HHS Public Access

Author manuscript

J Robot Surg. Author manuscript; available in PMC 2018 April 30.

Published in final edited form as:

J Robot Surg. 2015 December ; 9(4): 269–275. doi:10.1007/s11701-015-0526-z.

Cost comparison of robotic-assisted laparoscopic hysterectomy versus standard laparoscopic hysterectomy

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Abstract

The aim of the study was to assess if the cost of robotic-assisted total laparoscopic hysterectomy is similar to the cost of standard laparoscopic hysterectomy when performed by surgeons past their initial learning curve. A retrospective chart review of all hysterectomies was performed for benign indications without concomitant major procedures at Orange Coast Memorial Medical Center (OCMMC) and Saddleback Memorial Medical Center between January 1, 2013 and September 30, 2013. Robotic-assisted total laparoscopic hysterectomies (RTLH) and standard laparoscopic hysterectomies (LAVH and TLH) were compared. Data analyzed included only those hysterectomies performed by surgeons past their initial learning curve (minimum of 30 previous robotic cases). The primary outcome was the direct total cost of patient's hospitalization related to hysterectomy. The secondary outcomes were estimated blood loss, surgery time, and days in hospital post-surgery. A multiple linear regression model was applied to evaluate the difference between RTLH and LAVH/TLH in hospital cost, blood loss, and surgery time, while adjusting for hospital, patient's age, body mass index (BMI), whether or not the patient had previous abdominal/pelvic surgery, and uterine weight. The χ^2 test was applied to examine the association between hospital stay and surgery type. There were 93 hysterectomies (5 LAVH, 88 RTLH) performed at OCMMC and 90 hysterectomies (6 LAVH, 17 TLH, 67 RTLH) performed at Saddleback Memorial Medical Center. The hospitalization total cost result showed that, after adjusting for hospital, age, BMI, previous abdominal/pelvic surgery, and uterine weight, RTLH was not significantly more expensive than LAVH/TLH (mean diff. = $283.1, 95 % CI = [−569.6, 1135.9]; $p = 0.51$) at the 2 study hospitals. However, the cost at OCMMC was significantly higher than Saddleback Memorial Medical Center (mean diff. = $2008.7, 95 % CI = [1380.6, 2636.7]; $p < 0.0001$); and the cost increased significantly with uterine weight ($\beta = 3.8$, 95 % CI = [2.3, 5.3]; $p <$

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Compliance with ethical standards

Conflict of interest: MLW: Preceptor for Intuitive Surgical, SZL: None, DCL: None, GB: None.

0.0001). Further analysis showed significantly less blood loss (mean diff. = −78.5 ml, 95 % CI = [−116.8, −40.3]; $p < 0.0001$) and shorter surgery time (mean diff. = −21.9 min., 95 % CI = [−39.6, −4.2]; $p = 0.016$) for RTLH versus LAVH/TLH. There was no significant association between hospital stay and surgery type ($p = 0.43$). After adjusting for patient-level covariates, there was no statistically significant cost difference of performing robotically assisted laparoscopic hysterectomy versus standard laparoscopic hysterectomy when performed by surgeons past their initial learning curve at two community hospitals.

Keywords

Robotic; Hysterectomy; Cost

Introduction

The use of robotic-assisted surgery has rapidly increased in the last 10 years. Approximately one-third of all hysterectomies for benign indications and three quarters of all hysterectomies for malignant indications are performed using robotic assistance [1, 2].

As the adoption of robotic-assisted surgery has increased in gynecology, there remains concern regarding a higher cost associated with robotic assistance [3–15]. A previous cohort study of over 264,000 patients showed the cost of robotic-assisted hysterectomy to be nearly $2200 more than standard laparoscopic hysterectomy [3]. In a subsequent analysis, the cost of robotic-assisted hysterectomy decreased with both surgeon and hospital experience but was still significantly more expensive than standard laparoscopic hysterectomy [13]. This analysis did not evaluate surgical difficulty or compare weight of uteri removed.

In an analysis of a gynecologic surgical group transitioning to robotic-assisted surgery, significant reductions in operating room time and ability to treat more complex pathology were seen as surgical experience progressed beyond the initial learning curve [16].

Virtually, all prior cost studies have been limited by comparing outcomes and costs between experienced laparoscopic surgeons with novice robotic surgeons who were early in their learning curve [3–15]. Also, definition of cost varies greatly from institution to institution. Technology has advanced rapidly since robotic-assisted hysterectomy obtained FDA approval in 2005. Advancements that could decrease operative time include a more ergonomic robotic platform (SI™), use of a reduced waveform bipolar device with a cutting blade (Vessel Sealer™) and software updates to be able to control multiple energy sources (Smart Pedal™). The efficiency derived from technological advances could decrease cost.

The objective of this study is to compare the cost of robotic-assisted laparoscopic hysterectomy (RTLH) versus the cost of standard laparoscopic hysterectomy when performed by surgeons past their respective laparoscopic and robotic initial learning curves [17–19].

Materials and methods

This study was approved by the MemorialCare Health System Institutional Review Board, Project Number 351-14CR. A retrospective chart review was performed of all hysterectomies with benign indications without concomitant major procedures at Orange Coast Memorial Medical Center (OCMMC) in Fountain Valley, California and Saddleback Memorial Medical Center (SMMC) in Laguna Hills, California between January 1, 2013 and September 30, 2013. Both of these hospitals are part of the MemorialCare Health System and have uniform methods of attributing cost. For robotic-assisted surgeries, both hospitals use the DaVinci Si™ platform, both use SmartPedal™ software and had Vessel Sealer™ availability. Robotic-assisted total laparoscopic hysterectomies (RTLH) and standard laparoscopic hysterectomies:laparoscopic-assisted vaginal hysterectomy (LAVH) and total laparoscopic hysterectomy (TLH) were compared. Data analyzed included only those hysterectomies performed by fourteen surgeons past their initial learning curve (greater than or equal to 30 previous robotic-assisted surgeries). There were ten surgeons in the standard laparoscopic group. They had been well trained in laparoscopy in their residency and/or have been in private practice for many years. They all had performed well over 30 previous laparoscopic hysterectomies in addition to hundreds of previous operative laparoscopies. The primary outcome was the direct total cost of patients' hospitalization related to hysterectomy. Direct costs were determined by the hospitals' accounting departments and are defined as the actual cost of total hospital care. This included operating room time costs, operating room reusable and disposable instrument costs, staff, hospital regular floor room rate, pharmacy, and laboratory costs. The acquisition and maintenance cost of the DaVinci robot were accounted for in the operating room reusable instrument costs. The secondary outcomes were estimated blood loss, surgery time, and days in hospital post-surgery.

Statistical analysis

The two-sample t test was first applied to evaluate if there is a difference in patients' characteristics between those with RTLH and standard laparoscopic hysterectomy (LAVH/TLH). The t test was also used to compare the uterine weight, hospital cost, blood loss, and surgery time between surgery groups and between hospitals without considering any effect of covariates. Further, the linear regression model was utilized to evaluate the difference between LAVH/TLH and RTLH in hospital cost, blood loss, and surgery time, while adjusting for hospital, patient's age, and body mass index (BMI), whether or not the patient had previous abdominal or pelvic surgery, and uterine weight. The χ^2 test was applied to examine if the rate of previous abdominal surgery or the days of hospital stay was different between the two surgery groups. For summary statistics, data were presented as mean ± standard deviation (SD) or frequency and percentage. For the results from linear regression model, the mean difference between groups or the mean change (slope, β) of outcome (e.g., hospitalization cost) for every unit change in predictor (e.g., 1 year increase in age), the corresponding 95 % confidence interval and p value from F-test were presented. The significance level was set a 0.05 and all analyses were performed using SAS 9.4 (Cary, NC).

Results

Basic characteristics

From January 1, 2013 to September 30, 2013, there were 183 hysterectomies performed (28 LAVH/TLH, 155 RTLH); 93 hysterectomies (5 LAVH, 88 RTLH) performed at OCMMC and 90 hysterectomies (6 LAVH, 17 TLH, 67 RTLH) performed at SMMC. The mean (and SD) age of patients was 47.8 ± 9.3 years, the mean BMI was 28.7 ± 7.1 (kg/m^{-2}), the mean gravidity was 2.2 ± 1.7, and the mean parity was 1.8 ± 1.4. About 55 % of patients had previous abdominal or pelvic surgery and among them 87 % underwent RTLH, while among the 45 % patients with no previous abdominal or pelvic surgery, 82 % underwent RTLH. There was no difference between the two surgery groups in patients' basic characteristics. Table 1 summarizes the patients' basic characteristics by hospital and surgery type.

Surgery and hospitalization—no adjustment

Table 2 shows the summary statistics for patients' surgery/hospitalization information related to hysterectomy. The uterine weight was significantly greater in the RTLH group ($p < 0.0001$), and 43 out of 44 subjects with uterine weight ≥ 250 g were operated with RTLH. Without adjusting for any covariate, the hospital cost was significantly higher for RTLH ($p < 0.0001$), but the difference in blood loss ($p = 0.11$) and surgery time ($p = 0.22$) was not significant between the two surgery groups. Over 90 % of patients were discharged from the hospital in one day, and only one patient stayed in the hospital over 2 days. There was no association between hospital stay and surgery type ($p = 0.43$). In addition, the hospital cost was significantly higher at OCMMC ($p < 0.0001$) and the surgery time was significantly longer at OCMMC ($p = 0.022$).

Surgery and hospitalization—adjusting for covariates

Hospitalization Total Cost: After adjusting for hospital, age, BMI, previous abdominal or pelvic surgery, and uterine weight using a linear regression model, we found the cost for RTLH was higher but not statistically significant than LAVH/TLH (mean diff. = $283.1, 95 % CI = [−569.6, 1135.9]; $p = 0.51$) in the two study hospitals. As to the effect of covariates, the cost at OCMMC was significantly higher than SMMC (mean diff. = $2008.7, 95 % CI = [1380.6, 2636.7]; $p < 0.0001$), and the cost increased significantly with age (β = $37.4/year, 95 % CI = [5.9, 69.0]; $p = 0.021$) and uterine weight (β = $3.8/g, 95 % CI = [2.3, 5.3]; $p < 0.0001$). There was not a significant effect on cost from BMI ($p = 0.071$) or previous abdominal or pelvic surgery ($p = 0.36$).

Blood loss and surgery time—In the two study hospitals, the estimated blood loss was significantly less for RTLH (mean diff. = 78.5 ml, 95 % CI = [40.3, 116.8]; $p < 0.0001$), and significantly increased with uterine weight ($\beta = 0.32$ ml/g, 95 % CI = [0.25, 0.38]; $p < 0.0001$). The surgery time was significantly shorter for RTLH (mean diff. = 21.9 min., 95 % CI = [4.2, 39.6]; $p = 0.016$), significantly shorter at SMMC (mean diff. = 34.4 min., 95 % CI = [21.4, 47.5]; $p < 0.0001$), and significantly increased with uterine weight ($\beta = 0.16$ min./g, 95 % CI = [0.13, 0.19]; $p < 0.0001$). Table 3 shows the summary statistics for patients' surgery/hospitalization related to hysterectomy after adjusting for covariates.

Uterine weight < 250 g—Since uterine weight significantly affects the cost, blood loss, and surgery time, a separate model was performed only for patients with uterine weight <250 g (27 LAVH/TLH, 112 RTLH). The conclusion was similar to all patients as described above except uterine weight became not significant. After adjusting for hospital, age, BMI, previous abdominal or pelvic surgery, and uterine weight, the mean difference (RTLH–LAVH/TLH) in hospitalization cost was $123.4 (95 % CI = [−735.3, 982.1]; $p = 0.78$); the mean difference (LAVH/TLH–RTLH) in blood loss was 66.5 ml (95 % CI = [36.1, 97.0]; $p < 0.0001$); and the mean difference (LAVH/TLH-RTLH) in surgery time was 25.2 min. (95 % CI = [11.4, 38.9]; $p = 0.0004$). Without adjusting for any covariate, the hospitalization cost was significantly higher for RTLH ($p = 0.007$), the blood loss was significantly less for RTLH ($p = 0.007$), and there was no significant difference in uterine weight ($p = 0.49$) and surgery time ($p = 0.37$). Table 4 provides summary statistics for uterine weight less than 250 g. Table 5 provides summary statistics for uterine weight less than 250 g after adjusting for covariates.

Complications—There were no significant complications, readmissions, or conversions in the standard laparoscopic hysterectomy group. From the RTLH group, there were seven patients with significant complications including three readmissions. Reasons for readmission were urinary tract injury, pyelonephritis, and post-operative hemorrhage. The total cost of the three readmissions was $8710.00, which was an additional 0.7 % to the total robotic-assisted hysterectomy cost of $1,241,936. There were two conversions to total abdominal hysterectomy in the RTLH group secondary to severe adhesions. Table 6 shows the summary of RTLH complications, readmissions, and conversions by hospital.

Discussion

The results of our study showed that without adjusting for patient-level covariates, the cost of RTLH was significantly higher than standard laparoscopic hysterectomy as shown in other studies [3–15]. However, after adjusting for hospital and patient-level covariates, the hospital cost was not significantly more expensive for RTLH performed by surgeons past their initial learning curve at two separate community hospitals.

In both hospitals, a high volume of robotic-assisted hysterectomy was seen compared to standard laparoscopic hysterectomy. The average uterine weight was higher in the robotic-assisted group. There was no difference in operative time and estimated blood loss between the two surgery groups when no covariate effect is considered. However, after adjusting for covariates, the operative time and estimated blood loss were lower in the robotic-assisted group. There was no difference in length of stay.

The strength of the study is the usage of two separate community hospitals, where individual patient data could be incorporated into a multiple linear regression analysis so the comparison between robotic-assisted and standard laparoscopic hysterectomy could be adjusted for patient-level covariates. Our study adjusted for variables that might affect surgical complexity and cost such as uterine weight, age, BMI, and previous abdominal or pelvic surgery. After these adjustments, the cost of performing robotic-assisted hysterectomy was not significantly higher than performing standard laparoscopic hysterectomy. In

addition, using the hospitals' accounting department costs for total patient care per hospitalization (not charges or reimbursement), we had an accurate comparison of cost data.

There are several limitations to this study. This was a retrospective cohort study that was limited by the time period and the surgeons' preference for the type of hysterectomy performed. The time period was chosen for the surgeons to achieve proficiency at robotic surgery beyond the initial learning curve and make effective use of the available advanced technology that continues to progress. However, during the study period, the majority of hysterectomies had been shifted to robotic assistance, thus the sample for standard laparoscopic hysterectomy was small. At both hospitals, larger uteri (greater than 500 g) were treated almost exclusively with robotic-assisted surgery, not allowing a direct comparison of women with a large uterus. The standard laparoscopic hysterectomy group had no complications while the robotic-assisted hysterectomy group had a complication rate of 3.7 %. This difference is likely due to the high adoption of robotic surgery at both hospitals, the low number of standard laparoscopic hysterectomies performed, and more complex surgery (larger uteri) was performed with robotic assistance. Any complication costs from the original hospitalization would have been included. Since the readmission rate was so low and the readmission cost was less than 1 %, of the total costs, this was not reflected in our analysis. Our study would need larger numbers for readmission costs to be meaningful. A recent study with larger numbers showed a decrease readmission rate and lower overall costs with robotic-assisted hysterectomies versus all other types of hysterectomies [20].

Many factors contribute to the degree of surgical difficulty including uterine weight. To attempt to better compare the cost of hysterectomies with a similar degree of difficulty, a sub-analysis was performed for uterine weight less than 250 g. In this analysis, the cost was not significantly different. The surgical operative time was significantly decreased in the RTLH group. Our results differed with previous studies that showed greater cost and longer operative time with robotic-assisted hysterectomy [3–15]. Factors that may contribute to our findings include that robotic surgeons' were past their initial learning curves, both hospitals having extensive experience performing robotic hysterectomy prior to our study period, and our study time period (2013) reflecting latest advances in robotic technology. Since the majority of standard laparoscopic hysterectomies were in this subgroup (under 250 g), this enabled a better direct comparison of surgeries of similar difficulty.

Both hospital cost and operative time at OCMMC were significantly higher than SMMC. Comparison of RTLH at both hospitals showed a mean decrease in operating room time of 23 min at SMMC. A partial explanation may be a technique variation in robotic surgery as SMMC surgeons used Vessel Sealer™ as the main energy source for most hysterectomies and OCMMC surgeons used a plasma kinetic bipolar device. The use of the Vessel Sealer™ appeared to reduce operative time, which is a significant factor of cost. This may be an example of advancing technology improving surgical efficiency. Further studies need to be performed to validate this finding.

Conclusion

In a recent economic analysis, an $800 increase was seen in robotic-assisted hysterectomy, even among surgeons who performed greater than 50 previous robotic surgeries [13] but this did not take into account the very experienced surgeons (greater than 100 cases) or complexity of surgery. A recently published randomized prospective comparison of robotic-assisted versus standard laparoscopic hysterectomy showed no significant cost difference [21]. This study had several similar elements to our study including hospital and surgeons experienced in robotic-assisted surgery and their results support our findings. Our study suggests that robotic-assisted hysterectomy may be similar in cost to standard laparoscopic hysterectomy when considering patients' characteristics. However, the results from our study are limited to two community hospitals in Southern California with a small sample size. The pattern may or may not be the same as other hospitals in the United States. This should be evaluated further with a population study or a larger multicenter study.

Acknowledgments

None, SZL: Statistical Analysis was partially supported by the National Center for Advancing Translational Sciences, National Institutes of Health through grant UL1 TR000153. DCL: None, GB: None.

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Table 1

Summary statistics for patients' basic characteristics

Surgery type	**OCMMC**		**SMMC**		**Combined**	
Sample size	**LAVH 5**	**RTLH 88**	**LAVH/TLH 23**	**RTLH 67**	**LAVH/TLH 28**	**RTLH 155**
Age (years)[a]	47.6 ± 15.3	47.0 ± 9.8	47.2 ± 8.8	49.1 ± 8.3	47.3 ± 9.9	47.9 ± 9.2
BMI (kg/m^2)[a]	29.5 ± 8.8	30.1 ± 8.0 (n = 83)	26.8 ± 5.9	27.6 ± 5.8	27.3 ± 6.4	29.0 ± 7.2 (n = 150)
Gravidity[a]	3.4 ± 0.9	2.0 ± 1.9	2.4 ± 1.3 (n = 17)	2.3 ± 1.6 (n = 62)	2.6 ± 1.3 (n = 22)	2.2 ± 1.8 (n = 150)
Parity[a]	2.2 ± 0.8	1.7 ± 1.6	1.9 ± 1.1 (n = 17)	1.8 ± 1.1 (n = 62)	2.0 ± 1.0 (n = 22)	1.8 ± 1.4 (n = 150)
Previous abdominal or pelvic surgery[b]						
Yes	3 (60 %)	44 (50 %)	10 (43.5 %)	44 (65.7 %)	13 (46.4 %)	88 (56.8 %)
No	2 (40 %)	44 (50 %)	13 (56.5 %)	23 (34.3 %)	15 (53.6 %)	67 (43.2 %)

[a]Presented are mean ± SD

[b]Presented are frequency and column percentage

Table 2

Summary statistics of surgery/hospitalization information related to hysterectomy for all patients

Surgery type	**OCMMC**		**SMMC**		**Combined**	
Sample size	**LAVH 5**	**RTLH 88**	**LAVH/TLH 23**	**RTLH 67**	**LAVH/TLH 28**	**RTLH 155**
Uterine weight (grams)[a]	107.2 ± 86.2	207.9 ± 209.7	140.5 ± 70.7	274.1 ± 227.0	134.6 ± 73.1	236.5 ± 219.1
Estimated blood loss (milliliters)[a]	135.0 ± 151.7	99.5 ± 121.0 (n = 86)	130.4 ± 86.3	91.4 ± 87.0	131.3 ± 97.3	96.0 ± 107.4
Surgery elapsed time (minutes)[a]	135.4 ± 44.4	133.1 ± 58.5	109.2 ± 26.9	110.1 ± 47.8	113.9 ± 31.4	123.2 ± 55.2
Hospitalization total cost (dollars)[a,b]	8304.7 ± 2561.5	8682.8 ± 1960.8	5983.6 ± 922.7	7002.1 ± 2464.3	6398.1 ± 1576.5	7956.3 ± 2339.3
Length of hospital stay from post-op to discharge[c]						
0 day	0 (0 %)	18 (20.5 %)	2 (8.7 %)	8 (11.9 %)	2 (7.1 %)	26 (16.8 %)
1 day	3 (60 %)	61 (69.3 %)	20 (87.0 %)	54 (80.6 %)	23 (82.1 %)	115 (74.2 %)
≥2 days	2 (40 %)	9 (10.2 %)	1 (4.3 %)	5 (7.5 %)	3 (10.7 %)	14 (9.0 %)

[a] Presented are mean ± SD

[b] Include operating room cost (OR time, reusable and disposable instrument costs), regular floor room cost, laboratory, pharmacy, and staff costs

[c] Presented are frequency and column percentage

Table 3

Adjusted summary statistics of surgery/hospitalization information related to hysterectomy for all patients (adjusted for covariates)

Procedure	**Mean cost difference**	**% CI**	***p***
RTLH:LAVH/TLH	+$283.1	95 % [−569.6, 1134.9]	0.51
Procedure	Mean blood loss	% CI	*p*
RTLH:LAVH/TLH	−78.5 ml	95 % [40.3, 116.8]	<0.0001
Procedure	Surgery elapsed time	% CI	*p*
RTLH:LAVH/TLH	−21.9 min	95 % [4.2, 39.6]	0.016

Table 4

Summary statistics of surgery/hospitalization information related to hysterectomy for patients whose uterine weight <250 g

Surgery type **Sample size**	**LAVH/TLH** **27**	**RTLH** **112**
Uterine weight (grams)[a]	125.9 ± 57.7	134.4 ± 58.5
Estimated blood loss (milliliters)[a]	128.7 ± 98.2	72.6 ± 54.7 (n = 111)
Surgery elapsed time (minutes)[a]	113.4 ± 31.9	106.9 ± 34.3
Hospitalization total cost (dollars)[a,b]	6401.5 ± 1606.4	7627.6 ± 2189.3

[a]Presented are mean ± SD

[b]Include operating room cost (OR time, reusable and disposable instrument costs), regular floor room cost, laboratory, pharmacy, and staff costs

Table 5

Adjusted statistics of surgery/hospitalization information related to hysterectomy for patients whose uterine weight <250 g (adjusted for covariates)

Procedure	**Mean cost difference**	**% CI**	***p***
RTLH:LAVH/TLH	+$123.4	95 % [735.3, 982.1]	0.78
Procedure	Mean blood loss	% CI	*p*
RTLH:LAVH/TLH	−66.5 ml	95 % [36.1, 97.0]	<0.0001
Procedure	Surgery elapsed time	% CI	*p*
RTLH:LAVH/TLH	−25.2 min	95 % [11.4, 38.9]	0.0004

Table 6

Summary statistics of complications related to robotic-assisted hysterectomy

Hospital	OCMMC	SMMC	Combined
Sample size	93	90	183
Urinary tract injury	2 (2.2 %)	2 (2.2 %)	4 (2.2 %)
Pyelonephritis	1 (1.1 %)	0	1 (0.5 %)
Hemorrhage	1 (1.1 %)	0	1 (0.5 %)
Abscess	0	1 (1.1 %)	1 (0.5 %)
Readmissions	3 (3.2 %)	0	3 (1.6 %)
Conversions	1 (1.1 %)	1 (1.1 %)	2 (1.1 %)