Outcomes and Cost Comparisons After Introducing a Robotics Program for Endometrial Cancer Surgery

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OBJECTIVE: To evaluate the effect of introducing a robotic program on cost and patient outcome.

METHODS: This was a prospective evaluation of clinical outcome and cost after introducing a robotics program for the treatment of endometrial cancer and a retrospective comparison to the entire historical cohort.

RESULTS: Consecutive patients with endometrial cancer who underwent robotic surgery (n=143) were compared with all consecutive patients who underwent surgery (n=160) before robotics. The rate of minimally invasive surgery increased from 17% performed by laparoscopy to 98% performed by robotics in 2 years. The patient characteristics were comparable in both eras, except for a higher body mass index in the robotics era (median 29.8 compared with 27.6; $P<.005$). Patients undergoing robotics had longer operating times (233 compared with 206 minutes), but fewer adverse events (13% compared with 42%; $P<.001$), lower estimated median blood loss (50 compared with 200 mL; $P<.001$), and shorter median hospital stay (1 compared with 5 days; $P<.001$). The overall hospital costs were significantly lower for robotics compared with the historical group (Can$7,644 compared with Can$10,368 [Canadian dollars]; $P<.001$) even when acquisition and maintenance cost were included (Can$8,370 compared with Can$10,368; $P=.001$). Within 2 years after surgery, the short-term recurrence rate appeared lower in the robotics group compared with the historic cohort (11 recurrences compared with 19 recurrences; $P<.001$).

CONCLUSION: Introduction of robotics for endometrial cancer surgery increased the proportion of patients benefitting from minimally invasive surgery, improved short-term outcomes, and resulted in lower hospital costs.

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The past 30 years have seen a significant change in the surgical treatment of women with cancer.[1,2] A recent large randomized trial for endometrial cancer showed a decrease of 33% in serious complications, a 50% reduction in hospital stay, and an improved quality of life when laparoscopy was compared with laparotomy.[3] Despite these compelling findings, only a minority of cancer patients benefit from the laparoscopic technique.[4–6] The U.S. Food and Drug Administration approved the da Vinci Surgical System as the only computer-assisted (robotics) system for use in gynecologic procedures in 2005. It confers advantages of increased dexterity with the operating instruments, three-dimensional immersion views, and improved ergonomics.[7,8]

The main barriers to the acquisition of this technology include the cost and the lack of research evidence showing improved outcomes that could influence health care administrators and policymakers. The objectives of this study are to describe the effect of introducing a robotic surgical system and to evaluate its cost-effectiveness and clinical effectiveness.

MATERIALS AND METHODS

All consecutive women undergoing surgery for endometrial cancer since the initiation of the division of gynecologic oncology in a tertiary cancer center in March 2003 were included in this study. Two cohorts were included as follows: 1) all women who underwent either laparotomy or laparoscopy for the surgical treatment of endometrial cancer from March 2003 until December 2007, just before the introduction of robotic surgery at the hospital, and 2) all women who had robotic-assisted surgery for treatment of their endometrial cancer from the beginning of the robotics program in gynecologic oncology in December 2007 until March 2010. The latter patients were universally informed about the evaluation of this new surgical technology and all signed the regular hospital informed consent for surgery that described the robotic approach; in addition, patients signed a second independent informed consent form for the prospective evaluation of the robotic program. The hospital institutional review board approved the study protocol and the informed consent to evaluate the outcomes of robotic surgery. Surgical training for robotics is described in Appendix 1. All women found suitable to undergo surgery for the treatment of their endometrial cancer were offered robotic surgery regardless of body habitus or previous medical or surgical history. Both cohorts represent unselected consecutive women with endometrial cancer. Primary end points were to evaluate the clinical effectiveness and cost-effectiveness of introducing a robotics program for the treatment of endometrial cancer.

Study variables and their categories were designed objectively and not as open-ended explorations of chart data. All robotic surgeries were recorded in their entirety on DVD for skills evaluation and teaching purposes. Information was collected prospectively and a database was created for the purpose of documenting and evaluating the experience with this new minimally invasive technique. Data collection for the prerobotic era was based on data retrieval using patient charts maintained with the same level of clinical detail. Charts are electronic and rigorously maintained and intraoperative and postoperative complications are always documented. The clinical research staff was extensively trained to ensure that the data collection was performed systematically and uniformly, regardless of study era.

We used *t* tests and Wilcoxon rank-sum test to compare means and medians for interval-scaled variables and χ^2 or Fisher exact tests for categorical or ordinal variables. Postoperative complications, hospital stay, and overall hospital costs were used as outcome variables in logistic regression models. Hospital stay and overall hospital costs were dichotomized above and below the median (Can$7,224 [Canadian dollars]) based on their distributions in the control cohort (laparotomy and laparoscopy).

Covariates adjusted for in each of the six models (shown in parentheses) were selected empirically based on a 5% change in estimate for the odds ratio of the specified outcome given the choice of robotic compared with historic cohort. Original cohorts were complications (age, blood loss, body mass index [BMI, calculated as weight (kg)/[height (m)]^2], pelvic or periaortic lymphadenectomy, uterine volume), hospital stay (age, blood loss, American Society of Anesthesiologists [ASA] score, BMI, preoperative gastrointestinal disease, preoperative cardiovascular disease, histologic grade, periaortic lymphadenectomy, uterine volume), and cost (age, ASA score, blood loss, BMI, periaortic lymphadenectomy, histologic grade, surgical stage, uterine volume). Restricted cohorts were complications (age, ASA score, number of preoperative comorbidities, blood loss, BMI, smoking, histologic grade, periaortic lymphadenectomy, uterine volume), hospital stay (age, ASA score, blood loss, BMI, preoperative cardiovascular disease, preoperative gastrointestinal disease, histologic grade, periaortic lymphadenectomy, uterine volume), and cost (age, number of preoperative comorbidities, blood loss, BMI, periaortic lymphadenectomy, uterine volume).

RESULTS

Between December 2007 and March 2010, 143 consecutive women had robotic-assisted total hysterectomy and staging for endometrial cancer. Our purpose was to compare these patients to the historical cohort of 160 consecutive women who were surgically treated and staged for their endometrial cancer in the years 2003 to 2007, before the real-life initiation of the robotics program, and underwent either laparotomy (n=133) or laparoscopy (n=27), without further comparing between these techniques. Staging procedures were similar between both periods (Appendix 2). The preoperative patient characteristics of the two cohorts were similar (Table 1). The mean and median BMI were higher in the robotics cohort

Table 1. Preoperative Patient Characteristics in Both Cohorts

Category	Robotic Cohort (n=143)	Historic Cohort (n=160)	χ^2 *P*
Age (y)			
Younger than 56	26 (18.2)	32 (20.0)	
56–65	51 (35.7)	57 (35.6)	.905
66–75	30 (21.0)	36 (22.5)	
Older than 75	36 (25.2)	35 (21.9)	
Body mass index (kg/m^2)			
Normal (lower than 25)	31 (21.7)	46 (28.8)	
Overweight (25–29.9)	41 (28.7)	49 (30.6)	.174
Obese (30–39.9)	48 (33.6)	51 (31.9)	
Morbidly obese (40 or higher)	23 (16.0)	14 (8.8)	
American Society of Anaesthesia score			
Normal or mild (1 or 2)	107 (74.8)	127 (79.4)	.346
Severe (3 or higher)	36 (25.2)	33 (20.6)	
No. of pregnancies			
Nulliparous	26 (18.3)	27 (16.9)	
1–2	60 (42.2)	66 (41.3)	.640
3–4	38 (26.8)	52 (32.5)	
5 or more	18 (12.7)	15 (3.4)	
No. of deliveries			
None	36 (25.3)	35 (21.9)	
1–2	64 (45.1)	84 (52.5)	.518
3–4	39 (27.5)	36 (22.5)	
5 or more	3 (2.1)	5 (3.1)	
No. of medications			
None	17 (11.9)	29 (18.1)	
1–2	37 (25.9)	43 (26.9)	.377
3–4	42 (29.3)	46 (28.8)	
5 or more	47 (32.9)	42 (26.3)	
No. of comorbidities			
None	11 (7.7)	17 (10.6)	
1	17 (11.9)	23 (14.4)	.483
2	17 (11.9)	24 (15.0)	
3 or more	98 (68.5)	96 (60.0)	
Comorbidity*			
Hypertension	88 (61.5)	86 (53.8)	
Diabetes	31 (21.7)	35 (21.9)	.638
Cardiovascular	26 (18.2)	22 (13.8)	
Cerebrovascular	6 (4.2)	6 (3.8)	
Pulmonary disease	30 (21.0)	34 (21.3)	
Gastrointestinal	21 (14.1)	34 (21.3)	
Second malignancy	24 (16.8)	19 (11.9)	
No. of abdominal or pelvic surgeries			
None	67 (46.8)	84 (52.5)	
1	47 (32.9)	39 (24.4)	.415
2	19 (13.3)	26 (16.3)	
3 or more	10 (7.0)	11 (6.9)	

Data are n (%) unless otherwise specified.
* Totals do not add up because of multiple comorbidities.

compared with the historical cohort (mean 31.5 compared with 28.8; median 29.8 compared with 27.6, respectively; both *P*<.005). Tumor characteristics did not differ significantly between the two cohorts (Table 2). The rate of completion of a pelvic lymphadenectomy was higher in the robotics group (Table 2), whereas the number of lymph nodes retrieved was similar in both groups, and no differences were seen in the rate of periaortic lymph node dissections between the two groups (Table 2).

The overall incidence of complications of moderate severity or more was significantly lower in the robotics group compared with the historical cohort (13% compared with 42%; *P*<.001), and intraoperative complications were similarly low in both cohorts (Table 3). The most common adverse event was superficial wound separation or infection, which occurred in 15.6% of the historical cohort and in 3.5% of the robotic cohort (*P*<.001). Cardiovascular morbidity, including exacerbation of heart failure (five cases postlaparotomy, one patient died), infarction (three cases postlaparotomy), and atrial fibrillation (two

Table 2. Stage, Grade, and Histologic Parameters of Patients in Both Cohorts

Category	Robotic Cohort	Historic Cohort	χ^2 *P*
Entire study	143 (100)	160 (100)	
Tumor stage			
I	112 (78.3)	113 (70.6)	
II	9 (6.3)	10 (6.3)	.364
III	19 (13.3)	30 (18.8)	
IV	3 (2.1)	7 (4.3)	
Grade			
1	63 (44.0)	55 (34.4)	
2	36 (25.2)	59 (36.9)	.070
3	44 (30.8)	46 (28.7)	
Grade			
Low or medium (grade 1 or grade 2)	99 (69.2)	114 (71.3)	
High (grade 3)	44 (30.8)	46 (28.8)	.701
Histology			
Endometrioid	111 (77.6)	121 (75.6)	
Clear cell	6 (4.2)	8 (5.0)	.482
Serous	13 (9.1)	13 (8.1)	
Mucinous	4 (2.8)	1 (0.6)	
Adenosquamous	5 (3.5)	7 (4.4)	
Carcinosarcoma	4 (2.8)	10 (6.3)	
Pelvic lymphadenectomy			
Not performed	0 (0.0)	2 (1.3)	
Sampling	1 (0.7)	10 (6.3)	.014
Dissection	142 (99.3)	148 (92.5)	
Periaortic lymphadenectomy			
Restricted to preoperative grade 3	n=37	n=45	
Not performed	15 (40.5)	15 (33.3)	
Performed	22 (59.5)	30 (66.7)	.599

Data are n (%) unless otherwise specified.
For uniformity, we used the 2009 surgical International Federation of Gynecology and Obstetrics classification for disease staging.[9]

Table 3. Perioperative Complications (Grade 2 or Higher) in Both Cohorts

Category	Robotic Cohort	Historic Cohort	χ^2 *P*
Entire study	143 (100)	160 (100)	
Any complications			
No	124 (86.7)	93 (58.1)	
Yes	19 (13.3)	67 (41.9)	<.001
Intraoperative complications			
Bowel injury			
No	141 (98.6)	159 (99.4)	
Yes	2 (1.4)	1 (0.6)	.497
Vessel injury			
No	142 (99.3)	156 (98.1)	.367
Yes	1 (0.7)	3 (1.9)	
Nerve injury			
No	142 (99.3)	159 (99.4)	.936
Yes	1 (0.7)	1 (0.6)	
Postoperative complications			
Wound			
No	138 (96.5)	135 (84.4)	<.001
Yes	5 (3.5)	25 (15.6)	
Infection			
No	139 (97.2)	154 (96.3)	
Yes	4 (2.8)	6 (3.8)	.643
Cardiovascular morbidity			
No	142 (99.3)	150 (93.8)	
Yes	1 (0.7)	10 (6.3)	.010
Need for transfusion			
No	141 (98.6)	150 (93.8)	
Yes	2 (1.4)	10 (6.3)	.318
Thromboembolic morbidity			
No	141 (98.6)	155 (96.9)	
Yes	2 (1.4)	5 (3.1)	.318
Urinary tract infection			
No	139 (97.2)	153 (95.6)	
Yes	4 (2.8)	7 (4.4)	.464
Complicated hypertension			
No	142 (99.3)	160 (100)	.472*
Yes	1 (0.7)	0 (0.0)	
Complicated diabetes			
No	142 (99.3)	159 (99.4)	
Yes	1 (0.7)	1 (0.64)	.936
Ileus			
No	138 (96.5)	150 (93.8)	.270
Yes	5 (3.5)	10 (6.3)	
Pulmonary complications			
No	142 (99.3)	158 (98.8)	.629
Yes	1 (0.7)	2 (1.3)	
Gastrointestinal complications			
No	143 (100.0)	152 (95.0)	.007
Yes	0 (0.0)	8 (5.0)	
Other			
No	141 (98.6)	145 (90.6)	.007
Yes	2 (1.4)	15 (9.4)	
Need for reoperation			
No	140 (97.9)	155 (96.9)	.578
Yes	3 (2.1)	5 (3.13)	
Rehospitalization			
No	137 (95.8)	150 (93.8)	.425
Yes	6 (4.2)	10 (6.3)	

Data are n (%) unless otherwise specified.
The perioperative complications were classified according to the National Cancer Institute Common Toxicity Criteria.[10] Cystotomy and fever were not classified as grade 2 complications.
* Fisher exact test was used instead of χ^2.

cases postlaparotomy and one case postrobotic), were more frequent in the historical cohort (6.3% compared with 0.7%; *P*=.01). Gastrointestinal complications were only seen in the historical group (*P*=.007).

The median operative time was significantly lower in the historical cohort (207 minutes) compared with robotics (241 minutes; Table 4). The median blood loss was significantly higher in the historical group (266 mL) than in the robotics cohort (73 mL). Only two patients (1.4%) underwent transfusion in the robotics group as compared with 10 (6.3%) in the historical group. Uterine weight, which is often higher in laparotomy cohorts, was higher in the robotics cohort (Table 4; *P*=.003). The mean hospital stay was substantially shorter in the robotics group compared with the historical group (2.2 days compared with 5.5 days; *P*<.001). The combination of reduced hospital stay and fewer complications in the robotics group contributed to an overall lower cost for the procedure. Excluding the amortization cost, the mean cost in Canadian dollars to treat a patient with endometrial cancer with robotic surgery was Can$7,644 compared with Can$10,368 treated in the historical cohort (*P*<.001; Table 5). When the average perioperative cost was calculated including the acquisition and yearly maintenance cost for workloads of 10 cases per week,

Table 4. Interval-Scaled Perioperative Parameters in Both Cohorts

Continuous Variables	Robotic Cohort (n=143)	Historic Cohort (n=160)	*P**
Operation time (skin to skin, min)			
Mean, median	241, 233	207, 206	<.001
IQR (P25-P75)†	(205–272)	(158.5–243.5)	
Estimated blood loss (mL)‡			
Mean, median	73, 50	266, 200	
IQR (P25-P75)	(20–100)	(100–300)	<.001
No. of lymph nodes			
Mean, median	11.3, 11	11.5, 11	.659
IQR (P25-P75)	(8–14)	(7–15)	
Uterus weight (g)			
Mean, median	158, 122	137, 104	.003
IQR (P25-P75)	(90–203)	(73.1–154)	
Hospital stay (d)			
Mean, median	2.2, 1	5.5, 5	<.001
IQR (P25-P75)	(1–2)	(4–6)	

IQR, interquartile range; P, percentile.
* Two-sample Wilcoxon rank-sum (Mann-Whitney) test.
† IQR actual range is shown between 25^{th} and 75^{th} percentiles.
‡ The estimated blood loss was a total of the amount in the suction bottle subtracting irrigation fluids combined with the estimation of blood in the surgical sponges.

Table 5. Average Costs of Robotic Staging Compared With Staging Before Robotics

Cost-Related Characteristics	Robotic Cohort (n=143)	Historic Cohort (n=160)	*P**
Hospital accommodation	2,658 (1,814–3,503)	6,623 (5,880–7,367)	<.001
Surgeon costs	822 (822–822)	693 (685–702)	<.001
Anesthetist costs†	551 (342–1,054)	621 (385–1,154)	<.001
Theater costs			
Operating room use and supplies	2,977 (2,977–2,977)	237 (203–271)	<.001
Nursing	184 (177–190)	173 (166–180)	.038
Anaesthesia	175 (169–181)	158 (143–172)	.038
Pharmacy costs	67 (22–150)	88 (34–142)	<.001
Radiology costs	32 (4–69)	51 (24–78)	.040
Laboratory costs	76 (54–98)	139 (103–175)	<.001
Overall cost			
Without amortization	7,644 (6,364–8,925)	10,368 (8,236–12,500)	<.001
With amortization‡	8,370 (7,090–9,651)	10,368 (8,236–12,500)	.002

Data are mean Canadian $ (95% confidence interval) unless otherwise specified.
The hospital business office performed the financial analysis and abstracted the direct and indirect costs (standardized in 2010 Canadian dollars) associated with each of the surgical modalities.
The costs included surgery supplies (including trocars and disposables), central supplies (those outside the operating room), surgery procedure (time-based and physician cost), radiology, pharmacy, laboratory, anaesthesia (including the physician cost), and room and board.
* Mann-Whitney *U* test was used according to the distributional patterns based on histograms.
† Anesthetist cost and acute pain management costs.
‡ The amortization cost of the da Vinci Surgical System was calculated on the basis of the sum of the cost of the robotic system and the service cost of 10% per year for 10 years divided the total number of cases expected to be performed during that period (5,200 patients, ie, Can$726 per patient) based on the current case load of two cases per day.[10]

the average cost for robotic surgery remained significantly lower at Can$8,370 (*P*=.002; Appendix 4).

The gains with robotic surgery are even more pronounced in the multivariable analysis when we consider both the entire cohorts and the restricted (matched) subcohorts (Table 6). Compared with the conventional procedures, the odds of any complication grade two or higher significantly decreased by threefold to fourfold in the robotics era when adjusted for all empirical confounders. Likewise, a nearly 20-fold decline in hospital stay was observed in the robotics cohort. As a result, overall cost was also reduced fourfold during the robotics period. The analyses on the restricted subcohorts with age-

Table 6. Risk of Postoperative Complications, Extended Hospital Stays, and Excessive Overall Costs Associated With Robotic Surgery Relative to the Historic Cohort for the Treatment and Staging of Endometrial Cancer

	Entire Cohort		Restricted Cohorts† (Matched on Age and BMI)	
Outcome*	n Without and With Outcome	Adjusted OR (95% CI)	n Without and With Outcome	Adjusted OR (95% CI)
Complications				
Historic cohort	93, 67	1.0 (referent)	67, 54	1.0 (referent)
Robotics	124, 19	0.27 (0.14–0.51)	106, 15	0.22 (0.10–0.50)
Length of hospital stay				
Historic cohort	74, 86	1.0 (referent)	55, 66	1.0 (referent)
Robotics	133, 10	0.06 (0.03–0.16)	115, 6	0.02 (0.01–0.09)
Overall cost				
Historic cohort	80, 80	1.0 (referent)	60, 61	1.0 (referent)
Robotics	117, 26	0.26 (0.13–0.53)	103, 18	0.21 (0.09–0.47)

BMI, body mass index; OR, odds ratio; CI, confidence interval.
In the interest of conservatism in controlling for confounding, we also conducted matched analyses using frequency-restricted subcohorts of patients selected randomly from combined strata based on age and BMI (see Appendix 3), two variables that typically help predict the degree of surgical difficulty and rate of complications.
* Outcomes defined as follows: complications, grade 2 or higher; hospital stay, 5 days or longer; cost, equal or higher than median.
† Restricted cohorts obtained by randomly sampling equal numbers of patients from combined strata based on age and BMI (see Appendix 3).

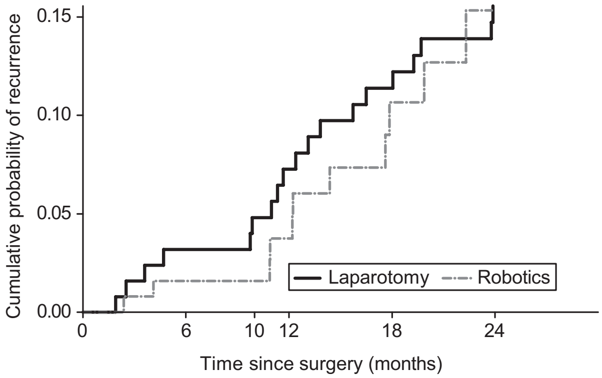

Fig. 1. Cumulative rates of endometrial cancer recurrence within 2 years of surgery, stratified by cohort (y-axis shows the cumulative probability of recurrence). There were 19 recurrent cases in the historic cohort (*solid line*) and 11 recurrences in the robotics cohort (*dotted line*) within 2 years of surgery. Both log-rank and Gehan-Wilcoxon tests show a significantly lower recurrence rate when surgery was performed by robotics ($P<.001$).

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matched and BMI-matched characteristics showed even more pronounced reductions in complications, hospital stay, and cost.

A key factor in evaluating any cancer treatment procedure is oncologic outcome. At present, the length of follow-up of 2 years after robotic surgery indicates a lower recurrence rate compared with the historical cohort (Fig. 1; Wilcoxon $P<.001$; log-rank $P<.001$).

DISCUSSION

In this study, we are not comparing robotics to either laparotomy or laparoscopy, but rather we are evaluating the clinical and economic implications of introducing a robotics program in a tertiary care institution. Similar to others,[7,8,11] we have seen an increase in minimal invasive surgery rates from 17% performed by laparoscopy to 98% by robotics. In the LAP2 study comparing laparoscopy to laparotomy, the conversion rate from laparoscopy to laparotomy was 25.8%,[3] contrasting with 4.2% in the present study, in which all were performed at the completion of the robotic surgery through a Pfannenstiel incision solely to remove enlarged uteri that were not deliverable intact through the vagina. In August 2009, we adapted our technique and since then, no "conversions" were necessary.[12] Other institutions also cite low rates of conversion from robotics to laparotomy, ranging from 2.9% to 4.0%.[8,11,13]

We designed our study conservatively to ensure that any differences in outcomes between eras would be ascribed primarily to the treatment intervention. Several study design characteristics add to this conservatism. The spans of both eras (prerobotic and postrobotic) captured in the study covered a modern period in terms of patient accrual and information management in our McGill teaching hospital. There were no variations in catchment area during the study period. The variations we observed between eras were mostly in the direction of a conservative bias, ie, more "difficult to treat" patients in the robotic era. As a result of the improved perception of security and confidence to treat more complex cases with the robot, characteristics such as age, BMI, ASA level, and previous surgeries were not determinants for patient selection for minimal invasive surgery procedures.

Both the lower complication rate[13–15] and shorter hospitalization, mainly in the elderly and obese populations, translated into a significant decline in the cost of the surgical intervention per patient, even after accounting for the acquisition and yearly maintenance costs of the robot. Nevertheless, the economic advantage presented in this article may underestimate the actual value because only direct and indirect hospital costs were included, without calculating the overall gains to the patient and society related to quicker recovery and return to normal activities.

A limitation of this study relates to the retrospective nature of the data collection for the historical cohort. However, the study variables and their categories were designed objectively and not as open-ended explorations of chart data to minimize any possible biases in data retrieval. The fact that we collected data in the postrobotic era prospectively only indicates the direction of the study inquiry in terms of time and in no way suggests that the level of detail in data collection varied between phases. Furthermore, all endometrial cancer patients treated before the robotics program were included for completeness.

The strengths of this study include the analysis of real-life conditions in a university-based gynecologic oncology division with unselected laparotomy and laparoscopy patients in the historical cohort. In addition, the results remained robust whether we included the laparoscopy cases. For the main comparisons between surgical eras, we conducted analyses that adjusted conservatively for all empirical confounders and repeated these analyses in subcohorts selected randomly from joint strata based on frequency-matched age and BMI. These epidemiologic analyses yielded unbiased estimates for the primary outcomes, thus lending credibility to our results.

Clearly, introduction of robotics for endometrial cancer surgery in our tertiary Canadian center has increased the proportion of patients benefitting from minimally invasive surgery, has improved short-term outcomes without oncologic compromise, and has resulted in lower hospital costs.

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Appendix 1. Surgical Training

Physician	Training
Attendings	Fellowship-trained gynecologic oncologists with experience in advanced laparoscopy Three sessions of simulator training A 2-d certified clinical observership and hands-on animal laboratory course 2 d of proctoring during the first robotic surgeries
Fellows and residents*	2 sessions on simulator training Perform gradually more steps in the procedure starting by suturing vaginal cuff

* Two fellows became fully trained and proficient in robotic surgery for gynecologic oncology indications.

Appendix 2. Surgical Procedure

Histologic Type	Procedure
All endometrial cancers	Peritoneal washings Total hysterectomy Bilateral salpingo-oophorectomy Systematic complete bilateral pelvic lymphadenectomy
Grade 3 Clear cell cancers Papillary serous cancers	Additional: para-aortic lymphadenectomy from the common iliac artery up to the level of the gonadal vessels near the duodenum on the right, and at least to the inferior mesenteric artery on the left
Papillary serous cancers	Additional: infracolic omentectomy

Appendix 3. Original Cohort and Frequency-Matched Restricted Subcohorts Based on Random Selection Within Combinations of Age and Body Mass Index

Strata		Original Cohorts		Restricted Cohorts*	
Age (y)	Body Mass Index (kg/m^2)	Robotic (n=143)	Historic (n=160)	Robotics (n=121)	Historic (n=121)
Younger than 65	Normal (lower than 25)	17	28	17	17
Younger than 65	Overweight (25–29.9)	22	35	22	22
Younger than 65	Obese (30–39.9)	29	35	29	29
Younger than 65	Morbidly obese (40 or higher)	21	7	7	7
65 or older	Normal (lower than 25)	14	18	14	14
65 or older	Overweight (25–29.9)	19	14	14	14
65 or older	Obese (30–39.9)	19	16	16	16
65 or older	Morbidly obese (40 or higher)	2	7	2	2

* Based on randomly selecting participants from the larger of the two sets in each stratum formed by a combination of two age groups and four body mass index categories. The chosen age cut-point was the one yielding the highest Youden J index (sensitivity plus specificity −1) in a receiver-operating characteristics plot of sensitivity and false-positive rate for postoperative complications as outcome in the historic group.

Appendix 4. Cost of Robotics

Item	Can$
Acquisition of da Vinci (2007)	$2,200,000
Maintenance cost for 10 y	$1,550,000
2-d training per surgeon	$6,000
2-d proctorship	$4,000
Biomedical and nursing staff training	$15,000
Disposables for robotics per surgery	$2,015

Can$, Canadian dollars.