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All-Cause Cost Differences Between Robotic, Vaginal, and Abdominal Hysterectomy

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Abstract

Objective—To compare the all-cause costs of vaginal and abdominal hysterectomy with robotically assisted hysterectomy.

Methods—We identified all cases of robotically assisted hysterectomy, with or without bilateral salpingo-oophorectomy, treated at Mayo Clinic (Rochester, Minnesota) from January 1, 2007, through December 31, 2009. Cases were propensity score–matched (1:1) to cases of vaginal and abdominal hysterectomy, selected randomly from the 3 preceding years (before acquisition of the robotic surgical system). All-cause costs were abstracted through the sixth postoperative week from the Olmsted County Healthcare Expenditure and Utilization Database and compared between cohorts with a generalized linear modeling framework. Predicted costs were estimated with the recycled predictions method. Costs of operative complications also were compared.

Results—Predicted mean cost of robotically assisted hysterectomy was $2,253 more than that of vaginal hysterectomy ($13,619 vs $11,366; *P*<.001), although costs of complications were not significantly different. The predicted mean costs of robotically assisted vs abdominal hysterectomy were similar ($14,679 vs $15,588; *P*=.35), and the costs of complications were not significantly different.

Conclusions—Overall, vaginal hysterectomy was less costly than robotically assisted hysterectomy. Abdominal hysterectomy and robotically assisted hysterectomy had similar costs.

Keywords

abdominal hysterectomy; cost; da Vinci; hysterectomy; robotically assisted; vaginal hysterectomy

Introduction

In the current climate of increasing health care spending, many efforts aim to curb costs without compromising patient care. The Independent Payment Advisory Board, created

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under the Affordable Care Act in 2010, is one such effort; its sole purpose is to reduce costs through modification of Medicare reimbursement rates on the basis of clinical efficacy (1). In gynecology, the cost of various routes of hysterectomy will likely come under scrutiny because nearly 600,000 hysterectomies are performed annually in the United States (2).

Approaches to hysterectomy include abdominal, vaginal, laparoscopic, and, more recently, robotic. As a primary route of hysterectomy, vaginal hysterectomy is the method recommended by the American Congress of Obstetricians and Gynecologists (ACOG) (3,4) and has been shown to be less costly than either abdominal or traditional laparoscopic approaches (5–7). Advantages of the robotic approach have led practitioners to incorporate it into their practice, although several studies have shown that the robotic technique may be more expensive than traditional laparoscopy and laparotomy (8–12).

Intuitively, vaginal hysterectomy should be less expensive than robotic hysterectomy. However, data on this topic are curiously lacking, with only one study directly comparing inpatient costs between the 2 methods (13). Because performance of robotically assisted hysterectomy is increasing in the setting of an evolving mandate to provide value-based health care, we aimed to evaluate the cost of robotic hysterectomy and compare it with abdominal and vaginal routes by using an all-cause cost model.

Materials and Methods

This study was approved by the Mayo Clinic Institutional Review Board.

Patient Identification

We identified all robotically assisted hysterectomy cases, with or without bilateral salpingo-oophorectomy, that were performed at Mayo Clinic (Rochester, Minnesota) from January 1, 2007, through December 31, 2009. We used Surgical Operative Note Explorer software (Mayo Clinic), which searches all text in the operative note, regardless of adjacent letters or spaces, to identify those with the selected terms *robotic* and *da Vinci*. The identified operative notes were then manually reviewed to confirm robotic hysterectomy. We included any indication for hysterectomy, but cases of radical hysterectomy, hysterectomy with lymphadenectomy or cancer staging, and hysterectomy with any concomitant nongynecologic surgery other than appendectomy were excluded from the study. The resultant cohort of patients was then cross-referenced with a list generated by the institutional surgical information recording system to ensure accuracy and capture of all robotic hysterectomies.

For the comparison groups, the surgical information recording system was searched for cases of abdominal or vaginal hysterectomy, with or without bilateral salpingo-oophorectomy. To minimize selection bias, only the 3 years immediately preceding acquisition of the da Vinci surgical system (2004–2006) were searched. A random sample of abdominal and vaginal hysterectomies was then generated from the identified cases. We followed the same exclusion criteria as for robotic cases but also excluded cases of vaginal hysterectomy with concurrent pelvic floor reconstructive surgery because this is a known risk factor for perioperative morbidity (14).

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Data on all surgical cases were then recorded using a standardized data collection form and abstracted from the medical record. Data collected included basic demographic information, body mass index, comorbid conditions, uterine weight, operative time, and intraoperative and postoperative complications until time of discharge. Binary indicators for comorbidities in major therapeutic areas were also abstracted.

Patients undergoing robotic hysterectomy were matched to patients undergoing abdominal or vaginal hysterectomy. Matches were established separately through 1-to-1 propensity score matching to ensure comparable baseline characteristics between robotic and abdominal hysterectomy patients and between robotic and vaginal hysterectomy patients. Propensity score is defined as "the conditional probability of being treated given the covariates" (15). Each robotic case was matched to a vaginal and abdominal hysterectomy case with a similar propensity score, which ensured that the observed covariates were similar among the cohorts. Because each group was matched by propensity score, the robotic cohorts were slightly different for each comparison group. Comparison of continuous covariates between the study cohorts was based on the *t* test, whereas categorical variables were compared using the χ^2 test.

Cost Data

All-cause costs were captured from the Olmsted County Healthcare Expenditure and Utilization Database (OCHEUD) (16–18). Using claims data, OCHEUD collects information on resource utilization and the corresponding charges, which is standardized with inflation adjustment using 2009 constant dollars, and also accounts for geographic wage differences. OCHEUD uses a "bottom-up" approach in which health care resource utilization is grouped into a Medicare Part A and Part B classification system. Part A items such as room and board, radiology, physical therapy, and supplies provided to hospital patients are valued by multiplying the billed charge for each item by the cost-center-specific Medicare cost-to-charge ratio for the year in which the service was delivered.

Medicare Part B reimbursement rates are applied to health care services that are covered under Medicare Part B, including physician-billed services (eg, consultation, diagnostic, and therapeutic procedures) and other services such as laboratory, radiology, etc (18). OCHEUD has cost data for medications provided during hospitalization, but medications dispensed to outpatients are not available in OCHEUD and the associated costs thus cannot be valued. Although the information on health care service utilization reflects the practice patterns at Mayo Clinic, the value of each unit of service has been adjusted to national norms by using widely accepted valuation techniques (19).

All-cause cost from the day of index admission through the end of the sixth week was extracted for the study patients. Cost data were analyzed both descriptively and after multivariable adjustment. For the matched data, mean (SD) and median costs were provided for robotic vs abdominal hysterectomy and for robotic vs vaginal hysterectomy.

Multivariable adjustment of costs in the matched samples was conducted using a generalized linear modeling (GLM) framework (20). The GLM methodology adjusted for predictors that significantly differed between groups, even after propensity-score matching. Furthermore, it

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also included factors that were considered determinants of cost, including operative time, uterine weight, and binary indicators of intraoperative and postoperative complications. Intraoperative complications included incidental cystotomy, intraoperative transfusion, bowel injury, ureteral injury, vascular injury, and conversion to laparotomy in the robotic cases.

Occurrence of complications such as pulmonary edema, pulmonary embolism, and sepsis was captured with a binary indicator variable. Predicted costs for robotic and abdominal or vaginal procedures and the difference in predicted costs between groups were estimated using the recycled predictions method based on 200 bootstrap replications (21). We also assessed the average marginal effects of intraoperative and postoperative complications, which provided the estimated difference in total costs between those with and without complications (assuming all other patient characteristics remained the same).

Results

Table 1 describes propensity score–matched baseline characteristics between robotic vs abdominal hysterectomy and robotic vs vaginal hysterectomy. Overall, baseline characteristics such as age, race, insurance status, body mass index, gravidity, live births, vaginal deliveries, and prior abdominal surgery were similar between abdominal and robotic hysterectomy cohorts. A higher proportion of patients with an endocrine comorbidity was noted in the abdominal group. The distribution of surgical indications was also significantly different between these groups (Table 1). No difference was seen between groups for the indications of pain or fibroids.

Baseline characteristics between robotic and vaginal approaches showed several significant differences, although comorbidities were similar. Age at surgery was higher in the robotic group. Distribution of race was different, with a significantly higher proportion of nonwhite patients and a significantly lower proportion of patients of unknown race in the robotic group. Insurance status also differed between robotic and vaginal surgery groups, with significantly fewer commercially insured patients and significantly more Medicare patients in the robotic cohort. Patients undergoing vaginal hysterectomy had an overall higher gravidity, number of live births, and number of vaginal deliveries than patients in the robotic group. Differences in indications were also noted, with a higher proportion of patients undergoing vaginal hysterectomy for abnormal uterine bleeding and a higher proportion of patients undergoing robotic hysterectomy for gynecologic cancer. Indications such as hyperplasia, pain, fibroids, adnexal mass, and others were similar between the 2 groups (Table 1).

Table 2 shows intraoperative and postoperative characteristics, including complications, for robotic vs abdominal and robotic vs vaginal hysterectomy. When comparing the robotic vs abdominal hysterectomy groups, intraoperative complications were significantly more frequent in abdominal hysterectomy, although the occurrence of postoperative complications and uterine weight did not differ between groups. Length of hospitalization was shorter (1.6 vs 3.4 days; $P<.001$) and operative time was longer (3.0 vs 1.8 hours; $P<.001$) for the robotic group compared with the abdominal hysterectomy group.

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When comparing the robotic vs vaginal hysterectomy cohorts, the robotic group had a higher rate of postoperative complications, a longer operative time, and an overall larger uterine weight. Length of hospitalization, however, was significantly shorter for the robotic hysterectomy group.

Costs incurred in the first 6 weeks after the index surgery were not significantly different between the abdominal and robotic groups (Table 3). In addition, costs were not significantly different between robotic and abdominal groups for the subsets of patients with no complications, with either an intraoperative or postoperative complication, or with both intraoperative and postoperative complications, as indicated by the overlapping 95% CIs in Table 4. The additional incurred cost of both intraoperative and postoperative complications compared with no complication was $11,430 and $12,137 for the robotic and abdominal groups, respectively, suggesting that surgical complications contribute a considerable amount to the overall cost of the procedure.

The robotic group incurred an adjusted cost that on average was $2,253 higher per patient than that of the vaginal hysterectomy group (Table 3). A similar cost difference ($2,154) between robotic and vaginal patients persisted for the subset of patients with no complications (Table 4). However, costs were not significantly different between robotic and vaginal hysterectomy groups for patients with either an intraoperative or postoperative complication or with complications both intraoperatively and postoperatively (Table 4). The additional incurred cost of both intraoperative and postoperative complications compared with no complication was $6,016 and $5,020 for the robotic and vaginal groups, respectively.

Discussion

Our results reveal that robotic hysterectomy is more costly than vaginal hysterectomy but of similar cost to the abdominal approach. The cost difference between vaginal and robotic approaches persisted in patients who experienced no intraoperative or postoperative complications, but the difference was not significant in patients who had both complications. Patients undergoing vaginal hysterectomy had shorter operative times (1.2 vs 3.1 hours) and a lower postoperative complication rate (8.0% vs 17.9%) compared with patients who had a robotic procedure. Although the vaginal hysterectomy group had a longer hospital stay (1.9 vs 1.5 days), cost differences between groups appeared to be driven by decreased operative times and lower complication rates in the vaginal hysterectomy group.

The only other study comparing costs between robotic, abdominal, and vaginal approaches also included laparoscopic hysterectomy and examined 1,474 consecutive cases (13). Although cost differences were similar to our study, it included costs only from admission through discharge and did not consider costs due to complications or readmissions. Furthermore, nearly two-thirds of cases in that series were robotic; because they attempted to treat complex cases robotically, complexity may have accounted for most of the reported cost differences. Lastly, use of consecutive cases introduces sampling bias. Our approach to evaluation of cost mitigates these problems. We included all costs billed through 6 weeks after the procedure by using the OCHEUD, which captures every dollar spent on medical

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care (eg, initial surgery, hospitalization, inpatient medications, subsequent physician visits, interventions for complications, readmissions). This all-cause approach provides an umbrella cost estimate for the different approaches and allows an overall cost comparison using nationally standardized dollar amounts. Selection bias was also decreased, although not eliminated, in our study by using comparison cohorts from the years immediately preceding the introduction of the robotic surgery at our institution and through propensity-score matching.

In the 2 years preceding the introduction of robotic hysterectomy, 50.6% of the nearly 1,000 hysterectomies performed annually at our institution were vaginal. In 2011 and 2012, both the absolute number and the percentage of vaginal hysterectomy decreased to an average of 35.3%, suggesting that the robotic practice is decreasing performance of both abdominal and vaginal hysterectomy. Assuming a consistent rate (~1,000 hysterectomies annually), 153 fewer vaginal hysterectomies were performed (converted to robotically assisted hysterectomy) in 2012 compared with the years immediately preceding the introduction of robotic surgery, at an estimated annual expense of $344,709. If this trend is representative of the 600,000 hysterectomies performed annually in the United States, adoption of the robotic system represents an estimated increased cost of nearly $207 million per year.

Our study likely underestimates the cost differences between approaches. First, the analysis did not account for the initial purchase price of the robotic system, yearly maintenance costs, or decreased operating room use for robotic cases. Second, costs associated with the learning curve also were not considered; this may consist of up to 91 cases when using operative complications as the measure of proficiency (22). Third, the analysis was restricted to the use of Medicare-reimbursed amounts in the OCHEUD. If true billing costs were used, including those from private insurers, costs for all approaches may be considerably higher and cost differences may also vary. Moreover, we assigned an average expense cost for variable expenses in robotic surgery, but these have been shown to be a major source of cost (12), regardless of the specific amount used in a particular procedure.

Our group has recently shown (unpublished data) that a novel approach to the perioperative management of patients having vaginal reconstructive procedures resulted in a significantly shorter hospital stay and potentially decreased hospitalization cost. It is therefore plausible that the widespread implementation of this approach may further limit the length of hospital stay in patients having vaginal hysterectomy and amplify the cost difference observed.

The inclusion of costs in the postoperative period, although advantageous from an all-cause standpoint, may potentially capture additional costs not associated with the procedure itself because hospital costs and physician visits unrelated to the procedure may have been included. However, the cost of robotic procedure remained higher than that of vaginal surgery, even among patients without complications, suggesting that capture of unrelated costs likely did not have a major impact in our analysis. Furthermore, the OCHEUD captures the cost of pharmaceuticals provided in the inpatient setting only (ie, no outpatient pharmaceutical data). We were also unable to assess the cost of total laparoscopic hysterectomy compared with robotic hysterectomy because the laparoscopic approach is infrequently performed at our institution.

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Based on these data, we conclude that the vaginal approach is safer, faster, and more cost-effective than the robotic approach. Although robotic hysterectomy may have advantages in certain niches in gynecologic practice, the data presented here caution against the widespread use of this technology. Rather, the data reinforce the ACOG recommendation that the preferred route of hysterectomy be vaginal (3,4). Further analyses of the cost of robotic hysterectomy are needed and will likely have a role in future health care reimbursement policies in gynecologic practice.

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Abbreviations

ACOG	American Congress of Obstetrics and Gynecology
GLM	generalized linear modeling
OCHEUD	Olmsted County Healthcare Expenditure and Utilization Database

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Table 1

Matched Baseline Characteristics

	Robotic vs Abdominal			Robotic vs Vaginal		
Characteristic	**Robotic (n=234)**	**Abdominal (n=234)**	***P* Value**	**Robotic (n=212)**	**Vaginal (n=212)**	***P* Value**
Age at surgery, mean (SD), y	49.7 (12.1)	49.1 (12.1)	.54	49.0 (11.6)	46.7 (9.2)	.02
Race, No. (%)			.17			.004
White	211 (90.2)	201 (85.9)		186 (87.7)	187 (88.2)	
Nonwhite	10 (4.3)	9 (3.8)		16 (7.5)	4 (1.9)	
Unknown	13 (5.6)	24 (10.3)		10 (4.7)	21 (9.9)	
Insurance status, No. (%)			…			.04
Commercial	183 (78.2)	186 (79.5)		174 (82.1)	188 (88.7)	
Medicare	35 (15.0)	31 (13.2)		22 (10.4)	7 (3.3)	
Other government	14 (6.0)	16 (6.8)		13 (6.1)	14 (6.6)	
No insurance	2 (0.9)	1 (0.4)		2 (0.9)	2 (0.9)	
Body mass index, mean (SD), kg/m^2	30.4 (9.1)	29.4 (7.4)	.60	30.3 (8.8)	31.3 (22.7)	.39
Pregnancies, mean (SD), No.	2.0 (1.7)	2.2 (2.1)	.72	2.0 (1.7)	2.8 (1.5)	<.001
Live births, mean (SD), No.	1.6 (1.5)	1.7 (1.7)	.74	1.5 (1.4)	2.3 (1.2)	<.001
Vaginal deliveries, mean (SD), No.	1.1 (1.4)	1.3 (1.7)	.14	1.1 (1.5)	2.1 (1.2)	<.001
Abdominal surgical procedures, mean (SD), No.	1.5 (1.7)	1.4 (1.4)	.87	1.4 (1.7)	1.2 (1.3)	.55
Comorbid conditions						
Cardiovascular, No. (%)	78 (33.3)	77 (32.9)	.92	66 (31.1)	47 (22.2)	.11
Pulmonary, No. (%)	36 (15.4)	28 (12.0)	.28	34 (16.0)	26 (12.3)	.54
Gastrointestinal tract, No. (%)	50 (21.4)	41 (17.5)	.29	44 (20.8)	46 (21.7)	.97
Genitourinary tract, No. (%)	0 (0)	0 (0)	…	2 (0.9)	1 (0.5)	.85
Endocrine, No. (%)	68 (29.1)	48 (20.5)	.03	53 (25.0)	42 (19.8)	.44
Hematologic, No. (%)	47 (20.1)	32 (13.7)	.06	43 (20.3)	38 (17.9)	.83
Social, No. (%)	32 (13.7)	41 (17.5)	.25	34 (16.0)	34 (16.0)	>.99
Other, No. (%)	60 (25.6)	56 (23.9)	.67	56 (26.4)	46 (21.7)	.52
Indication						
Biopsy-proven hyperplasia, No. (%)	15 (6.4)	5 (2.1)	.02	12 (5.7)	10 (4.7)	.66
Abnormal uterine bleeding, No. (%)	49 (20.9)	27 (11.5)	.006	31 (14.6)	87 (41.0)	<.001

Characteristic	Robotic vs Abdominal			Robotic vs Vaginal		
	Robotic (n=234)	**Abdominal (n=234)**	***P* Value**	**Robotic (n=212)**	**Vaginal (n=212)**	***P* Value**
Gynecologic cancer, No. (%)	48 (20.5)	25 (10.7)	.003	38 (17.9)	15 (7.1)	.001
Pain, No. (%)	31 (13.2)	31 (13.2)	>.99	22 (10.4)	16 (7.5)	.31
Fibroids, No. (%)	74 (31.6)	70 (29.9)	.69	70 (33.0)	52 (24.5)	.05
Adnexal mass, No. (%)	14 (6.0)	53 (22.6)	<.001	12 (5.7)	13 (6.1)	.84
Other indication, No. (%)	29 (12.4)	24 (10.3)	.47	27 (12.7)	20 (9.4)	.28

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Table 2

Intraoperative and Postoperative Characteristics

	Robotic vs Abdominal			Robotic vs Vaginal		
Characteristic	**Robotic (n=234)**	**Abdominal (n=234)**	***P* Value**	**Robotic (n=212)**	**Vaginal (n=212)**	***P* Value**
Intraoperative complications, No. (%)	18 (7.7)	32 (13.7)	.04	17 (8.0)	10 (4.7)	.16
Postoperative complications, No. (%)	37 (15.8)	39 (16.7)	.80	38 (17.9)	17 (8.0)	.002
Uterine weight, mean (SD), g	259.2 (302.1)	325.4 (403.1)	.11	289.3 (347.9)	165.3 (151.8)	<.001
Length of hospitalization, mean (SD), d	1.6 (1.6)	3.4 (2.3)	<.001	1.5 (1.2)	1.9 (0.8)	<.001
Operative time, mean (SD), h	3.0 (1.1)	1.8 (0.8)	<.001	3.1 (1.2)	1.2 (0.7)	<.001

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Table 3

Unadjusted and Adjusted Costs for Different Hysterectomy Routes[a]

	Unadjusted Costs		Multivariable-Adjusted Cost	
	Mean Cost	**95% CI**	**Predicted Mean Cost**	**95% CI, Bootstrapped**
Robotic vs Abdominal				
Robotic (n=234)	$14,386	$13,718 to $15,055	$14,679	$14,321 to $16,854[b]
Abdominal (n=234)	$15,079	$13,698 to $16,461	$15,588	$13,489 to $15,870[b]
Difference	−$693	−$838 to $2,224	−$909	−$2,832 to $1,016
Robotic vs Vaginal				
Robotic (n=212)	$14,402	$13,645 to $15,159	$13,619	$12,628 to $14,610[b]
Vaginal (n=212)	$10,318	$9,811 to $10,826	$11,366	$10,668 to $12,063[b]
Difference	$4,084	$3,175 to $4,992[b]	$2,253	$972 to $3,535[b]

[a]Costs incurred in the first 6 weeks after the index surgery.

[b]P<.001

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Table 4

Average Marginal Effects of Intraoperative and 6-Week Postoperative Complications

Surgical Approach	Intraoperative Complication	Postoperative Complication	Predicted Cost	95% CI
Robotic vs Abdominal				
Robotic	No	No	$13,145	$12,427–$13,863
	No	Yes	$17,490	$15,199–$19,781
	Yes	No	$18,471	$15,317–$21,625
	Yes	Yes	$24,575	$20,411–$28,740
Abdominal	No	No	$13,959	$12,978–$14,939
	No	Yes	$18,572	$16,186–$20,957
	Yes	No	$19,614	$16,607–$22,620
	Yes	Yes	$26,096	$22,365–$29,827
Robotic vs Vaginal				
Robotic	No	No	$13,020	$12,285–$13,756
	No	Yes	$16,141	$14,160–$18,122
	Yes	No	$15,355	$12,617–$18,093
	Yes	Yes	$19,036	$15,486–$22,585
Vaginal	No	No	$10,866	$10,118–$11,613
	No	Yes	$13,470	$11,732–$15,209
	Yes	No	$12,814	$10,716–$14,913
	Yes	Yes	$15,886	$13,143–$18,629