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ORIGINAL ARTICLE

Robotic hysterectomy compared with laparoscopic hysterectomy: is it still more costly to perform?

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Abstract

To establish the economic value of simple robotic hysterectomy vs laparoscopic hysterectomy and assess the impact of surgeon's experience. Retrospective cohort study. University-affiliated US regional healthcare system. Reproductive and post-menopausal women undergoing hysterectomy for benign indications. Robotic or laparoscopic hysterectomy. Between January 2018 and December 2019, a total of 985 simple laparoscopic and robotic hysterectomies were performed by 47 different gynecologists. Overall, the mean payment, direct cost, and profit were comparable (p value > 0.05) among simple robotic and laparoscopic hysterectomy. However, the mean operative time was significantly shorter for robotic hysterectomy compared to laparoscopic hysterectomy (106 min vs 127 min, respectively, $p < 0.05$). Operative time decreased as a surgeon's annual robotic case volume increased. Per-minute profitability of robotic hysterectomy increased significantly when a surgeon performed greater than 45 cases annually ($p = 0.04$). This effect became most pronounced when a surgeon performed 60 or more cases per year ($p = 0.01$). Simple robotic hysterectomy has shorter operative time compared to laparoscopic hysterectomy, with direct costs being similar. Robotic hysterectomy has higher per-minute profit compared to laparoscopic hysterectomy when a surgeon performs > 45 cases per year.

Keywords Hysterectomy · Laparoscopy · Robotic · Cost · Operative time

Introduction

The da Vinci® robotic surgical platform (Intuitive Surgical, Sunnyvale, CA, USA), received Food and Drug Administration (FDA) approval for gynecologic surgery in 2005 and quickly gained a presence throughout the United States [1, 2]. Performance of robotic hysterectomy increased nearly 1000% between 2007 and 2010 (from 0.5 to 9.5% of all hysterectomies) while the rate of laparoscopic hysterectomy rose by only 6.2% over the same time period [3].

Despite the rapid incorporation of robotic hysterectomy into clinical practice, prospective head-to-head evidence comparing robotic hysterectomy to traditional laparoscopy is sparse [2, 4]. Early reports favored laparoscopy in terms of operative time and cost, while there was no difference in clinical outcomes [5, 6]. Without clear indications for benign robotic hysterectomy, many—including The American College of Obstetricians and Gynecologists (ACOG)—previously discouraged its use due to increased cost and no benefits in perioperative outcomes [7]. This is likely because much of the literature investigating cost comparisons between robotic and laparoscopic hysterectomy occurred during the robotic learning curve when operative efficiency had not been achieved. More recent studies have questioned the classic "anti-robot stigma", as shifts in operative time and cost increasingly appear to favor robotic hysterectomy [8–10]. In September 2020, ACOG updated its stance on robotic surgery for noncancerous gynecologic conditions, concluding that robotic surgery should be selected based on prospects of improved outcome with special consideration

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given to costs [11]. Given the high utilization of robotics within many healthcare systems, an economic-focused analysis is warranted.

The primary goal of this study was to establish the economic value of simple robotic hysterectomy compared to laparoscopic hysterectomy in a healthcare system with a mature robotic surgical program. The secondary aim of this study was to assess the impact of surgeon's experience on cost, operative time, and per-minute profit.

Materials and methods

This study was reviewed and approved by the institutional review board of a regional healthcare system in the northeast U.S.A. Authors have no conflicts of interest to report. Financial data, including direct costs, charges, and payments for all simple robotic and laparoscopic hysterectomies from January 2018 through December 2019 were extracted in a de-identified database from patient management software platform that the healthcare system uses to capture information in real time. Direct costs refer to any and all cost associated with the procedure and hospital stay. This includes medication, supply, operating room, staff and anesthesia costs. "Simple hysterectomy" was defined as any hysterectomy performed for benign indications, without any concomitant procedure, extensive lysis of adhesions, or myomectomy. Operative time was defined from time of surgical time out until completion of skin closure.

Payment, direct cost, profit, operative time, and profit per minute were compared between the groups, including an assessment of the influence of surgical volume on operative time and profitability. Charity cases (as defined by the cases for which the diagnosis-related group payment was below Medicaid hysterectomy hospital reimbursement of $1800) were excluded from the analysis.

To assess the impact of surgeon hysterectomy volume on outcomes in the secondary analysis, incremental cut-off points of 15, 30, 45, and > 60 annual robotic cases were used. Statistical analysis was performed using MS Excel 2016. For all costs and time metrics, mean values and standard deviations are presented. For the calculation of p values, a two-sided Welch's t-test was applied to control for potentially unequal variances and for the unequal sample sizes [12]. A p value < 0.05 presents a statistically significant difference between simple robotic and laparoscopic hysterectomy cases.

Results

During 2018 and 2019, there were a total of 985 simple hysterectomies performed (856 robotic, 129 laparoscopic). Robotic surgery was performed at three hospital sites within the healthcare system by 30 different gynecologists. The robotic program in the healthcare system was established 10 years before data collection began in 2018. The laparoscopic group included 28 different gynecologists, with a weighted average of 15 years of experience in laparoscopic surgery. The robotic platform was used in 86.9% of simple hysterectomy cases (856 of 985 procedures). Overall, the mean payment, direct cost, and profit were comparable (p value > 0.05 in all cases) between the simple robotic and laparoscopic hysterectomy cases, regardless of scenario analyzed (Table 1).

Operative time was significantly shorter among robotic hysterectomy cases compared to laparoscopy (106 min vs 127 min, $p < 0.05$), regardless of scenario analyzed. Overall, mean per-minute profit was $3 higher when the robotic platform was used to perform a hysterectomy, but this difference did not reach statistical significance ($p = 0.6669$). Robotic operative time declined as the surgeons' robotic experience increased: the higher the annual robotic case volume, the lower the operative time in minutes. The reduction in operative time was observed to be proportional to annual robotic case volume. This reduction in operative time led to a statistically significant increase in per-minute profitability of robotic cases when > 45 cases were performed by a surgeon annually. This effect became most pronounced when a robotic surgeon performed 60 or more cases per year with a greater incremental per-minute profit of $21 ($54 vs $33, $p = 0.011$). The influence of surgeon's experience on profit per minute is illustrated in Fig. 1.

Discussion

To the authors' knowledge, the present study is the first economic analysis focusing on the per-minute profitability of robotic hysterectomy within a healthcare system, showing that profit per minute of robotic hysterectomy exceeded that of laparoscopic hysterectomy when a surgeon performed > 45 cases per year. The analysis further revealed that profit per minute of robotic hysterectomy increased as a function of surgeon's case volume. This economic advantage reflects increased operative efficiency that becomes most significant when evaluating the performance of high-volume robotic surgeons with a minimum surgical case volume of 60 per year.

Costs, revenues, and metrics of productivity are seen as the key drivers of economic value with respect to robotic system improvement, resource allocation and optimization. Only with this type of assessment can the value of a procedure be established and compared. Per-minute analysis of profit allows for a standardized comparison across procedures and provides an informative measure that combines time, efficiency, and procedure cost. In economic terms, this

Table 1 Fiscal productivity comparison between simple robotic hysterectomies with simple laparoscopic hysterectomies

Cenario	Type	*N*	Measurement	Payment	Direct cost	Profit	OR time	Profit/minute
All robotic cases	Simple robotic	825	Mean	$9129	$5916	$3213	106	$36
			SD	$3592	$1471	$3684	46	$46
	Simple lap	115	Mean	$9584	$6094	$3489	127	$33
			SD	$3260	$7542	$7695	50	$70
	Simple robotic vs. simple lap	940	*p* value	0.16886	0.80089	0.70552	0.00003	0.66685
Robotic (> 15 cases/year)	Simple robotic (> 15 cases per year)	699	Mean	$9134	$5836	$3298	99	$39
			SD	$3594	$1482	$3706	41	$48
	Simple lap	115	Mean	$9584	$6094	$3489	127	$33
			SD	$3260	$7542	$7695	50	$70
	Simple robotic (> 15) vs. simple lap	814	*p* value	0.17836	0.71442	0.79408	0.00000	0.40846
Robotic (> 30 cases/year)	Simple robotic (> 30 cases per year)	541	Mean	$9114	$5742	$3373	91	$42
			SD	$3646	$1530	$3729	37	$52
	Simple lap	115	Mean	$9584	$6094	$3489	127	$33
			SD	$3260	$7542	$7695	50	$70
	Simple robotic (> 30) vs. simple lap	656	*p* value	0.17150	0.61850	0.87403	0.00000	0.20743
Robotic (> 45 cases/year)	Simple robotic (> 45 cases per year)	213	Mean	$9596	$6117	$3479	77	$49
			SD	$4115	$1623	$4046	32	$62
	Simple lap	115	Mean	$9584	$6094	$3489	127	$33
			SD	$3260	$7542	$7695	50	$70
	Simple robotic (> 45) vs. Simple lap	328	*p* value	0.97726	0.97515	0.98941	0.00000	0.04081
Robotic (> 60cases/year)	Simple robotic (> 60 cases per year)	174	Mean	$9643	$5989	$3654	68	$54
			SD	$4042	$1064	$4000	19	$65
	Simple lap	115	Mean	$9584	$6094	$3489	127	$33
			SD	$3260	$7542	$7695	50	$70
	Simple robotic (> 60) vs. simple lap	289	*p* value	0.89072	0.88206	0.83277	0.00000	0.01096

Payment, direct costs, and profit are presented in US dollar ($). Analysis performed using a two-tailed Welch's *t*-test; $p < 0.05$ considered statistically significant

can also be referred to as marginal analysis and may serve as an analytic metric to benefit more effective procurement and fiscal decision making. Resource optimization and improved per-case profitability can help increase the number of total surgical cases in a healthcare system as well as subsidize areas without significant profitability.

Changing the focus of surgical economic analytics away from cost limitations and toward identifying where actual economic profit centers reside gives hospital leadership greater fiscal flexibility to pursue numerous approaches to optimize patient care and overall healthcare delivery. In economic terms, using more profitable procedures means that resources are being utilized more efficiently and allowing for productivity gains from one procedure to spill over into other areas.

A strength of this study is its novel economic investigation into "fiscal productivity" based on the use of medical technology in a commonly performed procedure. This analysis reports, in a practical manner, the economic value of robotic hysterectomy compared to traditional laparoscopy, reflecting current consumer utilization. Such real-world studies provide a pragmatic assessment to better understand the value of surgical technology well beyond the limitations of basic cost analysis. Additionally, all cost data were collected in real time and do not rely on arbitrary multipliers (i.e., cost-to-charge ratios) to estimate cost. Moreover, the relatively large number of procedures included in this analysis provides confirmation of the validity of best practices in a robotics program and the reliability these results generate. Comparable payment, direct cost, and profit data further suggest alignment of the cases with regard to complexity.

There are several limitations inherent to this study [13]. Selection and information bias may be present due to limited ability to control for all factors that can influence economic evaluations within a healthcare system. Additionally, the interpretation of the data herein reflects outcomes that are based on a specific healthcare system, which may or may not reflect findings of other integrated delivery networks. Unique to the findings are the high proportion of robotic hysterectomies performed, which may reflect a local training bias and surgeon preference. Despite having a disproportionately smaller number of cases, the laparoscopic group nevertheless represented a

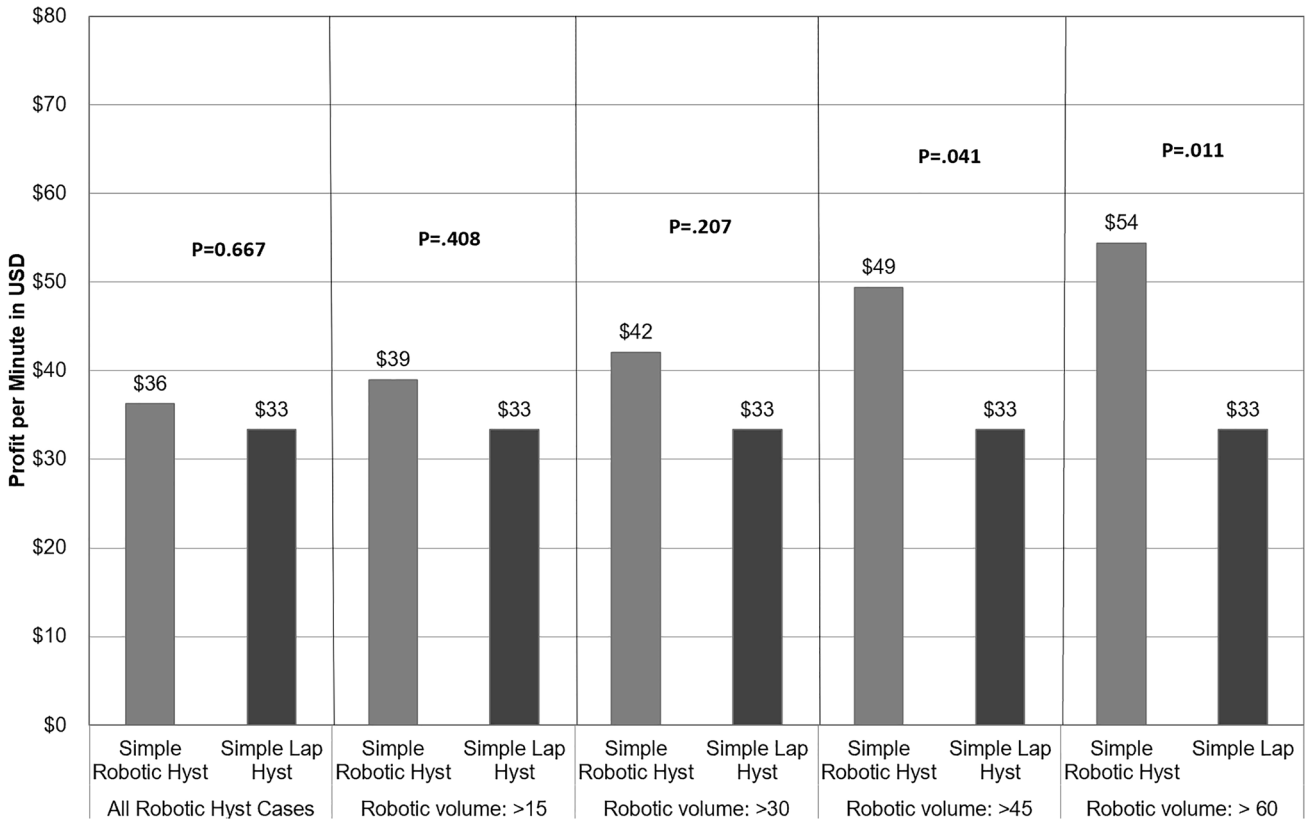

Fig. 1 Profit per minute comparing simple robotic hysterectomies with simple laparoscopic hysterectomies related to surgeon's robotic experience in US dollar ($). Analysis performed using a two-tailed Welch's *t*-test; $p < 0.05$ considered statistically significant

proficient "real-world" sample given their experience and performance. The average laparoscopic operative time of 127 min in this study compares favorably with what has been shown in the medical literature [14]. Another weakness of the study is that other factors influencing operative time, such as uterine weight and BMI, were not controlled for, though this limitation is unlikely to have influenced the study findings given the large sample size within each group.

Despite these limitations, this analysis provides a real-world investigation reflecting a large number of procedures, which mitigates the risk of selection bias. Inclusion of all simple hysterectomies, performed by surgeons with varying levels of expertise, using the surgeon's approach of choice, may increase the generalizability of the analysis. Additionally, increased profitability was noted across multiple locations within the healthcare system, further limiting the influence of selection bias that may be seen with analysis of a single-center.

Conclusion

Robotic hysterectomy was observed to have similar direct cost compared with laparoscopic hysterectomy. Robotic hysterectomy, when performed by high-volume surgeons (> 45 cases per year), resulted in higher per-minute profit compared with the laparoscopic approach.

Author contributions Conceptualization: AG, JF; Methodology: AG, WN; Formal analysis and investigation: BS, WN; Writing—original draft preparation: AG; Writing—review and editing: AG, WN, DS, RS, JF, BS; Funding acquisition: None; Resources: None; Supervision: AG.

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Data availability De-identified data available upon request.

Code availability Not applicable.

Declarations

Conflict of interest None reported.

Ethical approval This study was reviewed and approved by Institutional Review Board at Catholic Health System, Buffalo, New York.

Consent to participate Patients were consented for collection of medical information upon hospitalization. Information obtained in de-identified fashion.

Consent for publication Authors hereby give consent to publication of this manuscript. This work is not currently submitted elsewhere for publication.

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