Effect of a Disposable Automated Suturing Device on Cost and Operating Room Time in Benign Total Laparoscopic Hysterectomy Procedures

Stuart Hart, MD, Lobat Hashemi, MS, Craig J. Sobolewski, MD

ABSTRACT

Background and Objectives: To determine the effect of a disposable automated laparoscopic suturing device, the Endo Stitch (ES) (Covidien, Mansfield, MA, USA), on hospital cost and surgical time in patients undergoing a benign total laparoscopic hysterectomy procedure compared with the use of the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) or traditional laparoscopic suturing technique.

Methods: The Premier Perspective Database (Premier, Charlotte, NC, USA) was used to identify all inpatient hospital discharges with the primary procedure of a total laparoscopic hysterectomy (*International Classification of Diseases, Ninth Revision, Clinical Modification* code 68.41) for benign conditions between January 1, 2009, and June 30, 2011. Patients were further categorized into 3 groups: (1) those for whom the ES was used during the laparoscopic hysterectomy procedure, (2) those for whom robotic assistance (RA) was used, and (3) those for whom neither ES nor RA (NER) was used. Multivariate analysis was performed to examine the association among the ES, RA, and NER groups with respect to hospital cost, length of stay, and surgery time. The multivariate analysis controlled for the patient's age, race, severity of illness, and comorbid conditions, as well as hospital characteristics, such as bed size, region, and teaching status.

Results: A total of 9308 patients undergoing an inpatient total laparoscopic hysterectomy procedure between January 1, 2009, and June 30, 2011, were eligible for the study. The ES was used in 974 of the patients (10%), RA was used in 3971 (43%), and neither technique was used in 4363 (47%). After adjusting for confounding variables, the mean hospital cost was $1769 ($P = .0332$) lower, with a 42-minute ($P < .001$) surgery time savings, for the ES group compared with the RA group. The mean hospitalization cost for the ES group was also $634 ($P < .0879$) less expensive, with a 21-minute ($P = .0131$) surgery time savings, compared with the NER group.

Conclusion: Use of a disposable automated laparoscopic suturing device, the ES, is significantly more cost-effective than the use of the da Vinci surgical system or traditional laparoscopic suturing techniques for the performance of a total laparoscopic hysterectomy procedure for benign conditions.

Key Words: Total laparoscopic hysterectomy, Robotic-assisted total laparoscopic hysterectomy, Automated suturing device

Department of Obstetrics and Gynecology, USF Health Center for Advanced Medical Learning and Simulation, Morsani College of Medicine, University of South Florida, Tampa, FL, USA (Dr. Hart).

Healthcare Economics and Outcomes Research, Covidien, Mansfield, MA, USA (Dr. Hashemi).

Division of Minimally Invasive Gynecologic Surgery, Department of Obstetrics and Gynecology, Duke University, Durham, NC, USA (Dr. Sobolewski).

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Address correspondence to: Stuart Hart, MD, Department of Obstetrics and Gynecology, USF Health Center for Advanced Medical Learning and Simulation, Morsani College of Medicine, University of South Florida, Tampa, FL, USA. 124 South Franklin Street, Tampa, FL 33602, Telephone: (813) 259-8671, Fax: (813) 259-8671, E-mail: shart1@health.usf.edu

INTRODUCTION

Hysterectomy is the most common major gynecologic surgical procedure performed in the United States. Although there are more than 600 000 hysterectomies performed annually, most of these procedures (>65%) are performed through open laparotomy incisions and for benign indications. Overall, total laparoscopic hysterectomy represents only a small percentage of all hysterectomy procedures performed, despite the many benefits of this approach, including decreased postoperative pain and blood loss, shorter hospitalization and return to normal activity, fewer wound infections, and smaller reduction in hemoglobin levels.[1–5]

The poor adoption of the total laparoscopic hysterectomy procedure for benign conditions probably relates to several factors, including the steep learning curve and longer operative times of the procedure, as well as the development of the necessary laparoscopic suturing skills.[4–10] Gynecologic

surgeons have more recently adopted robotic-assisted hysterectomy as a way to mitigate some of the challenges associated with the total laparoscopic hysterectomy procedure while maintaining many benefits of the laparoscopic surgical approach. The da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA), the only Food and Drug Administration–approved robotic surgical platform for gynecologic surgery, offers an articulating wristed motion with 7 *df* that mimics many of the movements of the surgeon's hand, 3-dimensional stereoscopic visualization, and improved ergonomics. This may enable the surgeon to perform more natural laparoscopic suturing during vaginal cuff closure, which is often considered a rate-limiting step in developing the appropriate skills needed to perform the laparoscopic hysterectomy procedure.[9–17]

Despite these benefits, the cost of performing robotic-assisted hysterectomy procedures remains high, and such procedures may not result in any operating room time savings or overall improved outcomes.[14–17] The Endo Stitch (ES) (Covidien, Mansfield, MA, USA) is a disposable automated laparoscopic suturing device that allows the surgeon to perform efficient laparoscopic suturing using traditional laparoscopic surgical technique, without the associated steep learning curve of using needle drivers for laparoscopic suturing or the need for robotic surgical assistance. This device has been shown to reduce laparoscopic suturing and knot-tying time.[18–20] The following question is then raised: Can a disposable automated laparoscopic suturing device, by facilitating more efficient vaginal cuff closure, enable surgeons to perform more cost-effective total laparoscopic hysterectomy procedures for benign conditions? The goal of this study is to evaluate hospital cost and operating room time differences in the performance of an inpatient total laparoscopic hysterectomy procedure, by use of a large standardized multihospital database, to compare an ES-facilitated total laparoscopic hysterectomy for benign conditions and a total laparoscopic hysterectomy without the use of the device using traditional laparoscopic technique, as well as a robotic-assisted laparoscopic hysterectomy.

METHODS

Data Source

The University of South Florida Institutional Review Board reviewed the study and determined that Institutional Review Board approval was not necessary to conduct this study. A retrospective study was conducted using data from the database maintained by Premier (Premier Perspective Database [PPD]; Premier, Charlotte, NC, USA) (2010). The PPD is one of the largest hospital-based, service-level comparative databases in the United States, providing detailed resource utilization data along with patients' principal and secondary diagnoses and procedure codes. The PPD contains drug utilization data on >150 million hospital-outpatient visits and >45 million inpatient visits over the past 7-year period from >400 hospitals. This equates to approximately 1 of every 5 inpatient discharges in the United States. The PPD provides a broad perspective of patient discharge data from a variety of health systems, including not-for-profit, nongovernmental, community, and teaching hospitals.

The Uniform Billing–92 discharge forms provide data on demographic characteristics, discharge diagnoses, and discharge status (including death, but not its cause). Patient records in the PPD used for this study were deidentified in compliance with the Health Insurance Portability and Accountability Act of 1996. Each record in the PPD documents a single hospital discharge episode. The discharge record includes medical and surgical procedure codes (*International Classification of Diseases, Ninth Revision, Clinical Modification* [ICD-9-CM] procedure codes), hospital length of stay, and hospitalization cost. In the PPD costs are defined as the actual cost to treat the patient, which includes all supplies, labor, and depreciation of equipment. These costs include both fixed costs, which do not vary based on the volume of procedures performed, and variable costs, which are the direct costs and may vary based on the volume of procedures performed, hospital census, and average wholesale price. Hospitalization costs include, but are not limited to, costs associated with room and board (including the intensive care unit), surgery (including operating room costs), central supplies (including all medical devices and disposables such as staplers, sutures, and ES refills), anesthesia, laboratory, pharmacy, emergency department, pathology, blood bank, and ultrasonography. The cost of a device, such as an ES and its reloads, are included in central supplies. All direct hospital costs are reported, with the exception of the acquisition or maintenance costs of the da Vinci surgical system.

Study Population

All inpatient discharges with a primary procedure for a total laparoscopic hysterectomy (ICD-9-CM procedure code 68.41) between January 1, 2009, and June 30, 2011, were selected. Detailed billing data were used to search for the use of ES and robotic procedures. Patients were further categorized into 3 groups: (1) those for whom ES was used during the procedure, (2) those for whom robotic assistance (RA)

was used, and (3) those for whom neither ES nor RA (NER) was used. In addition to billing data, ICD-9-CM procedure code 17.42 (laparoscopic robotic-assisted procedures) was used to identify robotic-assisted surgery discharges. All patients with a primary diagnosis of cervical, uterine, ovarian, or tubal cancers were excluded because the performance of a laparoscopic hysterectomy in these patients is typically more complicated and time-consuming, these procedures are generally performed by subspecialist gynecologic oncologists, and these procedures are not reflective of most benign laparoscopic hysterectomy procedures performed in the United States.

Adjustment for Comorbid Conditions and Severity of Illness

The Charlson Comorbidity Index was used to identify comorbid conditions.[21] The Charlson Comorbidity Index was developed in 1987 and was based on 1-year mortality data from a New York hospital. Nineteen comorbidities were identified with this method (myocardial infarction, diabetes, etc.).

All Patient–Refined Diagnosis-Related Groups are a joint development of 3M Health Information Systems (3M™ Health Information Systems, Salt Lake City, UT) and the National Association of Children's Hospitals and Related Institutions. The All Patient–Refined Diagnosis-Related Groups expand the basic diagnosis-related group structure by adding 4 subclasses to each diagnosis-related group. The addition of 4 subclasses addresses patient differences related to severity of illness and risk of death. The severity of illness and risk of death relate to distinct patient attributes. The 4 severity-of-illness subclasses and the 4 risk-of-death subclasses are numbered sequentially from 1 to 4, indicating minor, moderate, major, and extreme severity of illness, respectively.[22]

Statistical Analysis

Descriptive statistics were calculated for patient demographic and hospital characteristics. Comparison of patient demographic and hospital characteristics was performed with 2-sided χ^2 tests for categorical variables and t tests for continuous variables. Multivariate analysis was performed to examine the association among the ES, RA, and NER groups with respect to hospital cost, length of stay, and surgery time. Hospital cost data were transformed by taking the natural log of the cost values to reduce the effects of skewed distribution. Generalized estimating equation models with gamma distribution and log-link function were used to measure the impact of the technique used on the out-

comes. Generalized estimating equation models represent an alternative generalization of generalized linear models that is often used to analyze correlated data. For patients treated in the same hospital, the overall cost and clinical outcomes are often correlated. The multivariate analysis controlled for the patient's age, race, severity of illness, and comorbid conditions, as well as hospital characteristics, such as bed size, region, and teaching status. Comorbid conditions included chronic obstructive pulmonary disease, diabetes, hypertension, and obesity. The analysis included clustering of patients receiving care from the same hospital. Statistical significance was evaluated at $\alpha = .05$. All analyses were performed with SAS software, version 9.1 (SAS Institute, Cary, NC, USA).

RESULTS

A total of 11133 patients with a primary procedure of an inpatient total laparoscopic hysterectomy between January 1, 2009, and June 30, 2011, were identified. All patients with a primary diagnosis of cervical, uterine, ovarian, or tubal cancers were excluded (n = 1825, 16.4%). Of the remaining 9308 patients, the ES was used in 974 (10%), RA was used in 3971 (43%), and neither technique was used in 4363 (47%) (**Figure 1**). Patients in the ES group were approximately 1.5 years younger than those in the RA and NER groups (**Table 1**). There were significantly more Hispanics in the ES group compared with the other 2 groups ($P < .001$). There was no difference in severity of illness among the 3 groups. Similarly, there were no differences in the number of patients with chronic pulmonary disease, diabetes, or non-obstetric/gynecologic cancers among the 3 groups. However, patients in the RA and NER groups had a higher rate of hypertension and obesity compared with the ES group. Teaching hospitals were more likely to use RA compared with the other 2 groups ($P < .001$).
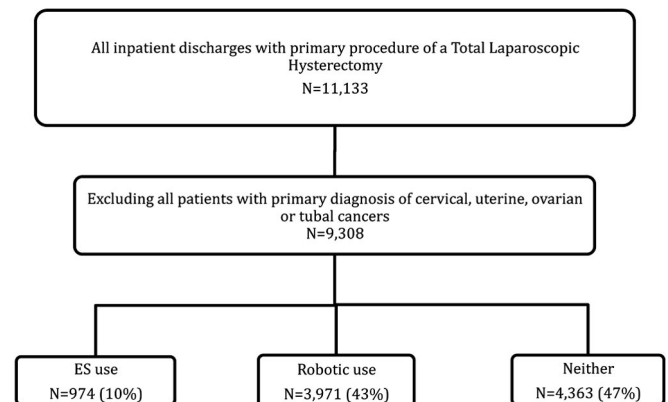

Figure 1. Patient selection flowchart.

Table 1.
Demographic Characteristics, Comorbid Conditions, and Hospital Characteristics for Patients With Use of ES, Use of RA, and Use of Neither Technique

	ES (n = 974), n (%)	RA (n = 3971), n (%)	P Value*	NER, n (%)	P Value†
Demographic characteristics					
Age, mean ± SD, y	44.3 ± 10	45.8 ± 11	<.001	45.7 ± 10	.0004
Race					
White	619 (63.6)	2909 (73.3)	<.001	2979 (68.3)	.0044
African American	127 (13.0)	469 (11.8)	.2913	568 (13.0)	.9863
Hispanic	91 (9.3)	201 (5.1)	<.001	192 (4.4)	<.001
Other	137 (14.1)	392 (9.9)	.0001	624 (14.3)	.8487
APR-DRG severity of illness					
Mild	715 (73.4)	2827 (71.2)	.1689	3136 (71.9)	.335
Moderate	232 (23.8)	1051 (26.5)	.0912	1107 (25.4)	.312
Severe	23 (2.4)	83 (2.1)	.6004	107 (2.5)	.8676
Extreme	4 (0.4)	8 (0.2)	.2344	13 (0.3)	.5724
Comorbid conditions					
Chronic pulmonary disease	107 (11)	425 (10.7)	.7984	435 (10.0)	.3428
Diabetes	52 (5.3)	296 (7.5)	.0207	306 (7.0)	.0589
Non-gynecologic primary cancer	24 (2.5)	88 (2.2)	.6411	73 (1.7)	.0948
Hypertension	198 (20.3)	987 (24.9)	.003	1062 (24.3)	.0077
Obesity	103 (10.6)	582 (14.7)	.001	556 (12.7)	.0629
Provider characteristics					
Region					
South	476 (48.9)	1308 (32.9)	<.001	1723 (39.5)	<.001
Northeast	179 (18.4)	664 (16.7)	.2179	885 (20.3)	.1782
Midwest	166 (17.0)	1301 (32.8)	<.001	1071 (24.6)	<.001
West	153 (15.7)	698 (17.6)	.1661	684 (15.7)	.9807
Hospital characteristics					
Teaching hospital	268 (27.5)	1423 (35.8)	<.001	1642 (37.6)	<.001
Urban	956 (98.2)	3104 (78.2)	<.001	3970 (91.0)	<.001
Hospital bed size					
<250	176 (18.1)	626 (15.8)	.0803	930 (21.3)	.038
250–500	366 (37.6)	2008 (50.6)	<.001	2369 (54.3)	<.001
>500	432 (44.4)	1337 (33.7)	<.001	1064 (24.4)	<.001

*For the ES and RA groups, the P value is based on χ^2 and t tests for categorical and continuous variables, respectively.
†For the ES and NER groups, the P value is based on χ^2 and t tests for categorical and continuous variables, respectively.
APR-DRG = All Patient–Refined Diagnosis-Related Group.

Tables 2 and **3** show the unadjusted differences in total hospital costs, departmental costs, length of stay, and surgery time for the ES group versus RA group and the ES group versus NER group, respectively. The use of RA for the laparoscopic hysterectomy procedure was asso-ciated with a higher mean hospitalization cost compared with the use of the ES alone, a difference of $1287 (P < .001). This higher cost was mostly because of a higher surgery cost ($2760 vs $3585, P < .001). The mean surgery time was significantly shorter for the ES

Table 2.
Unadjusted Hospital Cost, Departmental Cost, Length of Stay, Surgery Time, and Cost Between ES and RA Groups

	ES (n = 974)		RA (n = 3971)			
	Mean	95% Confidence Interval	Mean	95% Confidence Interval	Difference	P Value
Hospitalization cost, $	8073	7852, 8295	9360	9216, 9504	−1287	<.001
Room and board	1266	1184, 1348	1106	1069, 1142	160	.0002
Central supply	2249	2161, 2338	2718	2649, 2786	−469	<.001
Surgery	2760	2656, 2864	3583	3502, 3664	−823	<.001
Anesthesia	574	537, 612	446	432, 460	129	<.001
Pharmacy	379	356, 402	396	374, 419	−18	.2893
Laboratory	90	82, 98	102	97, 108	−12	.0437
Other	896	837, 954	1231	1188, 1273	−335	<.001
Hospital length of stay, d	1.53	1.46, 1.60	1.40	1.36, 1.43	0.14	.0008
Surgery time, min	163	157.90, 167.10	203.80	200.50, 207.00	−41.30	<.001
Surgery cost/min, $	17	17, 18	17	16, 17	0.81	.0539

Table 3.
Unadjusted Hospital Cost, Departmental Cost, Length of Stay, Surgery Time, and Cost Between ES and NER Groups

	ES (n = 974)		NER (n = 4363)			
	Mean	95% Confidence Interval	Mean	95% Confidence Interval	Difference	P Value
Hospitalization cost, $	8073	7852, 8295	8728	8556, 8900	−655	<.001
Room and board	1266	1184, 1348	1294	1223, 1365	−28	.6195
Central supply	2249	2161, 2338	2133	2083, 2183	117	.0249
Surgery	2760	2656, 2864	3435	3360, 3511	−675	<.001
Anesthesia	574	537, 612	572	553, 592	2	.9138
Pharmacy	379	356, 402	398	371, 425	−19	.2966
Laboratory	90	82, 98	113	106, 120	−23	<.001
Other	896	837, 954	948	916, 981	−53	.1229
Hospital length of stay, d	1.53	1.46, 1.60	1.54	1.49, 1.59	−0.01	.8798
Surgery time, min	163	158, 167	191	189, 193	−29	<.001
Surgery cost/min, $	17	17, 18	17	17, 18	0.27	.487

group compared with the RA group, a difference of 41 minutes ($P < .001$). The use of the ES was also associated with a lower mean hospitalization cost compared with the NER group, a difference of $655 ($P < .001$). This lower cost was mostly attributed to lower surgery cost ($2760 vs $3435, $P < .001$). The mean surgery time was significantly shorter for patients in whom the ES was used compared with the NER group, a difference of 29 minutes ($P < .001$).

The results of the multivariate analysis, adjusted for confounders (including patient's age, race, severity of illness, and comorbid conditions and hospital teaching status, region, and bed size) are shown in **Tables 4** and **5**. The mean hospital cost remained significantly lower for the ES group compared with the RA group after we adjusted for confounding variables, with the difference increasing to $1769 ($P = .0332$). Similar to the unadjusted results, most of the cost difference observed was because of a lower

Table 4.
Adjusted Hospital Cost, Departmental Cost, Length of Stay, Surgery Time, and Cost Between ES and RA Groups

	ES (n = 974)		RA (n = 3971)			
	Mean	95% Confidence Interval	Mean	95% Confidence Interval	Difference	*P* Value
Hospitalization cost, $	7859	6730, 9176	9628	9216, 9504	−1769	.0332
Room and board	1271	1078, 1500	1091	1069, 1142	180	.0523
Central supply	2333	1894, 2874	2686	2649, 2786	−352	.1934
Surgery	2572	1960, 3374	4120	3502, 3664	−1548	.0065
Anesthesia	474	373, 603	481	432, 460	−7	.8299
Pharmacy	346	301, 398	354	374, 419	−8	.7129
Laboratory	101	81, 126	110	173, 3	−10	.3363
Other	1126	912, 1392	1073	1188, 1273	53	.5237
Hospital length of stay, d	1.48	1.37, 1.60	1.39	1.30, 1.43	0.10	.062
Surgery time, min	176	154, 200	218	203, 234	−42.38	<.001
Surgery cost/min, $	14	11, 16	17	15, 21	−3.91	.0015

Table 5.
Adjusted Hospital Cost, Departmental Cost, Length of Stay, Surgery Time, and Cost Between ES and NER Groups

	ES (n = 974)		NER (n = 4363)			
	Mean	95% Confidence Interval	Mean	95% Confidence Interval	Difference	*P* Value
Hospitalization cost, $	8186	7475, 8966	8820	8282, 9394	−634	.0879
Room and board	1256	1052, 1500	1270	1129, 1428	−13	.6195
Central supply	2192	1928, 2493	1988	1795, 2202	205	.0511
Surgery	3142	2733, 3611	3745	3375, 4156	−603	.0225
Anesthesia	522	448, 609	554	478, 643	−32	.1114
Pharmacy	328	282, 381	354	308, 407	−26	.2544
Laboratory	92	75, 114	109	92, 128	−17	.0281
Other	917	778, 1081	939	820, 1076	−22	.6851
Hospital length of stay, d	1.44	1.32, 1.57	1.48	1.38, 1.58	−0.04	.3611
Surgery time, min	180	163, 199	201	192, 211	−21	.0103
Surgery cost/min, $	17	16, 19	19	17, 20	−1.45	.0131

mean surgery cost in the ES group compared with the RA group: $2572 compared with $4120 (*P* = .0065). The mean surgery time remained significantly shorter for patients in the ES group compared with the RA group, a difference of 42 minutes (*P* < .001).

The mean hospitalization cost for the ES group also remained lower in the adjusted data (though not significantly) compared with the NER group, a difference of $634 (*P* < .0879). The mean surgery cost for the ES group was significantly lower than that for the NER group, a difference of $603

(*P* = .0225). The mean surgery time was also significantly shorter for the ES group compared with the NER group, a difference of 21 minutes (*P* = .0103).

DISCUSSION

One of the significant limiting factors preventing more surgeons from shifting from an open abdominal hysterectomy to a total laparoscopic hysterectomy procedure is the ability to suture laparoscopically. Although both RA and the ES automated suturing device facilitate more ef-

ficient development of this skill set, this study suggests that a benign total laparoscopic hysterectomy performed with a disposable automated laparoscopic suturing device is significantly more cost-effective than when performed with the da Vinci surgical system or with traditional laparoscopic suturing technique. This is also consistent with the limited data available in the medical literature, which have shown that overall costs are reduced by use of traditional laparoscopic techniques, compared with RA, for the performance of a laparoscopic hysterectomy procedure.[14–16] As cost containment takes on even greater importance in the US health care system, lower-cost alternatives to more expensive technologies will increasingly become necessary, and economic outcomes data will be used more often in appropriate surgical instrumentation use decision making.

Despite the many advantages of performing a total laparoscopic hysterectomy, as well as the increasing popularity of this procedure, most hysterectomies in the United States are still performed by the open abdominal route. This appears to be partially related to the steep learning curve of the total laparoscopic hysterectomy procedure, as well as the limited exposure of residents to this procedure during training.[1–10] The da Vinci surgical system has several advantages over traditional laparoscopic instrumentation, including 3-dimensional visualization, 7-*df* wristed motion, and improved ergonomics. These advantages have been promoted as a way for gynecologic surgeons to reduce the steep learning curve of the total laparoscopic hysterectomy procedure, especially related to the development of laparoscopic suturing skills, which is essential for laparoscopic vaginal cuff closure and represents one of the most challenging aspects of this procedure.[4,9–17]

These advantages of the da Vinci surgical system have led to a more rapid adoption of robotic-assisted hysterectomy procedures,[23] although widespread use is still limited by cost, lack of haptic feedback, and insufficient clinical comparative data showing improved outcome over traditional laparoscopic hysterectomy procedures. A Cochrane Database Systematic Review in 2012 concluded that the limited evidence in the medical literature did not show the benefit of robotic surgery for women with benign gynecologic diseases, including hysterectomy, in terms of effectiveness or safety.[16] Although this review only evaluated 2 randomized clinical trials consisting of 158 women, the authors concluded that the robotic-assisted approach to benign gynecologic procedures may increase postoperative complications and cost, may lengthen the operating time, and

failed to show any superiority compared with laparoscopic surgery.

In 2010 Sarlos et al.[15] performed a prospective matched case-control study of their first 40 consecutive robotic-assisted hysterectomies for benign conditions and matched these cases 1:1 with their laparoscopic hysterectomy cases. They found that the robotic hysterectomy procedure was feasible and safe with a quick learning curve and that surgical outcomes (complications, conversion to laparotomy, intraoperative bleeding, and hospital stay) were comparable. They also found that robotic-assisted hysterectomy procedures were associated with longer operating room times and higher costs compared with the matched laparoscopic hysterectomy cases. The mean operating room time was 109 minutes versus 82.9 minutes and the mean cost was €4067 versus €2151 in the robotic-assisted hysterectomy group versus the laparoscopic hysterectomy group. Most of the cost difference, €2217 versus €822, was in the material costs of the procedure.

Also in 2010, Pasic et al.[14] examined data in the Premier hospital database on 36188 patients treated at 358 hospitals undergoing a laparoscopic hysterectomy in 2007 and 2008. In this study 1661 robotic-assisted hysterectomy procedures were compared with 34 527 traditional laparoscopic hysterectomy procedures. The authors found that both inpatient and outpatient robotic-assisted hysterectomy procedural costs and surgical times were significantly higher than those of laparoscopic hysterectomy procedures, without any difference in adverse events. Inpatient robotic-assisted hysterectomy procedures were approximately $2600 more expensive and 0.4 hours longer and outpatient robotic-assisted hysterectomy procedures were approximately $1900 more expensive and 0.5 hours longer than a laparoscopic hysterectomy procedure.

In our study the cost of performing a robotic-assisted hysterectomy was significantly greater than the cost of performing an ES-assisted total laparoscopic hysterectomy after we adjusted for confounders (including patients' age, race, severity of illness, and comorbid conditions, as well as hospital teaching status, region, and bed size). The hospital cost of a robotic-assisted laparoscopic hysterectomy ($9628), as compared with the ES-assisted total laparoscopic hysterectomy ($7859), showed a cost difference of $1769 per surgical case. Most of the additional hospital cost differences between these 2 techniques were related to the cost of surgery ($1548 difference) and longer operating times (42-minute difference), making the robotic-

assisted hysterectomy procedure substantially more expensive and time-consuming. Even with the additional cost of the ES device to facilitate laparoscopic suturing during a total laparoscopic hysterectomy procedure, it was still more cost-effective compared with performing a traditional laparoscopic hysterectomy procedure without the device, resulting in a $634 cost savings and 21-minute time savings.

The data in this study only examined costs directly related to hospitalization and did not take into account the acquisition and maintenance costs of the da Vinci surgical system. The da Vinci surgical system costs between $1.0 and $2.3 million, with an annual service agreement of $100,000 to $170,000. Instruments and accessories cost approximately $1300 to $2200 per surgical procedure.[23] Although these costs are typically amortized over several years, this would still add significant additional costs to the robotic-assisted hysterectomy procedure and thus further increase the cost difference compared with an ES-assisted total laparoscopic hysterectomy procedure.

Strengths and Limitations

Strengths of our study include evaluation of a large database of patients and hospitals with a wide geographic representation of actual surgical costs throughout US hospitals. Additional strengths include the ability to compare cofounders including severity of illness, comorbid conditions, hospital teaching status, hospital region, and hospital bed size so that accurate cost comparisons are performed. Weaknesses of our study include dependence on billing data, which can have inherent inaccuracies, as well as having to infer the actual use of the ES during the total laparoscopic hysterectomy procedure. The indication for the total laparoscopic hysterectomy was also not available, which could potentially skew the type of hysterectomy performed toward robotic-assisted procedures for the more difficult cases. Information was also not available as to the surgeon's experience with the total laparoscopic hysterectomy procedure or the technique of laparoscopic suturing used in the NER group, which could impact surgical time. Another limitation of our study is the non-experimental study design. Although we have controlled for confounding variables, by using multivariate analysis, there still may exist variables that we were unable to control for.

CONCLUSION

Our study is consistent with the limited cost data that are available in the medical literature on laparoscopic versus robotic-assisted hysterectomy procedures. In this study we found that the use of a disposable automated laparoscopic suturing device, the ES, is significantly more cost-effective than the use of the da Vinci surgical system for the performance of an inpatient total laparoscopic hysterectomy procedure for benign conditions. The ES also does not add cost compared with traditional total laparoscopic hysterectomy procedures because of the time savings that it enables in laparoscopic suturing. Therefore a disposable automated laparoscopic suturing device is an efficient and cost-effective method for laparoscopic suturing to close the vaginal cuff during a total laparoscopic hysterectomy procedure for benign conditions.

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