OR for each category of BMI versus the referent BMI <30 kg/m<sup>2</sup>. Blue dots and lines are from the unadjusted logistic regression model; red dots and lines for model adjusted for pre-operative covariates in Table 1.



**Fig. 4.** Graphical depiction of odds ratios, 95% confidence limits, and p-values for multivariable logistic regression model to predict readmission within 30 days in patients undergoing robotic prostatectomy. OR, odds ratio; LCL, lower 95% confidence limit; UCL, upper 95% confidence limit; Afr Am, African Americans; COPD, chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists.

months (odds ratio 2.00,  $p < 0.001$ ) [19]. A large single-institution retrospective study with 11,152 participants, between 1982–2012, evaluated the impact of obesity on long-term survival following radical prostatectomy [20]. Patients with BMI  $\geq 35$  kg/m<sup>2</sup> were reported to have a 20-year biochemical free survival rate of 55.9%, lower than patients with normal BMI (76.3%) [20]. It was also reported that BMI showed significant prognostic predictability in assessing biochemical recurrence-free and overall survival, in patients with obesity [20]. Additionally, BMI was a statistically significant factor in assessing prostate-cancer specific survival [20]. Furthermore, obese patients experience increased rates of renal, wound, and thromboembolic complications, increased mean lengths of stay, and increased rates of readmission, and Clavien 3 and 4 complications when compared with normal BMI patients [21]. Patients considered to be obese also experienced longer operative times and reported an increased incidence of erectile dysfunction following radical prostatectomy than their normal-BMI counterparts [22].

Operative management of obese patients may present some technical challenges and require a slight modification of operative technique, particularly with port placement and positioning. Obese patients may be placed in the supine position (da Vinci Xi robotic platform; Intuitive Surgical, Sunnyvale, CA, USA), as opposed to a traditional dorsal lithotomy position, to mitigate rhabdomyolysis risk [23]. Additionally, bariatric trocars are often needed to ensure adequate identification of pelvic structures [23].

A rise in the percentage of men with BMI  $\geq 30$  kg/m<sup>2</sup> who underwent MI-RRP, between 2007–2017, along with an increase in the yearly mean BMI, indicating that more patients are becoming obese, and the severity of obesity seen in this patient population has also increased. We report that obese patients demonstrated increased mean lengths of stay and readmission than did normal-weight patients. These findings agree with those found in a 2017 report in which the authors demonstrated increased association with prolonged length of stay and hospital readmission as BMI rose, which the authors attributed to the increased prevalence of certain comorbidities seen in obese patients [21]. Conversely, separate report from 2015 suggests that increased BMI may not be an influencing factor. It is important to note with this study that the authors divided the study population into two groups, with one group comprised of patients with a BMI  $< 40$  kg/m<sup>2</sup> and another group comprised by a population with BMI  $> 40$  kg/m<sup>2</sup>. Furthermore, the majority of the BMI  $< 40$  kg/m<sup>2</sup> group could be classified as ‘overweight’ or ‘class 1 obesity,’ with a minority of patients having a normal BMI  $< 25$  kg/m<sup>2</sup>, thus potentially skewing LOS and readmis-

sion data findings [24]. Because diabetes and severe ASA score are independent risk factors leading to negative post-operative outcomes and are seen in a higher prevalence among obese patients, the presence of these comorbidities may lead to a further increased risk to surgical patients with high BMI values [25,26]. Even after controlling for other preoperative risk factors, a statistically significant increase in LOS and hospital readmission was noted. Although oncologic functional outcomes are difficult to study, the fact that the rate of readmission and LOS was significant in the obese population, coupled with the risk profile described in an earlier report [21], make this an essential part of preoperative counseling.

These data do not suggest that obesity be a contraindication to MI-RRP. Per American Urological Association guidelines, patients should be counseled concerning the associated increased risks with the procedure and lifestyle modification options [27]. Patients should be counseled preoperatively about weight loss options available to them, utilizing shared-decision-making. Lifestyle and diet modification should be the first offered. Patients should additionally be counseled to participate in  $\geq 30$  minutes of exercise around 5–7 days per week [28]. Diet recommendations should be simple, sustainable, and cost-effective, advising patients to consume more fresh vegetables and fish than red meat and to decrease consumption of alcohol, sugar, salt, and fast foods [29]. Furthermore, preoperative consultation with a certified nutritionist may be beneficial to allow for more time for proper patient education on the necessary dietary changes and guidance to appropriate resources.

Depending on the patient’s cancer staging, those who have failed diet and lifestyle modification may not be good candidates for surgery. Cryoablation or radiation therapy may be considered for this patient population.

Our study has several limitations, primarily due to inherent deficiencies in the NSQIP database. First, laparoscopic and robot-assisted laparoscopic prostatectomies are both coded under the same 55866 CPT code in the NSQIP database, thus delineating differences in outcomes between the two is not possible. Furthermore, a more nuanced analysis of different approaches and techniques (i.e., single vs. multi-port, Retzius-sparing vs. conventional technique, etc.) was not possible as CPT coding does not draw these distinctions. Though we believe it would be an interesting topic for additional study, we were also unable to investigate the role of lymph node dissection as this is coded under a different CPT code than the 55866 code that we had used. Second, we were unable to provide outcomes past thirty days post-op because NSQIP only provides data within that period, thus

our results may not be able to be extrapolated past 30 days. Third, severity of patient comorbidities nor patient medications are not reported in the NSQIP database, this may serve as an impediment to further assess risk in patients based on the severity of their comorbid condition. Fourth, NSQIP does not contain information on disease characteristics or prostate cancer staging, which could be a significant influencing factor on post-operative outcomes. Fifth, NSQIP does not contain data concerning the socioeconomic status of patients. This, in particular, is relatively significant because socioeconomic status may confound readmission/comorbidity data when racial factors are evaluated. Sixth, data compiled within this database does not contain information directly identifying hospital/facility location nor does it contain identifying information for the surgeon performing a specific operation. Lack of this information prevents us controlling for region-specific, culture-specific, or surgeon-specific post-operative practices, particularly in relation to accepted duration of postoperative hospital stay following MI-RRP. For instance, one recent report out of China found the mean LOS was 11.7 days [30]. Lastly, the NSQIP database does not report reasons for readmission, making more targeted analyses of specific causes for readmission not possible.

## CONCLUSIONS

The prevalence and severity of obesity in patients undergoing MI-RRP has increased, which negatively influences hospital readmission and LOS. Preoperative patient optimization and weight loss may be appropriate in select patients.

## CONFLICTS OF INTEREST

The authors have nothing to disclose.

## AUTHORS' CONTRIBUTIONS

Research conception and design: Ram A. Pathak, Timothy E. Craven, Ethan Matz, and Ashok K. Hemal. Data acquisition: Robert R.A. Wilson and Timothy E. Craven. Statistical analysis: Timothy E. Craven. Data analysis and interpretation: Ram A. Pathak, Robert R.A. Wilson, and Timothy E. Craven. Drafting of the manuscript: Ram A. Pathak, Robert R.A. Wilson, Timothy E. Craven, Ethan Matz, and Ashok K. Hemal. Critical revision of the manuscript: Ram A. Pathak and Ashok K. Hemal. Administrative, technical, or material support: Ram A. Pathak and Ashok K. Hemal. Supervision: Ashok K. Hemal. Approval of the final manuscript: Ram A. Pathak, Robert R.A. Wilson, Timothy E. Cra-

ven, Ethan Matz, and Ashok K. Hemal.

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