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Impact of Robotic Platforms on Surgical Approach and Costs in the Management of Morbidly Obese Patients with Newly Diagnosed Uterine Cancer

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Abstract

Background—Minimally invasive surgery (MIS) is associated with decreased complication rates, length of hospital stay, and cost compared with laparotomy. Robotic-assisted surgery—a method of laparoscopy—addresses many of the limitations of standard laparoscopic instrumentation, thus leading to increased rates of MIS. We sought to assess the impact of robotics on the rates and costs of surgical approaches in morbidly obese patients with uterine cancer.

Methods—Patients who underwent primary surgery at our institution for uterine cancer from 1993 to 2012 with a BMI ≥ 40 mg/m² were identified. Surgical approaches were categorized as laparotomy (planned or converted), laparoscopic, robotic, or vaginal. We identified two time periods based on the evolving use of MIS at our institution: laparoscopic (1993–2007) and robotic (2008–2012). Direct costs were analyzed for cases performed from 2009 to 2012.

Results—We identified 426 eligible cases; 299 performed via laparotomy, 125 via MIS, and 2 via a vaginal approach. The rates of MIS for the laparoscopic and robotic time periods were 6 % and 57 %, respectively. The rate of MIS was 78 % in this morbidly obese cohort in 2012; 69 % were completed robotically. The median length of hospital stay was 5 days (range 2–37) for laparotomy cases and 1 day (range 0–7) for MIS cases ($P < 0.001$). The complication rate was 36 and 15 %, respectively ($P < 0.001$). The rate of wound-related complications was 27 and 6 %, respectively ($P < 0.001$). Laparotomy was associated with the highest cost.

Conclusions—The robotic platform provides significant health and cost benefits by increasing MIS rates in this patient population.

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Uterine cancer is the most common gynecologic malignancy in the United States, with an estimated 54,870 cases diagnosed annually.¹ Approximately 40 % of women older than age 60 years are obese, which is a recognized, significant risk factor for endometrial carcinomas, particularly endometrioid adenocarcinoma.^{2,3} Furthermore, obesity leads to significant increased medical and surgical costs across all aspects of care, because managing these patients often requires specialized approaches.⁴ Surgeons must continue optimizing management strategies for obese patients diagnosed with uterine cancer, especially those who are morbidly obese (body mass index [BMI] ≥ 40).

Surgery is the primary treatment option for the majority of patients with newly diagnosed uterine cancer.⁵ This has traditionally consisted of a laparotomy to perform a total abdominal hysterectomy and bilateral salpingo-oophorectomy, with or without some form of nodal assessment. This changed, however, when the Gynecologic Oncology Group (GOG) published the results of the largest randomized trial (LAP2) comparing laparoscopy to laparotomy for patients with newly diagnosed uterine cancer and showed a clear advantage of laparoscopy in this cohort of patients in terms of perioperative outcomes and quality of life, without compromising oncologic outcomes.⁶⁻⁸ Unfortunately, the adoption of laparoscopy has not been widespread, mainly due to the limitations of the available instrumentation before the introduction of robotic surgical platforms. Morbidly obese patients present an additional surgical challenge with regard to minimally invasive surgery (MIS). For example, GOG LAP2 provided a predictive probability of conversion to laparotomy that was directly proportional to increasing BMI.⁶

We previously reported that the incorporation of a robotic surgical platform increased rates of MIS in patients with newly diagnosed uterine cancer.⁹ This increase led to cost benefits in addition to the already proven clinical benefits.¹⁰ Questions remain, however, as to whether an increased MIS rate can be attained with the use of robotics in challenging cases. Furthermore, there is continued criticism regarding the costs of robotically assisted surgery. We sought to analyze the rate of MIS in morbidly obese patients with newly diagnosed uterine cancer over a longer time period and to assess the impact of robotics on this MIS rate and on the costs of surgical care in these patients.

Methods and Materials

All patients with a BMI ≥ 40 mg/m² who underwent primary surgery at our institution for newly diagnosed uterine cancer from January 1, 1993 to December 31, 2012 were identified from our uterine cancer database. Clinical and pathologic data are continuously abstracted from medical records, and the database is updated routinely. Surgical approaches were categorized as laparotomy, laparoscopy, robotically assisted laparoscopy (robotic), or vaginal. Laparotomy cases included those planned for laparotomy and those converted to laparotomy. Similarly, laparoscopic, robotic, and vaginal cases only included cases successfully completed as such. Laparoscopic and robotic cases were considered MIS for certain analyses, and we noted the number of cases planned as laparoscopic or robotic and subsequently converted to laparotomy.

Laparoscopy was available and was performed routinely during the entire study period. A greater emphasis was placed on the development and advancement of laparoscopy in 2000, and a robotics surgery program was developed in 2008. We defined two surgical time periods: laparoscopic (1993–2007) and robotic (2008–2012). Overall MIS rates during these two time periods were compared. Complication rates within 30 days of surgery were captured and reported using a published institutional Surgical Adverse Events System.¹¹ Any case with a wound infection that was opened, either spontaneously or intentionally, was classified as a wound breakdown and not counted twice. Also, noninfected wounds that were opened were included in the wound breakdown category.

Nodal assessment practices and surgeons varied during the 20-year study period. All surgeons on staff during the robotic time period were trained and experienced in standard laparoscopy. In earlier years, we did not perform routine nodal dissections; however, in 2000, we transitioned to a period of more routine pelvic and para-aortic nodal dissections as a result of the GOG LAP2 protocol, which required a formal pelvic and aortic nodal dissection. After closure of the study, our institution began to transition into the era of sentinel lymph node (SLN) mapping. The first SLN mapping case for endometrial cancer occurred in September 2005, and 75 cases were performed on protocol up until June 2008. SLN mapping was then offered routinely once the protocol was completed. Of note, we do not routinely perform nodal dissections above the inferior mesenteric artery when a para-aortic nodal dissection is attempted. The number of cases in which any nodal assessment was performed, defined as the removal of at least one lymph node, in addition to the total number of lymph nodes retrieved were analyzed. Stage was assigned based on the 2009 International Federation of Obstetrics and Gynecology (FIGO) system. Nominal variables were compared using chi square or the Fischer exact test, as appropriate. Continuous variables were compared using Mann–Whitney *U* or Kruskal–Wallis tests, as appropriate. All statistical tests were performed using SPSS 20.0.

Direct institutional costs were obtained using a cost system that allocates the cost of resources used to treat each patient, as opposed to borrowing cost data from the hospital billing system, providing a more accurate assessment of true direct costs. This system of cost allocation was initiated at our institution in 2009; therefore, the cost analysis was limited to cases performed from January 1, 2009 to December 31, 2012. These costs included direct institutional costs for all aspects of care during the initial surgical event and immediate postoperative stay and costs incurred up to 30 days and 6 months postoperatively. Amortized cost included the capital cost of multiple dual-console DaVinci Si platforms and 5 years of service contracts for each of the platforms amortized over 5 years assessed to each case based on total robotic case volume from 2009 to 2012, as well as the total direct costs of other resources used to treat each patient, as previously described.¹⁰ The total robotic case volume includes all surgical cases performed across all services (not just the Gynecology Service) using the platform. Non-amortized cost was the amortized cost minus the capital equipment cost of the robotic platforms.

The Student's *t* test was used to compare mean costs between the laparoscopic and robotic cohorts. The Kruskal–Wallis test was used to compare costs among the three surgical approaches (laparoscopic, robotic, and laparotomy). Modeling was then performed to

estimate the mean cost of surgical care for patients presenting to our institution for newly diagnosed uterine cancer based on the rate distribution of laparoscopy, robotic, and laparotomy from 2006 (just before the incorporation of the robotic platform) to 2012. This model was created by calculating weighted projections of total surgical cost on retrospective case data. The actual costs from 2009 to 2012 were projected onto the 2006 cases, weighted by surgical method and case load. We did not adjust for inflation, because this would have a limited impact over such a short time period and would have equally affected costs across all three approaches.

Results

We identified 426 morbidly obese patients operated on by 15 surgeons during the 20-year study period. All were trained in laparoscopy and subsequently the use of the robotic platform. The number of morbidly obese cases performed annually increased from 5 in 1993 to 45 in 2012. The vaginal approach was rarely used and accounted for only 2 (0.5 %) of 426 cases. Therefore, these 2 cases were not included in the MIS cohort. The rate of successfully completed MIS ranged from 20 % (1 of 5 cases) in 1993 to 78 % (35 of 45 cases) in 2012. Only 14 (6 %) of 232 patients underwent MIS before the robotic time period compared with 111 (57 %) of 194 patients during the robotic time period ($P < 0.001$). Figure 1 shows the increase in the MIS rate as a result of incorporating robotically assisted laparoscopy. A total of 133 cases were planned for MIS, of which 8 (6 %) were converted to laparotomy. Of the 43 planned laparoscopic cases, 5 (12 %) were converted compared with 3 (3 %) of the 90 planned robotic cases ($P = 0.1$).

Median age and histology were similar across the two time periods (Table 1). There was a significant increase in the rate of nodal assessment across the time periods, with 50 % undergoing nodal assessment during the laparoscopic period (the majority after 2000) compared with 73 % during the robotic time period ($P < 0.001$). SLN mapping was used in 55 % of the cases in the robotic period compared with ~4 % in the laparoscopic period ($P < 0.001$).

The median estimated blood loss was 125 mL less for MIS compared with laparotomy ($P < 0.001$; Table 2). Thirty-two laparotomy cases (11 %) required a perioperative blood transfusion, whereas none of the MIS cases required a transfusion ($P = 0.001$). The median operative time was 21 min longer for MIS ($P = 0.009$). The median length of hospital stay after MIS was 1 day (range 0–7 days) compared with 5 days (range 2–37 days) after laparotomy ($P < 0.001$). Same-day discharge occurred in 6 (5 %) MIS cases. An additional 74 (59 %) MIS cases were discharged home the following day. The overall rate of any type of complication was 36 % (108/299) with laparotomy compared with 15 % (19/125) with MIS ($P < 0.001$). The vast majority of these complications were wound related. There were no instances of wound breakdown with MIS compared with a 6 % rate of wound breakdown after laparotomy ($P = 0.004$). Supplementary Table 1 details perioperative outcomes comparing laparoscopic to robotically assisted laparoscopic cases. Estimated blood loss and length of hospital stay were significantly less for robotic cases. Operative times and complication rates were similar.

Table 3 details direct cost results. Laparotomy was associated with the highest cost at all time points (immediate perioperative, up to 30 months postoperative, and up to 6 months postoperative) even when including the amortized capital costs of multiple robotic platforms. The mean cost per laparotomy case including up to 6 months of postoperative care was \$31,385 compared with \$21,015 for robotic and \$18,889 for laparoscopic cases when the amortized capital costs were included. Robotic cases were significantly more costly compared with laparoscopy up to 30 months postoperatively when amortized costs were included. At 6 months, the increased cost for robotic cases was not statistically significant. There was no statistical difference between robotic and laparoscopic mean costs when amortized costs were not included. There were five total planned MIS cases (2 laparoscopic and 3 robotic) that were converted to laparotomy from 2009 to 2012; these cases are included in the laparotomy group for our cost analysis. The conversion rate was 10.5 % (2/19) and 3.4 % (3/87) for planned laparoscopic and robotic cases, respectively ($P=0.5$). The mean non-amortized cost for these 5 cases, including the 6-month postoperative period, was \$25,191. Further analyses were not possible, as there were only five cases.

Table 4 details the cost model of mean costs of all morbidly obese patients undergoing surgery in 2006 compared with 2012. In 2006, the rate of laparotomy was 93 %; only 7 % of cases were performed laparoscopically before the incorporation of the robotic platform. In 2012, the rate of laparotomy decreased to 22 % compared with 9 and 69 % for laparoscopy and robotically assisted laparoscopy, respectively. There was a cost savings across all perioperative and postoperative periods, with nearly a \$9000 cost reduction at 6 months postoperatively irrespective of whether amortized costs were included.

Discussion

Many surgeons are adept in the use of standard laparoscopic instrumentation; however, even after 40 years of availability, the adoption of laparoscopy has not been as widespread as expected, possibly due to the limitations of this standard instrumentation. Obesity poses an additional challenge in performing laparoscopy, and many surgeons will not even attempt MIS in these patients, particularly morbidly obese patients. In the GOG LAP2 study, 261 (10 %) of 2616 patients enrolled on the trial were morbidly obese, and the reported conversion rate to laparotomy in that group exceeded 30 %.^{6,12} In our study, the conversion rate was 6 %. When stratified by MIS approach, 12 % of laparoscopic cases compared with 3 % of robotic cases required conversion. This difference was not significant, likely due to the small number of conversions overall.

The robotic platform is a tool to facilitate and optimize rates of MIS, but it is important to note that it is only a form of laparoscopy and not an entirely unique form of surgery. The rate of MIS was nearly 60 % in morbidly obese patients from 2008 to 2012 when the robotic platform was available, peaking at 80 % by the end of the study in 2012. Therefore, the acquisition and integration of the robotic platform into our surgical practice allowed many more morbidly obese patients to benefit from MIS. The limitations of standard laparoscopic instrumentation was the reason for the very low rate of MIS before 2008, prior to the introduction of the robotic platform, in these very challenging cases. This is a well-recognized issue within the field of gynecologic oncology.

Few published reports specifically address morbidly obese patients with endometrial cancer. Other publications report on the use of robotics in obese patients, and their findings are similar to ours; however, our series is unique in many aspects.¹³⁻¹⁹ Unlike our publication, the others had very small numbers of morbidly obese patients. The largest series had a total of 129 obese (BMI ≥ 30 kg/m²) patients undergoing robotic surgery and most were not morbidly obese.^{18,19} We report on 125 morbidly obese patients who underwent MIS, 87 of them performed via the robotic platform. None of the other reports assessed the impact of robotics on the rates of laparotomy in obese patients. They also did not address cost implications.

Laparotomy was the most expensive surgical approach in all our cost analyses whether or not the amortized capital costs of the robotic platforms were included. This is directly related to the longer length of hospital stay post-operatively, as well as the higher complication rate. The majority of complications after laparotomy were wound related, which lead to higher rates of hospital readmission, multiple office visits, use of wound care services, and use of antibiotics, with significant added cost. Additionally, wound complications are a known risk factor for the development of incisional herniae years after the initial surgery, which can lead to further long-term costs.²⁰ None of these factors have been considered in publications reporting the costs of robotic surgery. Laparoscopy was the least expensive approach, but a statistically nonsignificant higher conversion rate was noted compared to robotics in our cohort. If amortized cost was not included, however, this cost was not statistically different.

There are known inherent limitations of any retrospective analysis. Case selection is always a valid concern. The rate of robotic use increased across the robotic period, reflecting a learning curve. A robotic approach was increasingly offered to morbidly obese patients as overall surgeon experience increased. This may have affected the perioperative outcomes we reported in favor of MIS. Another concern with retrospective datasets is missing cases and/or data. We recognize this limitation and searched all databases to identify every single consecutive case presenting for surgery at our institution with newly diagnosed uterine cancer.

We recognize that there are many expert laparoscopic surgeons throughout the world who may feel comfortable operating on morbidly obese patients with uterine cancer. However, standard laparoscopic instrumentation does have limitations, which has hampered the widespread adoption of laparoscopy, especially in more challenging cases. The robotic platform can improve the rate of MIS and provide a safe and cost-beneficial alternative for these patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.
Rate of surgical approach by year. *LAP* laparotomy; *LSC* laparoscopy; *RBT* robotically assisted laparoscopy; *VAG* vaginal

Table 1
Select characteristics based on the three surgical time periods

Variable	LSC (1993–2007)	RBT (2008–2012)	P (across both periods)
<i>N</i>	232	194	
Age (year)			
Median (range)	59 (25–84)	61 (31–85)	0.05
BMI (kg/m ²)			
Median (range)	45 (40.1–69.3)	45.6 (40–69.3)	0.7
Histology			
Endometrioid	202 (87 %)	164 (85 %)	0.5
Nonendometrioid	30 (13 %)	30 (15 %)	
Nodal assessment [*]			
Any	117 (50 %)	141 (73 %)	<0.001
None	115 (49 %)	53 (27 %)	
SLN mapping performed			
<i>N</i> (%)	6 (3 %)	107 (55 %)	<0.001
Total lymph node count			
Median (range)	11 (0–51)	9 (0–46)	<0.001
Stage IIIC disease ^{**}			
<i>N</i> (%)	11 (5 %)	16 (8 %)	0.2
MIS rate			
<i>N</i> (%)	14 (6 %) [†]	111 (57 %)	<0.001

LSC laparoscopic, *RBT* robotic, *BMI* body mass index, *SLN* sentinel lymph node, *MIS* minimally invasive surgery (LSC and RBT cases)

^{*} Cases were considered to have had “any” nodal assessment if at least one LN was retrieved either via planned pelvic and para-aortic nodal dissection and/or using our institutional SLN mapping algorithm

^{**} Cases identified with nodal metastasis

[†] *P* = NS comparing minimally invasive surgery rates between early LSC and late LSC

Table 2
Perioperative outcomes comparing successful minimally invasive surgery (laparoscopic and robotic cases) with laparotomy

Variable	LAP	MIS	P
N	299	125	–
Approach			
LSC	–	38 (30 %)	–
RBT	–	87 (70 %)	
EBL (mL)			
Median (range)	250 (50–3000)	125 (5–900)	<0.001
Operative time (min)			
Median (range)	170 (40–419)	191 (87–448)	0.009
Length of stay (days)			
Median (range)	5 (2–37)	1 (0–7)	<0.001
Complications			
Any	108 (36 %)	19 (15 %)	<0.001
Wound (any)	82 (27 %)	8 (6 %)	<0.001
Wound infection	63 (21 %)	8 (6 %)	<0.001
Wound breakdown	19 (6 %)	0 (0 %)	0.004
SBO/ileus	8 (3 %)	1 (1 %)	0.3
Intra-abdominal infection	4 (1 %)	1 (1 %)	1.0
VTE	3 (1 %)	2 (2 %)	0.6
Transfused blood	32 (11 %)	0 (0 %)	0.001

LAP laparotomy, *MIS* minimally invasive surgery (laparoscopic and robotic cases), *SBO* small bowel obstruction, *EBL* estimated blood loss, *VTE* venous thromboembolism, including deep venous and/or pulmonary embolism

Table 3
Mean direct costs per morbidly obese patient presenting with newly diagnosed uterine cancer based on surgical approach (2009 2012, inclusive)

	LSC	RBT	P (LSC vs. RBT)	LAP	P (across all 3 groups)
<i>N</i>	17	84		46	
Amortized costs (AC)					
Immediate perioperative event and Hospital stay	12,709 (3,183)	16,443 (3,487)	0.0002	17,427 (5,774)	<0.0001
Including 30 days' postoperative care	13,621 (3,472)	16,854 (3,834)	0.002	20,030 (8,764)	0.0004
Including 6 months' postoperative care	18,889 (10,311)	21,015 (9,082)	0.4	31,485 (34,511)	0.0008
Nonamortized costs (NAC)					
Immediate perioperative event and Hospital stay	12,709 (3,183)	13,821 (3,453)	0.2	17,427 (5,774)	<0.0001
Including 30 days' postoperative care	13,621 (3,472)	14,232 (3,602)	0.5	20,030 (8,764)	<0.0001
Including 6 months' postoperative care	18,889 (10,311)	18,393 (9,145)	0.9	31,485 (34,511)	<0.0001

Data are mean \$ (±standard deviation) of direct costs of patient care associated with each surgical modality. Amortized costs include the cost of multiple robotic platforms according to a 5-year expected lifespan of the system and the total robotic case volumes of all robotic cases, both gynecologic and nongynecologic, performed from 2009 to 2012, plus annual maintenance costs for each platform

LSC laparoscopic cases, *RBT* robotic cases, *LAP* laparotomy

Table 4
Cost modeling based on surgical approach distribution at our institution in 2006
compared to 2012

	2006	2012	2012–2006
Surgical approach			
Laparotomy	93 %	22 %	–76 %
Laparoscopy	7%	9%	+29 %
Robotic	0%	69 %	+100 %
Amortized costs			
Immediate perioperative	17,097	14,083	–3014
Includes 30 days' postoperative	19,581	15,322	–4259
Includes 6 months' postoperative	30,603	21,851	–8752
Nonamortized costs			
Immediate perioperative	17,097	13,930	–3167
Includes 30 days' postoperative	19,581	15,086	–4885
Includes 6 months' Postoperative	30,603	21,615	–8988

Data are mean \$ per morbidly obese patient undergoing surgery for uterine cancer that year