

Cost Analysis When Open Surgeons Perform Minimally Invasive Hysterectomy

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ABSTRACT

Background and Objective: The costs to perform a hysterectomy are widely variable. Our objective was to determine hysterectomy costs by route and whether traditionally open surgeons lower costs when performing laparoscopy versus robotics.

Methods: Hysterectomy costs including subcategories were collected from 2011 to 2013. Costs were skewed, so 2 statistical transformations were performed. Costs were compared by surgeon classification (open, laparoscopic, or robotic) and surgery route.

Results: A total of 4,871 hysterectomies were performed: 34.2% open, 50.7% laparoscopic, and 15.1% robotic. Laparoscopic hysterectomy had the lowest total costs ($P < .001$). By cost subcategory, laparoscopic hysterectomy was lower than robotic hysterectomy in 6 and higher in 1. When performing robotic hysterectomy, open and robotic surgeon costs were similar. With laparoscopic hysterectomy, open surgeons had higher costs than laparoscopic surgeons for 1 of 2 statistical transformations ($P = .007$). Open surgeons had lower costs performing laparoscopic hysterectomy than robotic hysterectomy with robotic maintenance and depreciation included ($P < .001$) but similar costs if these variables were excluded.

Conclusion: Although laparoscopic hysterectomy had lowest costs overall, robotics may be no more costly than laparoscopic hysterectomy when performed by surgeons who predominantly perform open hysterectomy.

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This research was presented in an oral presentation at the 40th Annual Scientific Meeting of the Society of Gynecologic Surgeons, Scottsdale, Arizona, March 23–26, 2014.

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DOI: 10.4293/JSLS.2014.00181

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Key Words: Hysterectomy, Laparoscopy, Robotic-assisted laparoscopy.

INTRODUCTION

Hysterectomy remains one of the most common surgical procedures performed in women, with an estimated 500,000 performed annually in the United States.¹ Despite overwhelming evidence demonstrating that vaginal and laparoscopic approaches are associated with improved patient outcomes,² most hysterectomies are still performed using an abdominal approach.³ Gynecologists have identified barriers to performing laparoscopic hysterectomies (LHs), including inadequate training, technical difficulty, and personal surgical experience.⁴ However, >50% responded that they would prefer to increase the proportion of cases they performed laparoscopically.⁴ Robotic technology, with its improved visualization and wristed instrumentation, is thought to permit a larger number of physicians to learn and subsequently perform minimally invasive abdominal hysterectomies.⁵ Indeed, the percentage of hysterectomies completed robotically increased to 22.4% of all hysterectomies in just 3 years after a hospital introduced the technology.³

The decision to perform a robotic hysterectomy (RH) versus an LH is often debated.⁶ RH and LH have been shown to have similar and low complication rates but wide differences in costs.^{7,8} In a nationwide inpatient sample of >800,000 hysterectomies performed either robotically or laparoscopically in 2009 and 2010, RH cost on average \$2,489 more.⁷ In 2 recent studies, median hospital costs of hysterectomies performed robotically ranged from \$8,868 to \$9,788, compared with \$6,679 to \$7,299 for those performed laparoscopically.^{3,7} Total patient costs have been reported at much higher numbers, but still with RH contributing more to the overall expenses.^{9,10} Factors associated with increased cost include longer operative times and more expensive operative equipment.^{10–12}

The American College of Obstetricians and Gynecologists recommends minimally invasive hysterectomy, specifically vaginal hysterectomy, as the ideal surgical approach given the improved outcomes and lower costs.¹³ How-

ever, it acknowledges that in cases in which the vaginal approach is not feasible, laparoscopic and possibly robotic approaches should be performed instead of abdominal hysterectomies. Thus, we aimed to determine hysterectomy cost differences by surgical approach (open, laparoscopic, and robotic) and to determine whether surgeons who operate primarily with an abdominal approach can lower costs by attempting either laparoscopy or robotics.

MATERIALS AND METHODS

After institutional review board approval was obtained, costs were collected from all hysterectomies performed at the University of Pittsburgh Medical Center, including 10 hospitals during fiscal years 2011 to 2013. Costs were actual hospital costs accrued during the hospital stay and were not calculated by charges or reimbursement. Costs were provided in a deidentified database by our internal accounting department and were reported as total and subcategory costs. Hysterectomies were excluded if they were performed for malignancy or if concomitant procedures other than salpingo-oophorectomy were performed, as these could inflate costs. Because this analysis was focused on cost minimization by attempting either laparoscopic or robotic approaches when an abdominal hysterectomy would have otherwise been performed, vaginal hysterectomies were excluded. We recognize that vaginal hysterectomy is preferred, but it is also a unique subset of cases that can reasonably be completed by the vaginal route.

Initial analysis showed that costs were not normally distributed and were positively skewed. This is common, as procedures have minimum but no maximum cost limits. Given that routine statistical analyses such as analysis of variance cannot be performed on data that are not normally distributed, 2 transformations were performed to produce normal distributions. The first transformation calculated the natural logarithm for costs. The second transformation eliminated outliers by excluding the bottom fifth percentile and top fifth percentile of cases from the analysis. Both of these transformations produced normal distributions for total costs, and analysis was performed for both transformations. We elected to perform this analysis as opposed to using nonparametric statistics because of the increased power of the parametric tests.

The database did not originally include purchase and maintenance costs of the robot. This was calculated by adding yearly maintenance and depreciation costs, multiplying by the percentage of all robotic cases that were

hysterectomies, and dividing by the total number of hysterectomies performed robotically to arrive at a per-case robotic maintenance and depreciation (RMD) cost. This was added to all RHs, and analysis was performed both with and without RMD costs. This decision was made because similar costs with abdominal hysterectomy and LH were not as easily quantifiable but likely lower. When RMD costs were included, this cost was zero in both the laparoscopic and open hysterectomies for this reason. We did not want to bias results by over- or underestimating overall robotic costs, and the dual analysis was thought to be the fairest way to reduce this bias.

Surgeons were classified by type as open, robotic, or laparoscopic according to the routes by which they performed most of their cases. If they performed 2 routes equally, they were classified as unspecified and excluded from this portion of the analysis. We then aimed to determine if open surgeons attempting minimally invasive techniques would reduce costs by using the laparoscopic or robotic route. To do this, we performed 2 separate analyses. First we compared the difference in costs between robotic and laparoscopic cases when performed by open surgeons. We then compared LH costs between open and laparoscopic surgeons, followed by RH costs between open and robotic surgeons. The second analysis compared open surgeons' costs across each hysterectomy route. These 2 primary outcomes were chosen to determine how costs can be minimized when open surgeons attempt minimally invasive techniques.

Statistical analysis was performed using SPSS version 19 (SPSS, Inc, Chicago, Illinois). Total costs were compared among all 3 routes and surgeon types using analysis of variance of transformed data. Cost subcategories were compared between robotic and laparoscopic techniques. Although total costs were normally distributed after transformation, this was not true for cost subcategories. Therefore, Mann-Whitney *U* tests for data that were not normally distributed were performed on untransformed data. Initially, 17 cost subcategories were collected, but 8 were found to have a median cost of zero and were excluded from the subcategory analysis.

Because of the proprietary nature of actual hospital costs, all costs were reported as cost units (CUs). One CU was arbitrarily defined as the cost of performing hysterectomy via the least expensive route. For example, if total costs were determined to be \$5,000, \$10,000, and \$15,000, each would be divided by \$5,000 and reported as 1 CU, 2 CUs, and 3 CUs, respectively. In this manner, total costs are expressed as relative costs. On the subcategory analysis,

Table 1.
Comparison of Hysterectomy Total Costs by Surgery Route in Cost Units

Transformation Used	Open Costs, Mean ± SD	Open n	Laparoscopic Costs, Mean ± SD	Laparoscopic n	Robotic Costs, Mean ± SD	Robotic Costs Without RMD, Mean ± SD	Robotic n	ANOVA P Value
Natural logarithm	1.381 ± 0.723	1,666	1.034 ± 0.397	2,471	1.657 ± 0.600		734	<.001*
Outlier elimination	1.303 ± 0.450	1,500	1.000 ± 0.274	2,225	1.607 ± 0.375		662	<.001*
Natural logarithm	1.381 ± 0.723	1,666	1.034 ± 0.397	2,471		1.178 ± 0.600	734	<.001*
Outlier elimination	1.303 ± 0.450	1,500	1.000 ± 0.274	2,225		1.128 ± 0.375	662	<.001*

*Subsequent post hoc tests all with $P < .001$.

the CUs were calculated in the same manner, and therefore they approximate the percentage contribution to the total costs for each category.

RESULTS

During fiscal years 2011 to 2013, there were 4,871 hysterectomies performed, including 1,666 open (34.2%), 2,471 laparoscopic (50.7%), and 734 robotic (15.1%). An additional 1,090 vaginal hysterectomies were excluded. This encompassed 237 surgeons at 10 different hospitals, including 119 predominantly open surgeons (50.2%), 82 laparoscopic surgeons (34.6%), and 19 robotic surgeons (8.0%). Seventeen surgeons (7.2%) were equally divided between 2 or more routes and were classified as unspecified.

Total costs for the different surgical routes regardless of surgeon type are reported in **Table 1**. The least expensive route in both statistical transformations was LH ($P < .001$). Therefore, costs were normalized to this route, and LH is reported as 1 CU. When RMD costs of 0.479 CUs per case were included for RH, RH was the most expensive route, but open hysterectomy was most expensive when RMD costs were excluded.

LH had lower costs than RH in 6 of 9 cost subcategories (**Table 2**). Although laparoscopy had lower operating room (OR) equipment costs than robotics ($P < .001$), this variable was the largest contributor to total costs for both routes. Overall, OR equipment, OR time, anesthesia, and the medical/surgical floor accounted for the vast majority of total costs. The cost of the medical/surgical floor was lower for RH ($P < .001$), but there was no difference in the length of stay between the 2 routes (median, 1; $P = .29$).

Table 3 compares the costs of LH and RH when each procedure was performed by predominantly open, laparoscopic, or robotic surgeons. Of the 119 surgeons who were classified as open surgeons, 35 also performed LH and RH. When open surgeons performed RH, their costs were not significantly different than those of robotic surgeons for either statistical transformation ($P = .75$ and $P = .12$). When open surgeons performed LH, the results differed depending on which transformation was used. For the outlier elimination transformation, costs were higher for open surgeons compared with laparoscopic surgeons ($P = .007$). For the natural log transformation, there was no difference in costs between open and laparoscopic surgeons ($P = .48$).

An additional analysis was performed to help determine which route would reduce costs when open surgeons perform minimally invasive techniques by comparing costs among the 3 routes for open surgeons only (**Table 4**). When RMD was included, open surgeons had the lowest costs with the LH route for both statistical transformations ($P < .001$). However, when RMD was not included, there was no difference between laparoscopic and RH costs ($P = .94$ and $P = .27$), and both had lower costs than open surgery for both statistical transformations.

DISCUSSION

Total costs were lowest overall with LH compared with both robotic and open routes, which mirrors published research.^{3,10,11} LH had lower costs than RH in 6 of 9 cost subcategories, with OR equipment costs contributing most to the cost difference. Laparoscopic and robotic

Table 2.
Cost Subcategories by Surgery Route in Cost Units

Cost Subcategory	Laparoscopic Costs		Robotic Costs		Mann-Whitney <i>U P</i> Value	Interpretation
	Median	Mean	Median	Mean		
Anesthesia	0.147	0.162	0.147	0.179	<.001	Laparoscopic costs lower
Blood bank	0.021	0.023	0.021	0.026	<.001	Laparoscopic costs lower
Laboratory	0.035	0.047	0.042	0.061	<.001	Laparoscopic costs lower
Medical/surgical floor	0.219	0.198	0.143	0.165	<.001	Robotic costs lower
OR equipment	0.373	0.452	0.458	0.591	<.001	Laparoscopic costs lower
OR time	0.161	0.178	0.166	0.179	.036	Laparoscopic costs lower
Postanesthesia care unit	0.073	0.084	0.073	0.085	.217	No significant difference seen
Pharmacy	0.027	0.044	0.030	0.045	.003	Laparoscopic costs lower
Respiratory therapy	0.014	0.016	0.013	0.015	.083	No significant difference seen

Cost subcategories with median costs of zero were excluded from this analysis, including emergency room, intensive/critical care unit, diagnostic imaging, interventional radiology, noninvasive cardiology, outpatient clinic, and physical/occupational therapy.

Table 3.
Comparison of Hysterectomy Total Costs by Surgeon Type in Cost Units

Hysterectomy Route	Transformation Used	Open Surgeon Costs, Mean ± SD	Open n	Laparoscopic Surgeon Costs, Mean ± SD	Laparoscopic n	Robotic Surgeon Costs, Mean ± SD	Robotic n	ANOVA <i>P</i> Value
Robotic	Natural logarithm	1.736 ± 0.671	41	1.652 ± 0.415	67	1.669 ± 0.607	466	.753
Robotic	Outlier elimination	1.511 ± 0.340	35	1.588 ± 0.290	62	1.640 ± 0.400	414	.119
Laparoscopic	Natural logarithm	1.084 ± 0.451	145	1.013 ± 0.378	2,162	1.278 ± 0.517	100	<.001*
Laparoscopic	Outlier elimination	1.065 ± 0.294	126	0.982 ± 0.263	1,968	1.197 ± 0.321	76	<0.001†

*Subsequent post hoc tests: open versus laparoscopic, *P* = .483; open versus robotic, *P* = .032; laparoscopic versus robotic, *P* < .001.

†Subsequent post hoc tests: open versus laparoscopic, *P* = .007; open versus robotic, *P* = .012; laparoscopic versus robotic, *P* < .001.

equipment varied at our institution, but most cases included disposable energy devices, often the most expensive pieces of equipment. The cost of OR time was also lower with LH, reflecting shorter operative times than with RH. Given that robotic technology is relatively new, most cost studies have included robotic cases performed during a surgeon's learning curve, and thus it would be expected that operative times would be longer and contribute significantly to overall costs.^{3,8,11} As surgeons become more familiar with the robot, we anticipate that the cost of OR time may decrease. Unfortunately, in a retrospective study using deidentified data, we are unable to comment on surgeon experience as it affects costs.

We found that when open surgeons performed a minimally invasive approach, LH did not always remain the least expensive route. Open surgeons demonstrated no cost difference between RH and LH when RMD was excluded, but if RMD was included, LH was less expensive. The appropriateness of including or excluding RMD is debatable, and RMD costs have been omitted in prior cost research.⁸ These costs are easily calculated with the robot, but for other routes they are less tangible and were therefore not included. Nevertheless, the RMD costs are likely much larger and can more significantly affect conclusions related to minimizing costs with minimally invasive techniques.

Table 4.

Comparison of Hysterectomy Total Costs by Surgery Route in Cost Units, Open Surgeons Only

Transformation Used	Open Costs, Mean ± SD	Open n	Laparoscopic Costs, Mean ± SD	Laparoscopic n	Robotic Costs, Mean ± SD	Robotic Costs Without RMD, Mean ± SD	Robotic n	ANOVA P Value
Natural logarithm	1.335 ± 0.744	1,172	1.084 ± 0.451	145	1.736 ± 0.671		41	<.001*
Outlier elimination	1.259 ± 0.452	1,035	1.065 ± 0.294	126	1.511 ± 0.340		35	<.001*
Natural logarithm	1.335 ± 0.744	1,172	1.084 ± 0.451	145		1.257 ± 0.671	41	<.001†
Outlier elimination	1.259 ± 0.452	1,035	1.065 ± 0.294	126		1.032 ± 0.340	35	<.001‡

*Subsequent post hoc tests all with $P < .001$.

†Subsequent post hoc tests: laparoscopic versus robotic, $P = .269$; open versus laparoscopic, $P < .001$; open versus robotic, $P = .804$.

‡Subsequent post hoc tests: laparoscopic versus robotic, $P = .937$; open versus laparoscopic, $P < .001$; open versus robotic, $P < .001$.

The greatest strengths of our study are the large surgical volume from multiple hospitals and multiple surgeons, adding to the generalizability of the results. Our data also allow costs to be calculated on the basis of actual hospital costs, not charges or reimbursements. Although other studies have looked at larger national databases,³ our study is the first to divide costs into subcategories. In doing so, we were able to demonstrate that most hysterectomy costs were directly related to OR equipment, OR time, anesthesia, and medical/surgical floor. Our study is also the first to analyze whether there was a difference in costs on the basis of a surgeon's predominant route for hysterectomy and whether this can be exploited when open surgeons attempt minimally invasive techniques. Rhou et al¹⁴ found LH less costly than open once the learning curve was completed. Intraoperative costs were higher with laparoscopy, but postoperative costs were higher with open hysterectomy. However, no studies have compared the difference in attempting both LH and RH.¹⁴

The greatest weakness of this study is the lack of clinical correlates to accompany the cost information. Without demographic and surgical information, we cannot determine if there are variables influencing surgical costs that are unequally distributed among the surgical routes or surgeon types. Ultimately this is a limitation common to many large databases that logistically can not be overcome. It is conceivable that there is a large selection bias for individual surgeons choosing between open and minimally invasive routes on the basis

of predicted difficulty of the case that would ultimately bias comparative costs. However, we would predict that there is a bias toward choosing easier cases and smaller uteri for minimally invasive hysterectomy. There would likely not be a differential bias between choosing a laparoscopic or robotic approach, so the primary aim of this study would not be affected. Because our costs are expressed in CUs, these results cannot be compared with those of other studies on hysterectomy costs. However, this technique has been used by others and may make results easier to interpret, as the cost subcategories are expressed as fractional costs, and overall costs equate to relative costs.¹⁵

We also lack complication and outcome data, which would influence quality of life and thus cost-effectiveness. However, prior research has found no difference in complications among hysterectomies performed via abdominal, vaginal, laparoscopic, and robotic routes.^{3,7} Complications are also likely to increase costs via extended length of stay and operative times and are therefore partially accounted for in our analysis.

Finally, we appreciate that our analysis only considers the costs of intra- and perioperative care when an open surgeon performs a laparoscopic or robotic approach. It does not include the costs of training a surgeon in either technique. Likewise, it does not consider the overall learning curve for performing the procedures. The peripheral benefits of robotic surgery, including a 3-dimensional view, improved ergonomics, and improved instrument mobil-

ity,⁵ must also be considered when surgeons consider robotic versus laparoscopic approaches.

CONCLUSIONS

Overall costs are lowest for LH compared with the open and robotic routes. However, in a subpopulation of traditionally open surgeons attempting minimally invasive hysterectomy, this may not be the case. In multiple analyses, we found conflicting data in this subgroup. Therefore, the cost advantages of RH versus LH for surgeons who predominantly perform abdominal hysterectomy are uncertain, and prospective trials are needed.

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