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Robotic versus laparoscopic versus open surgery in morbidly obese endometrial cancer patients — A comparative analysis of total charges and complication rates

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HIGHLIGHTS

- Minimally invasive surgery is efficient in morbidly obese uterine cancer patients.
- Robotic surgeries had similar rates of complications to laparoscopic surgeries.
- Robotic surgeries had higher charges relative to laparoscopic surgeries.

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ABSTRACT

Objective. To compare the complications and charges of robotic vs. laparoscopic vs. open surgeries in morbidly obese patients treated for endometrial cancer.

Methods. Data were obtained from the Nationwide Inpatient Sample from 2011. Chi-squared, Wilcoxon rank sum two-sample tests, and multivariate analyses were used for statistical analyses.

Results. Of 1087 morbidly obese (BMI ≥ 40 kg/m^2) endometrial cancer patients (median age: 59 years, range: 22 to 89), 567 (52%) had open surgery (OS), 98 (9%) laparoscopic (LS), and 422 (39%) robotic surgery (RS). 23% of OS, 13% of LS, and 8% of RS patients experienced an intraoperative or postoperative complication including: blood transfusions, mechanical ventilation, urinary tract injury, gastrointestinal injury, wound debridement, infection, venous thromboembolism, and lymphedema ($p < 0.0001$). RS and LS patients were less likely to receive blood transfusions compared to OS (5% and 6% vs. 14%, respectively; $p < 0.0001$). The median lengths of hospitalization for OS, LS, and RS patients were 4, 1, and 1 days, respectively ($p < 0.0001$). Median total charges associated with OS, LS, and RS were $39,281, $40,997, and $45,030 ($p = 0.037$), respectively.

Conclusions. In morbidly obese endometrial cancer patients, minimally invasive robotic or laparoscopic surgeries were associated with fewer complications and less days of hospitalization relative to open surgery. Compared to laparoscopic approach, robotic surgeries had comparable rates of complications but higher charges.

1. Introduction

Over 52,000 patients are annually diagnosed with endometrial cancer in the United States [1]. Nearly two-thirds of females in the United States are either overweight or obese, and over 6% are morbidly obese (body mass index ≥ 40 kg/m^2) [2,3]. Obesity has been shown to be a significant risk factor for endometrial cancer and is associated with approximately 40% of cases [4–8]. Since surgery is the primary treatment for endometrial cancer, it is important to identify the safest and most effective surgical approach for these complex patients with multiple risk factors. Surgical expenditure for obese patients has been shown to be significantly higher compared to that for the non-obese [9].

Minimally invasive surgeries are used in nearly half of women with endometrial cancer [10]. However, these surgical approaches, particularly laparoscopy, are challenging to perform in obese patients due to

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difficulty in accessing the peritoneal cavity and restricted operative movements [11]. Retrospective studies from single institutions have shown that robotic surgery has enhanced visualization with improved range of motion over laparoscopic surgery [12]. Other retrospective research has also demonstrated that robotic surgery is safe and feasible in the morbidly obese [13–16]. In fact, these studies showed that robotic surgery on obese patients resulted in fewer complications and shorter lengths of hospitalization relative to open surgery [17–21]. Studies have also demonstrated that robotic surgery in obese patients is associated with higher costs due to greater equipment use and longer operating times [9,22–24]. However, these studies were limited due to small sample sizes and were based on single institutions.

In this current study of 1087 morbidly obese endometrial cancer patients, we compared the total charges and complications of robotic vs. laparoscopic vs. open surgeries using a nationwide database which included patients from multiple institutions.

2. Materials and methods

Data for morbidly obese women who underwent hysterectomies for endometrial cancer were extracted from the National Inpatient Sample (NIS), a part of the Healthcare Cost and Utilization Project (HCUP). The NIS is one of the largest health care databases in the United States and utilizes data from 8 million hospitalizations per year across 46 states [25]. Because the NIS is a de-identified, nationwide database, this study was exempt from approval by our Institutional Review Board.

Our study population consisted of all morbidly obese patients in the NIS database who underwent hysterectomies for endometrial cancer in 2011. Patients were defined as morbidly obese if they had a body mass index (BMI) greater than or equal to 40 kg/m^2. We used International Classification of Diseases, 9th Revision (ICD-9) codes to identify patients, procedures, and complications. Code 278.01 was used to identify morbidly obese patients. Among patients who were coded as having hysterectomies, the following codes were utilized to identify surgical types: 68.0, 68.3, 68.39, 68.4, 68.49, 68.5, 68.59, 68.6, 68.69, 68.7, 68.79, 68.9, and 68.99 for open surgery (OS); 68.31, 68.41, 68.51, 68.61, 68.71, and 68.91 for laparoscopic surgery (LS); 17.4, 17.41, 17.42, 17.43, 17.44, 17.45, and 17.49 for robotic surgery (RS). Patients who were scheduled for LS or RS but were converted to OS were coded as having undergone OS. The following codes were used for identification of complications: 99.04 for blood transfusion; 93.90, 96.01, 96.02, 96.03, 96.04, 96.05, 96.70, 96.71, and 96.72 for mechanical ventilation; 56.71, 56.74, 57.80, 57.89, and 593.3 for urinary tract injury; 863.0–863.99 for gastrointestinal injury; 86.22 and 86.28 for wound debridement; 998.5 and 998.59 for postoperative infection; 453.2, 453.3, 453.8, 453.9, 453.40–453.42, and 453.81–453.89 for venous thromboembolism; 457.1 for lymphedema. We included only complications occurring from surgery or in the post-operative hospitalization period.

The median age of the sample population was 59 years. Patients older than or equal to 59 were defined as “older” and patients less than 59 “younger.” Race was categorized as White, Black, Hispanic, or other. Based on median incomes from zip codes, the NIS categorized each patient's annual income for the year 2011 into the following quartiles: ≤$38,999 (low), $39,000–$47,999 (middle), $48,000–$63,999 (upper-middle), and ≥$64,000 (high). HCUP categorizes payer information into Medicare, Medicaid, private insurance (includes Blue Cross, commercial carriers, private HMOs and PPOs), other (includes Workers' Compensation, TRICARE/CHAMPUS, CHAMPVA, and Title V), and uninsured. Hospital location was determined based on U.S. Census defined regions of West, Midwest, South, and Northeast. Total charges represent the amount the hospital was billed for the patient stay but does not include physician fees.

For univariate analysis, we used Chi-squared tests to compare rates of complications across groups of categorical variables. Wilcoxon rank sum two-sample tests were used to test for significant differences between hospital charges by patient- and hospital-level characteristics. To model the occurrence of surgical complications by surgery type, we used a multivariate logistic regression model adjusted for patient characteristics (race, age, socioeconomic status, type of insurance, and comorbidity status) and hospital characteristics (hospital ID, geographic location, rural or urban, teaching or non-teaching, and hospital size). For patient comorbidity status, we controlled for all thirty Elixhauser comorbidities (excluding obesity), which include conditions such as hypertension, diabetes, valvular disease, and metastatic disease, and these comorbidities are explicitly coded for in the NIS database [26]. To control for extent of surgery, we included a variable for lymph node dissection (yes or no) for each type of surgery. Although often indicated when modeling clustered data, we did not employ a hierarchical model with random intercept by hospital in this analysis because, when tested, we calculated the intraclass correlation coefficient (the percent of total variation due to hospital-level clustering) to be zero. In order to include any patients who were missing covariate data for patient-level characteristics in the multivariate analysis, we used multiple imputation by chained equations (MICE) [27]. Multiple imputation is a common procedure that allows all observations in the sample to be included in the multivariate analysis while maintaining the variability of the data, and is valid assuming that the data are missing at random (MAR) (i.e., there are no unmeasured variables that systematically predict the missing data). In the NIS dataset, MAR is a reasonable assumption, and we used all analysis covariates for our imputation model. Multiple imputation reduces the bias inherent to missing data [28–30]. We performed all statistical analyses in R (Version 3.1.0, Vienna, Austria) and SAS (Version 9.3, Cary, NC).

3. Results

3.1. Patient and hospital characteristics

A total of 1087 morbidly obese patients in the NIS database underwent hysterectomies for endometrial cancer in 2011. Of these patients, 567 (52%) received open surgery (OS), 98 (9%) laparoscopic (LS), and 422 (39%) robotic surgery (RS) (Table 1). Thus, RS was used in 81% of minimally invasive surgical cases for these patients. The median age was 59 years (range: 22–89). 62% of patients were White, 13% were Black, 9% were Hispanic, and 4% other (12% missing). Based on median income by zip codes, 26%, 25%, 25%, and 23% of patients had incomes that were considered low, middle, upper-middle, and high, respectively (1% missing). Furthermore, 49% of patients used private insurance, 36% Medicare, 8% Medicaid, 4% had no insurance, and 3% used other insurance types. Geographically, 31% of patients received surgery in the South, 28% the Midwest, 23% the West, and 18% the Northeast. More surgeries were performed in urban compared to rural hospitals (97% vs. 1%, data missing for 2%) and in teaching hospitals relative to non-teaching hospitals (77% vs 21%, data missing for 2%). Lymphadenectomies were performed in 34% of OS, 18% of LS, and 30% of RS ($p < 0.001$).

3.2. General complications based on surgical approach

16% of patients had at least one of the following complications: blood transfusions (9.7%), mechanical ventilation (5.3%), urinary tract injuries (0.18%), gastrointestinal injuries (0.28%), wound debridement (0.28%), postoperative infection (1.9%), venous thromboembolism (0.92%), and lymphedema (1.3%). RS and LS were associated with significantly lower complications rates relative to OS (8%, 13%, 23%, respectively; $p < 0.0001$) (Fig. 1). More specifically, RS and LS required lower rates of blood transfusions compared to OS (transfusions: 5%, 6%, 14%; $p < 0.0001$). RS and LS also resulted in less postoperative infections in comparison to OS, though the difference was of borderline significance (1% and 1% vs. 3% $p = 0.08$). However, there were no significant differences among the surgical procedures in the rates of mechanical ventilation ($p = 0.27$), urinary injuries ($p = 0.4$), gastrointestinal injuries ($p = 0.25$), wound debridement ($p = 0.25$), venous thromboembolism ($p =$