

Value-based assessment of hysterectomy approaches

Natalya Danilyants, Paul MacKoul, Rupen Baxi, Louise Q. van der Does  and Leah R. Haworth

The Center for Innovative GYN Care, Rockville, Maryland, USA

Abstract

Aim: By evaluating operative outcomes relative to cost, we compared the value of minimally invasive hysterectomy approaches, including a technique discussed less often in the literature, laparoscopic retroperitoneal hysterectomy (LRH), which incorporates retroperitoneal dissection and ligation of the uterine arteries at their vascular origin.

Methods: Retrospective chart review of all women ($N = 2689$) aged greater than or equal to 18 years who underwent hysterectomy for benign conditions from 2011 to 2013 at a high-volume hospital in Maryland, USA. Procedures included: laparoscopic supracervical hysterectomy, robotic-assisted laparoscopic hysterectomy (RALH), total laparoscopic hysterectomy, laparoscopic-assisted vaginal hysterectomy, total vaginal hysterectomy (TVH), and LRH.

Results: Total vaginal hysterectomy had the highest intraoperative complication rate (9.6%; $P < 0.0001$) but the lowest postoperative complication rate (1.8%; $P < 0.0001$). Robotics had the highest postoperative complication rate (11.4%; $P < 0.0001$). LRH had the shortest operative time (71.2 min; $P < 0.0001$) and the lowest intraoperative complication rates (2.1%; $P < 0.0001$). LRH and TVH were the least costly (averaging \$4061 and \$6416, respectively), while RALH was the most costly (\$9354). Taking both operative outcomes and cost into account, LRH, TVH and laparoscopic-assisted vaginal hysterectomy yielded the highest value scores; total laparoscopic hysterectomy, RALH, and laparoscopic supracervical hysterectomy yielded the lowest.

Conclusion: Understanding the value of surgical interventions requires an evaluation of both operative outcomes and direct hospital costs. Using a quality-cost framework, the LRH approach as performed by high-volume laparoscopic specialists emerged as having the highest calculated value.

Key words: cost, hysterectomy, laparoscopic, retroperitoneal, value.

Introduction

The soaring costs of health care in the United States combined with the recent uncertainty of the Affordable Care Act have intensified the focus on value-based healthcare delivery. Healthcare spending has been growing as a share of the national income for decades – from 10% in 1985 to 17% in 2010 – and it is projected to keep rising to almost 25% in 2037.¹ Healthcare economists estimate that 40–50% of annual cost increases can be traced to new technologies, such as the da Vinci robot.² There is ongoing debate

regarding whether the benefits are worth the costs of this technology.³ To quote Yong *et al.*:

The rising healthcare costs in the United States in the face of global economic turmoil underscore the necessity for a health system that identifies and eliminates low-value services, minimizes inappropriate use of medical services, and responds to the explosion of costly new technologies, thus positioning value as a key cornerstone to improving the quality of care delivered in this country.⁴

Received: February 9 2018.

Accepted: October 8 2018.

Correspondence: Dr Louise van der Does, The Center for Innovative GYN Care, 3206 Tower Oaks Blvd., Suite 150, Rockville, MD 20852, USA. Email: lvanderdoes@innovativegyn.com

A corrective shift toward a value-based model is needed to move the healthcare system in the direction of greater sustainability, offering benefits to the provider, payor and the patient.⁵ While the need to use both cost and quality measures to assess the value of physician practices, hospitals and health plans is well established in the literature,^{4,6} there is currently no consensus or practical set of guidelines on how to compare the value of surgical modalities. As surgical care accounts for more than 40% of spending for inpatient care,⁷ operationalizing and identifying the value of varying surgical routes is critical for healthcare stakeholders seeking to control costs without sacrificing quality.

By developing a quality-cost framework, our study attempted to assess and compare the value of minimally invasive hysterectomy procedures to an approach less commonly performed: laparoscopic retroperitoneal hysterectomy (LRH).

Methods

We conducted a retrospective chart review of 2689 patients, 18 years and older, who underwent minimally invasive hysterectomy between January 2011 to December, 2013 at a not-for-profit, high-volume hospital in suburban Maryland serving the greater metropolitan Washington, DC area. The surgeons included obstetrician/gynecologist generalists, and laparoscopic surgeons trained in various gynecologic fellowships such as minimally invasive surgery, gynecologic oncology and urogynecology. This investigation was approved by the Holy Cross Hospital Institutional Review Board.

Cases with concomitant procedures frequently performed during a hysterectomy, such as adnexal removal, adhesiolysis and cystoscopy were included in the analysis. Cases with major concomitant procedures unrelated to the hysterectomy, such as bowel resection, appendectomy, cholecystectomy, hernia repair and major pelvic support procedures, were excluded from review because of the added surgical time and cost. Patients with malignant indications for hysterectomy were also excluded.

Hysterectomy procedures were identified and classified on the basis of the ICD-9 diagnostic codes for laparoscopic supracervical hysterectomy (LSH), robotic-assisted laparoscopic hysterectomy (RALH), total laparoscopic hysterectomy (TLH), laparoscopic-assisted vaginal hysterectomy (LAVH) and total vaginal

hysterectomy (TVH). Discharges with the International Classification of Diseases, Ninth Revision (ICD-9) procedure code for 'laparoscopic robotic-assisted procedure' (17.42 and 17.44) in combination with any of the hysterectomy codes were categorized as having undergone RALH. The LRH approach was originally coded by the hospital as LAVH; however, after reading the operative reports, patients who underwent laparoscopic hysterectomy with retroperitoneal dissection (RPD) and uterine artery ligation at its vascular origin were identified as having undergone LRH. The LRH approach was given its own category, as it was consistently performed in the manner described below by a group of surgeons with a significant volume of cases large enough for meaningful comparison.

LRH technique

During conventional TLH, the uterine vessels are typically identified and cauterized at the isthmo-cervical region of the uterus. However, pelvic pathology such as fibroids, endometriosis, adhesions from previous pelvic surgeries or ovarian remnants can distort anatomy and pose technical challenges during laparoscopic hysterectomies. A retroperitoneal laparoscopic approach, with ligation of the uterine artery at its origin at the anterior branch of the internal iliac artery, was originally described by Kohler *et al.*⁸ and Roman *et al.*⁹ as a technique to control blood loss and protect the ureter, even in cases with large uteri. The RPD required for this technique may also help prevent other visceral injuries by allowing full visualization and lateralization of the ureters.¹⁰⁻¹² A randomized study of 400 patients showed shorter operative time (OT) and significantly less blood loss in patients who underwent uterine artery ligation at the origin versus the isthmo-cervical region.¹³

We provide here the most important technical principles of the LRH technique for benign gynecologic surgery as described in the operative reports. The hysterectomy is initiated by transecting the round ligament and entering the retroperitoneal space. The paravesicle and pararectal spaces are completely developed and the vital structures are identified. The uterine artery is then ligated at its origin using the Harmonic Scalpel. A defect is made in the posterior leaf of the broad ligament, which lateralizes the ureter and aids in isolating the infundibulopelvic ligament. The anterior leaf of the broad ligaments is then opened on each side to create a bladder flap that is carried through to the midline along the vesicouterine peritoneum. The anterior vaginal fornix is delineated

using a simple sponge stick, and a colpotomy is created using the Harmonic Scalpel. The uterus is then extracted vaginally, and if needed in cases of large specimen, via extraperitoneal vaginal debulking techniques.^{14–16} The vaginal cuff is closed transvaginally. Although RPD, lateralization of the ureters and early ligation of uterine arteries at the origin are techniques that can be performed in various ways with other approaches, the LRH technique as described above was performed consistently in the group of patients included in our analysis, and thus evaluated as a distinctive hysterectomy approach.

Patient characteristics and operative outcomes

Patient characteristics analyzed included age, race, weight, body mass index (BMI), surgical history, indications for surgery, uterine weight and uterine pathology. The Elixhauser Comorbidity Index was used to identify and record comorbid conditions that have been shown to potentially affect operative outcomes.¹⁷ We also collected data on length of stay (LOS), which was counted as 0 if the patient was discharged before midnight on the same day of surgery. Surgical outcomes examined included the number of laparoscopic ports used, method of tissue extraction, estimated blood loss (EBL), skin-to-skin OT, intraoperative and postoperative complications and rate of conversion from laparoscopic to abdominal hysterectomy. EBL was obtained from anesthesiology reports. Complications were categorized as intraoperative when they occurred at the time of the procedure, and as postoperative when presented within 60 days of the hysterectomy procedure.

Assessing costs

While most comparative studies on hysterectomy use reimbursement amounts or hospital charge data,^{18,19} because of the limited transparency in resource used-cost data at the hospital level, our cost analysis was conducted from a healthcare system perspective, our cost analysis was conducted from a healthcare system perspective, incorporating direct hospitalization costs associated with each procedure. Relying on microcosting, we sought to improve the accuracy of cost estimation by including data on unit costs and resources utilized at the patient level.^{20,21} Direct hospital costs included the following variables: room and board, physician reimbursement, operating room and anesthesia time, surgical equipment and postoperative care (eg, pharmacy and laboratory tests). The 2013 OB/GYN Surgery Medicare reimbursement rates

were used to estimate physician reimbursement for each procedure. The cost of room and board per day, preoperative costs of setup or time spent in the preoperative holding area, and average per-minute costs for the operating room and anesthesia times were obtained from the hospital's billing department. The latter fee schedule is based on a combination of nursing labor and fixed equipment for the operating room and is adjusted for every calendar year. Detailed equipment costs were obtained from the hospital's purchasing department.

Costs of all disposable equipment (e.g., drapes, sealers, scalpel blades, trocars and forceps) required for each surgical procedure were included in the cost analysis. Reusable instruments were assumed to have no cost as no additional investment was needed. Similarly, the acquisition and amortization of the da Vinci robot was not factored in, as the initial capital investment and the annual maintenance costs of the robotic system were previously funded by the hospital.

The hospital's billing department also provided the estimate of postoperative care, which included pharmacy and laboratory tests. A standard cost-charge ratio of 0.6 was applied to the postoperative care estimate, as only charge data were provided by the hospital. Average costs were computed at the procedure level as well as at the patient level in order to provide more accurate estimates of the average, median and range of costs (operating room + LOS + equipment + surgeon fee + postoperative care).

Assessing value

Understanding the value of surgical interventions requires an evaluation of both outcomes and costs. While the need to use quality and cost to assess value is well established, there is no clear consensus on how to operationalize these two fundamental parameters.²² Ryan and Tompkins²³ describe the 'unconditional model' in which quality is assessed by a single indicator or a composite measure, and cost is assessed by a single measure of total costs. The quality and cost parameters are then assigned weights and collapsed into a single metric,²³ similar to the model used by the Centers for Medicare and Medicaid Services' (CMS) Hospital Value-Based Purchasing program.²⁴

For the purpose of this study, we relied on the unconditional model described above, defining value as quality (benefits) over costs (resources used). Quality was quantified by creating a summary composite score of the unadjusted average OT, EBL, complication and conversion rates.²³ Scores were calculated

using quartiles, with each outcome carrying equal weight.

Value = Quality/Direct Hospital Costs

where Quality = Operative Outcomes
and

Operative Outcomes = Operating time + EBL +
Complications + Conversion rate.

Statistical analysis

Operative outcomes were compared across hysterectomy procedures with and without adjustments for demographics (age, race and BMI) and case complexity factors (number of previous surgeries, uterine size, number of additional procedures, number of comorbidities and weight). Surgeon's experience was also controlled for by including the actual number of hysterectomies each surgeon performed during the study period as an independent covariate in the model.

For unadjusted comparisons of continuous clinical outcome (EBL, LOS), one-factor ANOVA was used to test overall mean differences, followed by all-pairs Tukey–Kramer *post hoc* comparisons to identify means that were significantly different from each other. Unadjusted comparisons of dichotomous clinical outcomes (intraoperative complications and postoperative complications) were performed using logistic regression without covariates. Similarly, conversion (none, minilaparotomy, laparotomy) was analyzed as a polygamous outcome with multinomial logistic regression. We used *post hoc* Bonferroni-adjusted comparisons of predicted probabilities to identify groups that differed significantly, while maintaining the overall significance probability at 5%.

For adjusted analyses, linear regression was used to model EBL, logistic regression was used to model complications and conversions and negative binomial regression was used to model LOS. Because of concerns about non-normality of the dependent variable, we used median regression to model EBL and surgery time. We used adjusted (marginal) medians, proportions or counts, and corresponding delta-method standard errors computed from the fitted models to perform Bonferroni-adjusted *post hoc* comparisons to identify groups that differed significantly, while maintaining the overall significance probability at 5%.

All statistical analyses were conducted with SPSS 21 (IBM Corp.). All statistical tests were two-tailed at the $P < 0.05$ level.

Results

We reviewed the medical records of 2689 patients who underwent minimally invasive hysterectomy, with the following patient distribution from highest to lowest: LRH = 756; RALH = 576; LSH = 471; LAVH = 404; TLH = 361; TVH = 121. Age, weight and BMI were equally distributed for each of the surgical groups (Table 1). Indications for surgery across procedures were similar, except for pelvic prolapse which was more highly represented in the TVH group. Indications in order of prevalence, greatest to least, included leiomyoma, abnormal menstruation, endometriosis, pelvic prolapse, endometrial hyperplasia, postmenopausal bleeding, benign ovarian cyst or neoplasm, cervical dysplasia, uterine polyp and prophylactic organ removal. The percentage of patients with comorbidities and prior abdominal surgeries were also similar across procedures. The most significant difference in demographic characteristics was race; there were a higher percentage of African American women in the LSH group. The average uterine specimen weight from highest to lowest was as follows: LSH (410.4 gm); LRH (328.9 gm); TLH (283.1 gm); RALH (276.8 gm); LAVH (273.6 gm); and TVH (153.2 gm) (Table 1).

Analysis of the operative outcomes across procedures showed statistically significant differences in EBL, LOS, OT, complications, and rate of conversion to laparoscopy. Adjusted results are summarized in Table 2 and discussed below.

LRH had the lowest mean EBL (100.1 mL; $P < 0.0001$), which was statistically significant when compared with LAVH and TVH. There were two intraoperative blood transfusions (1, LAVH; 1, LRH) and two postoperative transfusions (1, RALH; 1, LAVH).

LRH had the shortest OT; LSH had the longest OT compared with all other groups. The mean OT from shortest to longest were as follows: LRH (71.2 min), TVH (93.1 min), RALH (99.6 min), TLH (110.9 min), LAVH (117.0 min) and LSH (119.9 min).

The most frequently occurring intra- and postoperative complications are listed in Table 3. TVH had the highest rate of intraoperative complications (9.6%); LRH had the lowest (2.1%; $P = 0.0033$), which was statistically significant compared to RALH, TLH, LAVH and TVH ($P < 0.0001$). The rate of postoperative complications was the highest in the RALH group (11.4%); TVH had the lowest (1.8%). The overall incidence of vaginal cuff dehiscence

Table 1 Patient characteristics

Variable, Mean (SD) [†]	LRH	LSH	RALH	TLH	LAVH	TVH	P value
Age (yr)*	47.7 (9.5)	45.5 (5.7)	48.9 (8.8)	47.8 (9.0)	48.4 (9.1)	49 (11.8)	<0.0001
Uterine size (gm)*	328.9 (343.1)	410.4 (461.6)	276.8 (266.3)	283.1 (292.2)	273.6 (301.8)	153.2 (101.6)	<0.0001
Weight (kg)*	79.5 (21.1)	84.8 (21.4)	86 (26.4)	78.4 (20.4)	80.4 (21.5)	79.3 (22.0)	<0.0001
BMI (k/m ²)*	29.6 (7.3)	31.6 (7.4)	32 (9.6)	29.5 (7.1)	30.3 (8.4)	29.9 (7.5)	<0.0001
Race (%)**							
Black	45	71	41	39.1	44.8	40	—
White	46.8	20	50	42.4	42.3	42	—
Other	6.7	8	9	17.5	11.9	18	<0.0001
Previous abdominal surgeries (%)**							
None	33.1	29.3	30.6	34.3	31.5	40.5	—
1	33.6	34.4	30.9	35.2	38.7	37.2	—
2	20	23.6	21.9	19.9	19.1	17.4	—
>2	13.4	12.7	16.7	10.5	10.7	5	<0.0001
Comorbid conditions (%)**							
None	44.4	41.2	34	46	42.6	45.5	—
1	32.7	35.7	33.2	29.4	32.2	28.1	—
≥2	22.9	23.1	32.8	24.7	25.2	26.4	<0.0001
Total cases	756	471	576	361	404	121	—

*ANOVA $P < 0.001$; **Chi-squared test $P < 0.001$; †Unless otherwise indicated, values are given as Mean (standard deviation). ANOVA, analysis of variance; BMI, body mass index; LAVH, laparoscopic-assisted vaginal hysterectomy; LRH, laparoscopic retroperitoneal hysterectomy; LSH, laparoscopic supracervical hysterectomy; RALH, robotically assisted laparoscopic hysterectomy; SD, standard deviation; TLH, total laparoscopic hysterectomy; TVH, total vaginal hysterectomy.

within the 60-day postoperative period was rare in our analysis at 0.45%. Conversion to abdominal hysterectomy occurred in 14 cases: 9 cases in the TLH group, 4 in LSH and 1 in RALH. There were no conversions to abdominal hysterectomy in LAVH, LRH or TVH.

Costs

There were significant cost differences across procedures, which reflect similar cost comparisons found in the literature.^{18,25,26} Examining the average of the entire cohort, LRH was the least expensive with an average cost of \$4061, ranging from \$2782 to \$10 687

Table 2 Adjusted analysis of operative outcomes[†]

Variable, adjusted median (95% CI) [‡]	LRH	LSH	RALH	TLH	LAVH	TVH	P value
Number of ports – Adjusted counts	2.1 (2.0, 2.2)	3.3 (3.1, 3.5) [§]	4.7 (4.5, 4.9) [§]	3.5 (3.3, 3.7) [§]	3.3 (3.1, 3.5) [§]	N/A	<0.0001
EBL (ml)	100.1 (90.3, 109.9)	116.6 (106.1, 127.90)	100.9 (92.1, 109.7)	114.5 (103.2, 125.7)	135.9 (125.1, 146.7) [§]	188.9 (169.2, 208.6) [§]	<0.0001
LOS (days)	0.2 (0.2, 0.2)	0.5 (0.5, 0.6) [§]	1.1 (1.0, 1.2) [§]	0.8 (0.7, 0.9) [§]	0.8 (0.7, 0.9) [§]	1.2 (1.0, 1.4) [§]	<0.0001
OT (min)	71.2 (66.9, 75.5)	119.9 (115.3, 124.6) [§]	99.6 (95.7, 103.6) [§]	110.9 (105.8, 115.9) [§]	117.0 (112.1, 121.8) [§]	93.1 (84.3, 101.9) [§]	<0.0001
Prob. IntraOp comp, %	2.1 (1.0, 3.2)	5.1 (2.9, 7.3)	5.6 (3.7, 7.6) [§]	5.8 (3.3, 8.3) [§]	7.1 (4.4, 9.8) [§]	9.6 (3.1, 16.0) [§]	0.0033
Prob. PostOp comp, %	3.6 (1.9, 5.2)	4.9 (3.0, 6.9)	11.4 (8.7, 14.0) [§]	5.1 (2.8, 7.5)	8.4 (5.6, 11.3) [§]	1.8 (0.0, 4.3)	<0.0001
Prob. convert open, %	0.0 (0.0, 0.0)	1.0 (0.0, 1.9)	0.4 (0.0, 1.2)	4.8 (1.5, 8.2)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	N/A
Total cases	756	471	576	361	404	121	

†Adjusted for age, race, number of previous abdominal surgeries, BMI, number of comorbidities, weight, uterine size, number of additional procedures and surgeon's volume; ‡Unless otherwise indicated, values are given as adjusted medians (95% CI); §Statistical significance in *post hoc* analysis comparing each surgical procedure to LRH. Significance probability corrected to maintain the family-wise error rate at $\alpha = 0.05$. CI, confidence interval; Comp, complications; EBL, estimated blood loss; IntraOp, intraoperative; LAVH, laparoscopic-assisted vaginal hysterectomy; LOS, length of stay; LRH, laparoscopic retroperitoneal hysterectomy; LSH, laparoscopic supracervical hysterectomy; OT, operative time; PostOp, postoperative; Prob Convert Open, probability of conversion to laparotomy; RALH, robotically assisted laparoscopic hysterectomy; TLH, total laparoscopic hysterectomy; TVH, total vaginal hysterectomy.

Table 3 Most common complications

Complications ^{†, ‡} (%)	LRH	LSH	RALH	TLH	LAVH	TVH	Total
Intraoperative							
EBL > 1000 mL	1 (0.13)	7 (1.5)	2 (0.34)	2 (0.55)	6 (1.5)	2 (1.65)	20 (0.74)
Cystotomy	2 (0.26)	3 (0.63)	3 (0.52)	2 (0.55)	4 (0.99)	3 (2.48)	17 (0.63)
Ureteral injury	2 (0.26)	0 (0.0)	5 (0.86)	0 (0.0)	3 (0.74)	1 (0.83)	11 (0.41)
Enterotomy	0 (0.0)	0 (0.0)	2 (0.34)	2 (0.55)	5 (1.24)	1 (0.83)	10 (0.37)
Urethral injury	0 (0.0)	1 (0.21)	1 (0.17)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.074)
Blood transfusion	1 (0.13)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.25)	0 (0.0)	2 (0.074)
Iliac vein injury	1 (0.13)	0 (0.0)	0 (0.0)	1 (0.28)	0 (0.0)	0 (0.0)	2 (0.074)
Rectal injury	1 (0.13)	0 (0.0)	1 (0.17)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.074)
Postoperative							
Vaginal cuff dehiscence	4 (0.53)	0 (0.0)	3 (0.52)	4 (1.1)	1 (0.25)	0 (0.0)	12 (0.45)
Pelvic infection/abscess	4 (0.53)	4 (0.84)	19 (3.2)	1 (0.28)	2 (0.50)	0 (0.0)	30 (1.1)
Pulmonary embolus	1 (0.13)	1 (0.21)	0 (0.0)	0 (0.0)	1 (0.25)	0 (0.0)	3 (0.11)
Bacteremia	0 (0.0)	0 (0.0)	2 (0.34)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.074)
DVT	1 (0.13)	0 (0.0)	0 (0.0)	1 (0.28)	0 (0.0)	0 (0.0)	2 (0.074)
Cuff cellulitis	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.50)	0 (0.0)	2 (0.074)
Blood transfusion	0 (0.0)	0 (0.0)	1 (0.17)	0 (0.0)	1 (0.25)	0 (0.0)	2 (0.074)
Total cases	756	471	576	361	404	121	2689

[†]Only most common complications reported here; [‡]Includes multiple complications as dictated in operative notes, but counted as one event in statistical analysis to avoid double counting. EBL, estimated blood loss; DVT, deep vein thrombosis; LAVH, laparoscopic-assisted vaginal hysterectomy; LRH, laparoscopic retroperitoneal hysterectomy; LSH, laparoscopic supracervical hysterectomy; RALH, robotically assisted laparoscopic hysterectomy; TLH, total laparoscopic hysterectomy; TVH, total vaginal hysterectomy.

(Fig. 1). This is approximately half the cost of LSH, RALH, TLH and LAVH. The lower costs associated with LRH were attributed to the use of reusable instruments, shorter OT and LOS. RALH had the highest cost with an average of \$9354, ranging from \$6019 to \$19 815, which was driven primarily by disposable instruments, and longer OT and LOS (Table 4).

Value

We applied our value formula (value = quality/costs) to each hysterectomy procedure approach, where a

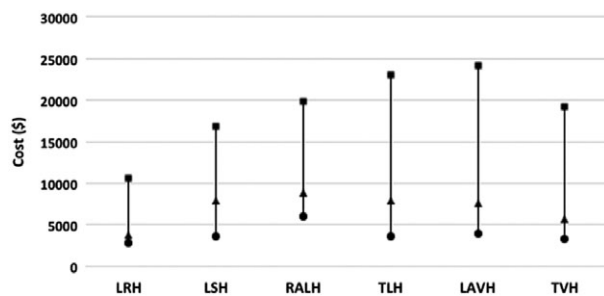


Figure 1 Estimated direct hospital costs by procedure. LAVH, laparoscopic-assisted vaginal hysterectomy; LRH, laparoscopic retroperitoneal hysterectomy; LSH, laparoscopic supracervical hysterectomy; RALH, robotic-assisted laparoscopic hysterectomy; TLH, total laparoscopic hysterectomy; TVH, total vaginal hysterectomy. (▲), Median; (●), Minimum; (■), Maximum.

summary composite score of the average OT, EBL, complication and conversion rates were calculated via equally weighted quartiles.²⁷ LRH (3.69), TVH (1.55) and LAVH (1.24) yielded the highest value scores, while TLH (0.96), RALH (0.86) and LSH (0.85) yielded the lowest scores. There was little meaningful difference between the lower scores.

Discussion

At a time when there is demand for more fiscal responsibility in healthcare and surgical care accounting for more than 40% of spending for inpatient care,⁷ constructing a reliable framework of the quality and the cost portions of the value equation is critical to evaluating surgical interventions. Rather than examining individual metrics alone, we used a value formula based on the CMS model to compare the value of the most common minimally invasive hysterectomy techniques.

LRH yielded the highest value score, driven by the low intraoperative complication rate and low costs. The low rate of intraoperative complications, which contributed to a shorter OT and LOS, is due in part to surgeon experience, but may also be attributed to the standard RPD, which allows for full visualization and lateralization of the ureters and early control of the blood supply by ligation of the uterine arteries at the

Table 4 Hospital costs

	LRH	LSH	RALH	TLH	LAVH	TVH
LOS at \$1043/day	208.60	730.10	1147.30	834.40	730.10	1251.60
Equipment †,‡	671.00	1915.00	2972.00	1915.00	1915.00	304.00
OR time at 29.22/min†	1577.90	4207.70	3272.60	3710.90	3652.50	3155.80
Anesth at 1.13/min†	61.00	162.70	126.60	143.50	141.30	122.00
Surgeon fee§	1181.00	1018.00	1181.00	1204.00	1181.00	859.00
Postop care (pharmacy + labs)†	353.00	331.00	591.00	530.00	353.00	505.00
Total Est. hospital Costs	4052.50	8364.50	9290.50	8337.80	7972.90	6197.40
Entire cohort at patient level						
Mean (SD)	4060.5 (931.9)	8227.1 (1898.9)	9353.8 (2103.9)	8372.1 (2531.8)	8054.5 (2352.6)	6415.8 (2331.1)
Median	3813.6	7888.3	8852.3	7898	7678.8	5776.3
Range	2781.7, 10 686.7	3597.8, 16 932.6	6018.7, 19 814.6	3679.3, 23 064.8	4025.7, 24 161.8	3257.3, 19 194.0
Total cases	756	471	576	361	404	121

†Based on information provided by hospital billing department hospital; ‡Equipment costs provided by hospital purchase department; equipment used in each procedure provided by senior OR nurse; §Based on 2014 OB/GYN Surgery Medicare reimbursement rates. Anesth, anesthesia; Est, estimate; Labs, laboratory; LAVH, laparoscopic-assisted vaginal hysterectomy; LOS, length of stay; LRH, laparoscopic retroperitoneal hysterectomy; LSH, laparoscopic supracervical hysterectomy; OR, operating room; Postop, postoperative; RALH, robotically assisted laparoscopic hysterectomy; SD, standard deviation; TLH, total laparoscopic hysterectomy; TVH, total vaginal hysterectomy.

vascular origin, thus minimizing hemorrhage and visceral injuries.

RALH had the highest rate of postoperative complications and was the most expensive procedure, yielding one of the lowest value scores. Despite its surge in popularity since the introduction of robotic surgery in 2005, the financial burden may not be justified when other hysterectomy techniques may equal or surpass the operative outcomes of robotics at much lower cost.

TVH had the highest rate of intraoperative complications of all procedures. Despite this fact, it had the lowest postoperative complication rate and lowest average cost, which yielded a higher value score than TLH, RALH, LAVH and LSH. It is noteworthy that the intraoperative complication rate for TVH in our study was higher than those reported in the literature. This is in part because the surgeons performing TVH were low volume surgeons (only five TVH cases were performed by high-volume surgeons).

Any discussion on value must also be considered within the context of surgeon training and expertise, as studies have shown that surgeon volume and experience are important factors influencing operative outcomes.^{28,29} While LRH had the highest value score, this surgical approach requires the advanced skills of an experienced laparoscopist. Arguably, if all gynecologists started performing LRH tomorrow, there would likely be an increased rate of complications,

OT, and cost. Therefore, in the pursuit of *value* in surgical care delivery, we suggest referrals to minimally invasive surgical specialists, along with a greater emphasis in residency and fellowship training programs on hysterectomy approaches and techniques that offer proven surgical outcomes at lower costs.

Limitations

The current study has several limitations. Its retrospective nature is limited by inherent selection bias. The availability and accuracy of the medical records, as well as transcription errors, also remain intrinsic limitations.

All hospital data on reoperation and readmittance within 60 days were collected; however, the total number of postoperative complications may be underreported, as patients with adverse events may have been seen in their physician's office or at a different hospital. In the same vein, we were not able to capture the costs of readmissions or re-operations, however, these occurrences are reflected in the complication rates.

Furthermore, LOS was included in the cost analysis, but it should be noted that LOS is often a protocol-driven outcome; it can be as much influenced by surgeon preference and the time of day of the procedure, as by the condition of the patient. However, when we omitted LOS from the cost

calculation, it did not change the ranking of the value scores.

Additionally, the three surgeons who performed the majority of the LRH procedures, and the two surgeons who performed the majority of the RALH procedures, are all skilled, high-volume laparoscopists, who are especially proficient in the reported technique and may not represent the general experience of the surgical community. As high-volume surgeons are associated with better surgical outcomes,³⁰ we attempted to make meaningful comparisons by controlling for surgeon volume as an independent covariate in our regression models.

Although the U.S. Panel on Cost Effectiveness in Health and Medicine recommends microcosting as the preferred approach to cost estimation,³¹ one of the limitations of this approach is that it lacks external validity; there is a limit to the extent that one can generalize to other settings. It should also be noted that costs were calculated from a healthcare system perspective, incorporating direct hospitalization costs associated with each procedure. A more rigorous cost analysis should also incorporate the costs from a societal perspective, including the indirect costs to society, such as lost wages from work absence and differential productivity costs. Additionally, while much of the conversation has centered around outcomes and costs, it is imperative that these value assessments also consider the experience of the most central player in the healthcare system: the patient.³² In order to build a more rigorous value model that includes the patient perspective, future studies should incorporate measures of the patient experience, including the time to return to normal daily activity for each surgical procedure, as well as changes in the patient's quality of life using a validated quality of life instrument.

Furthermore, our operational definitions may not accurately capture the intended construct of 'value'. Defining and operationalizing value in the context of surgical care is challenging, as there are no agreed upon standards for measuring the benefits provided (quality) nor resources used (costs). This remains one of the inherent limitations in measuring value; how it is defined dictates how the input measures are selected and weighted. Our value ratio was based on a summary composite score of short-term operative outcomes using equally weighted quartiles. Because this specific approach has not been used in previous studies, there is no assessment of the reliability and validity of measures combining quality and cost. However, we did not find an alternative approach

for combining quality and cost measures into quantifiable measures of value to evaluate surgical modalities.

Past studies on hysterectomy have considered operative outcomes and cost separately, but in today's value-driven healthcare marketplace, it is important to evaluate surgical outcomes relative to cost. To our knowledge, ours is the only study to attempt to quantify the value of the most common minimally invasive hysterectomy techniques. While the application of the value equation introduced in this study is untested, it is an attempt to refocus research efforts on the concept of value in the context of surgical care, and to open a dialogue regarding a value-based evaluation model. This type of equation can be applied to any surgical intervention across surgical specialties, and is a potentially effective tool for the ongoing quest to provide quality care while controlling costs in today's value-driven healthcare market.

Acknowledgments

We would like to thank June Kyrk, Kim Williams, Patty Smith, Kellie Washington, and Sandra Staicu for their diligent data abstraction. Dr. Britton Chahine provided guidance in data collection and contributed to the first draft of this paper. We would also like to thank Dr. Stella Blosser Lii for her critical review and recommendations regarding this publication; Nilofar Kazi and Laila Kazi for their help in preparing the manuscript; as well as The Center for Innovative GYN Care for its continued commitment to excellence in research.

Disclosure

The authors declare they have no conflict of interest. Data abstractors were independent contractors with no vested interest in The Center for Innovative GYN Care. Dr. N. Danilyants and Dr. P. MacKoul are both co-owners of The Center for Innovative GYN Care, and while they contributed to writing and editing of the manuscript, neither Dr. N. Danilyants nor Dr. P. MacKoul played a role in the collection, analysis, or interpretation of the data. Dr. R. Baxi and Dr. L. Q. van der Does are employed by The Center for Innovative GYN Care.

References

- Callahan D. Health care costs and medical technology. In: Crowley M (ed). *From Birth to Death and Bench to Clinic: The Hastings Center Bioethics Briefing Book for Journalists, Policy-makers and Campaigns*. Garrison, NY: The Hastings Center, 2008; 79–82.
- The affordable care act and trends in health care spending. 2013. [Cited 5 May 2015.]. Available from URL: https://obamawhitehouse.archives.gov/sites/default/files/docs/fact_sheet_implementing_the_affordable_care_act_from_the_erp_2013_final1.pdf
- Cutler DM, McClellan M. Is technological change in medicine worth it? *Health Aff* 2001; **20** (5): 11–29.
- Yong PL, Olsen LA, McGinnis JM. *Value in Health Care: Accounting for Cost, Quality, Safety, Outcomes and Innovation. Workshop Summary*. Washington, DC: National Academies Press, 2010.
- Wieand E, Lagrew DC. Value-based payment: What does it mean, and how can ObGyns get out ahead? *OBG Manag* 2018; **30** (1): 17–19, 25–26.
- Porter ME. What is value in health care? *N Engl J Med* 2010; **363**: 2477–2481. <https://doi.org/10.1056/NEJMp1011024>.
- Steiner C, Karaca Z, Moore B, Imshaug M, Pickens G. Surgeries in hospital-based ambulatory surgery and hospital inpatient settings [Internet]. HCUP Statistical Brief #223. [Hcup-us.ahrq.gov](http://www.hcup-us.ahrq.gov); 2014 [Cited 5 Jan 2018.] Available from URL: <http://www.hcup-us.ahrq.gov/reports/statbriefs/sb223-Ambulatory-Inpatient-Surgeries-2014.pdf>
- Kohler C, Hasenbein K, Klemm P, Tozzi R, Schneider A. Laparoscopic-assisted vaginal hysterectomy with lateral transection of the uterine vessels. *Surg Endosc* 2003; **17**: 485–490.
- Roman H, Zanati J, Friederich L, Resch B, Lena E, Marpeau L. Laparoscopic hysterectomy of large uteri with uterine artery coagulation at its origin. *JSLs* 2008; **12** (1): 25–29.
- Peters A, Stuparich MA, Mansuria SM, Lee TT. Anatomic vascular considerations in uterine artery ligation at its origin during laparoscopic hysterectomies. *Am J Obstet Gynecol* 2016; **215** (3, 3): 393.e1. <https://doi.org/10.1016/j.ajog.2016.06.004>.
- Volpi E, Bernardini L, Angeloni M, Cosma S, Mannella P. Retroperitoneal and retrograde total laparoscopic hysterectomy as a standard treatment in a community hospital. *Eur J Obstet Gynecol Reprod Biol* 2014; **172**: 97–101. <https://doi.org/10.1016/j.ejogrb.2013.10.013>.
- Kale A, Aksu S, Terzi H, Demirayak G, Turkay U, Sendag F. Uterine artery ligation at the beginning of total laparoscopic hysterectomy reduces total blood loss and operation duration. *J Obstet Gynaecol*. 2015; **35** (6): 612–615. <https://doi.org/10.3109/01443615.2014.990431>.
- Trivedi PH, Parekh NA, Trivedi SP, Gandhi AC. Tackling uterine artery at the origin is safe and effective for TLH. *J Minim Invasive Gynecol* 2015; **22** (6S): S106. <https://doi.org/10.1016/j.jmig.2015.08.286>.
- Sinha R, Sundaram M, Nikam YA, Hegde A, Mahajan C. Total laparoscopic hysterectomy with earlier uterine artery ligation. *J Minim Invasive Gynecol* 2008; **15** (3): 355–359. <https://doi.org/10.1016/j.jmig.2008.01.012>.
- Poojari VG, Bhat VV, Bhat R. Total laparoscopic hysterectomy with prior uterine artery ligation at its origin. *Int J Reprod Med* 2014; **2014**: 1–4. <https://doi.org/10.1155/2014/420926>.
- Lii SJ, Becker SF, Danilyants NE, Mackoul PJ. A novel approach to total laparoscopic hysterectomy using only two 5mm ports: initial clinical experience. *J Minim Invasive Gynecol* 2010; **17**: S87. <https://doi.org/10.1016/j.jmig.2010.08.381>.
- Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care* 1998; **36**: 8–27.
- Wright JD, Ananth CV, Lewin SN *et al*. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. *JAMA* 2013; **309**: 689–698.
- Barnett JC, Judd JP, Wu JM, Scales CD Jr, Myers ER, Havrilesky LJ. Cost comparison among robotic, laparoscopic, and open hysterectomy for endometrial cancer. *Obstet Gynecol* 2010; **116**: 685–693.
- Frick KD. Microcosting quantity data collection methods. *Med Care* 2009; **47**: S76–S81. <https://doi.org/10.1097/MLR.0b013e31819bc064>.
- Tan SS, Rutten FF, van Ineveld BM, Redekop WK, Hakkaart-van Roijen L. Comparing methodologies for the cost estimation of hospital services. *Eur J Health Econ* 2009; **10**: 39–45. <https://doi.org/10.1007/s10198-008-0101-x>.
- Kessler D, McClellan M. *The Effects of Hospital Ownership on Medical Productivity*. Cambridge, MA: National Bureau of Economic Research, 2001.
- Ryan AM, Tompkins CP. Efficiency and value in healthcare: Linking cost and quality measures [Internet]. National Quality Forum. 2014 [Cited 10 July 2017.] Available from URL: http://www.qualityforum.org/Publications/2014/11/Efficiency_and_Value_in_Healthcare_Linking_Cost_and_Quality_Measures_Paper.aspx
- CMS publishes data on consumer satisfaction for hospitals. 2015. [Cited 15 Aug 2017.] Available from URL: <http://www.e-mds.com/cms-publishes-data-consumer-satisfaction-hospitals>
- Sarlos D, Kots L, Stevanovic N, Schaer G. Robotic hysterectomy versus conventional laparoscopic hysterectomy: outcome and cost analyses of a matched case-control study. *Eur J Obstet Gynecol Reprod Biol* 2010; **150**: 92–96.
- Pasic RP, Rizzo JA, Fang H, Ross S, Moore M, Gunnarsson C. Comparing robot-assisted with conventional laparoscopic hysterectomy: impact on cost and clinical outcomes. *J Minim Invasive Gynecol* 2010; **17** (6): 730–738. <https://doi.org/10.1016/j.jmig.2010.06.009>.
- Fenton JJ, Jerant AF, Bertakis KD. The cost of satisfaction; A national study of patient satisfaction, health care utilization, expenditures, and mortality. *Arch Intern Med* 2012; **172** (5): 405–411.
- Boyd LR, Novetsky AP, Curtin JP. Effect of surgical volume on route of hysterectomy and short-term morbidity. *Obstet Gynecol* 2010; **116**: 909–915.
- Twijnstra ARH, Kolkman W, Trimbos-Kemper GCM, Jansen FW. Implementation of advanced laparoscopic surgery in gynecology: national overview of trends. *J Minim Invasive Gynecol* 2010; **17**: 487–492.
- Vree FE, Cohen SL, Chavan N, Einarsson JI. The impact of surgeon volume on perioperative outcomes in hysterectomy.

- JSLs* 2014; **18** (2): 171–181. <https://doi.org/10.4293/108680813X13753907291594>.
31. Gold MR, Siegel JE, Russell LB, Weinstein MC. *Cost-Effectiveness in Health and Medicine*. New York, NY: Oxford University Press, 1996.
32. Chow A, Mayer EK, Darzi AW, Athanasiou T. Patient-reported outcome measures: the importance of patient satisfaction in surgery. *Surgery* 2009; **146** (3): 435–443. <https://doi.org/10.1016/j.surg.2009.03.019>.