Utilization and perioperative outcomes of robotic vaginal vault suspension compared to abdominal or vaginal approaches for pelvic organ prolapse

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Abstract

Objectives: Robot-assisted vaginal vault suspension (RAVVS) for pelvic organ prolapse (POP) represents a minimally-invasive alternative to abdominal sacrocolpopexy. We measured perioperative outcomes and utilization rates of RAVVS.
Methods: RAVVS (n = 2381) and open VVS (OVVS, n = 11080) data were extracted from the 2009-2010 Nationwide Inpatient Sample. Propensity score-matched analysis compared patients undergoing RAVVS or OVVS for complications, mortality, prolonged length-of-stay, and elevated hospital charges.
Results: Use of RAVVS for POP increased from 2009 to 2010 (16.3% to 19.2%). Patients undergoing RAVVS were more likely to be white (77.2% vs. 69.6%), to carry private insurance (52.8% vs. 46.0%) and to have fewer comorbidities (Charlson Comorbidity Index [CCI] ≥1 = 17.5% vs. 26.6%). They were more likely to undergo surgery at urban (98.2% vs. 93.7%) and academic centres (75.7% vs. 56.7%). Patients undergoing RAVVS were less likely to receive a blood-transfusion (0.7% vs. 1.8%, $p < 0.001$) or experience prolonged length-of-stay (9.3% vs. 25.1%, $p < 0.001$). They had more intraoperative complications (6.0% vs. 4.2%, $p < 0.001$), and higher median hospital charges ($32 402 vs. $24 136, $p < 0.001$). Overall postoperative complications were equivalent (17.9%, $p = 1.0$), though there were differences in wound (0.4% vs. 1.3%, $p < 0.001$), genitourinary (4.9% vs. 6.5%, $p = 0.009$), and surgical (6.6% vs. 4.9%, $p = 0.007$) complications.
Conclusions: The increasing use of RAVVS from 2009 to 2010 suggests a growth in the adoption of robotics to manage POP. We show that RAVVS is associated with decreased length of stay, fewer blood transfusions, as well as lower postoperative wound, genitourinary and vascular complications. The benefits of RAVVS are mitigated by higher hospital charges and higher rates of intraoperative complications.

Introduction

The lifetime risk for women to experience pelvic organ prolapse (POP) or urinary incontinence is 11.1%.[1] It is estimated that over 200 000 surgeries for POP are performed every year; 29.2% of which subsequently require revision.[1,2] To determine the most effective surgical intervention for patients with POP, multiple studies have compared different approaches to vaginal vault suspension (VVS), including abdominal and transvaginal. Abdominal sacrocolpopexy (SCP) has become the gold standard for treating POP with higher relative success rates compared to a transvaginal approach.[3,4] In spite of inferior durability, more transvaginal surgeries have been performed due to the higher cost and morbidity associated with abdominal SCP.[2,5,6]

Recently, laparoscopic and robotic SCP have been proposed as alternatives to abdominal SCP, offering similar efficacy as the abdominal approach. They also have the added advantage of the robotic platform (decreased blood loss, length-of-stay and postoperative pain).[7] However, these approaches have been slowly adopted due to cost and technical challenges.[8-10]

Existing robotic SCP case series, retrospective and prospective comparisons between robotic and laparoscopic or abdominal SCP are limited by small sample size and experience of a single institution/surgeon. To date, no study has described robotic utilization for POP in the United States, or nationally representative rates of perioperative morbidity and mortality. With the adoption of a robot-assisted modifier code in October 2008, we were able to examine the 2009-2010 Nationwide Inpatient Sample (NIS) database to report current trends in utilization and perioperative outcomes for robot-assisted VVS compared to open VVS (OVVS).

Methods

Patient selection and variables

Patient information was obtained from the NIS between January 2009 and December 2010 as previously described.[11] In brief, the NIS includes inpatient discharge data associated with 8 million hospital discharges from more than 1000 hospitals in 44 states. This represents 20% of the public and academic hospitals within the United States.

Patients undergoing vaginal suspension and fixation *and* vaginal suspension and fixation with graft or prosthesis (ICD-9 [International Classification of Disease, 9th revision] procedure code 70.77 or 70.78) were extracted, yielding a weighted estimate of 13,539 patients. As recognized by the National Center of Health Statistics and the Centers for Medicare and Medicaid Services, beginning October 1, 2008, the robot-assisted modifier code (ICD-9-CM 17.4x) was introduced to identify robot-assisted VVS. Patients with the minimally-invasive modifier code (ICD-9-CM 54.21) without the robot-assisted modifier were classified as having undergone laparoscopic VVS and were removed from further analyses due to cohort size (n=78). Patients who did not have robotic or minimally-invasive code were assumed to have undergone open VVS.

Patient demographics included age, race, Charlson Comorbidity Index (CCI),[12,13] insurance payer, and year of surgery. Hospital information included location (rural vs. urban), geographical region, academic status, and annual caseload. Hospital-associated data were obtained from the American Hospital Association Annual Survey of Hospitals performed by the United States Census Bureau.

Outcome measures extracted from the NIS included perioperative complications, mortality during admission, requirement for blood-transfusions, length-of-stay, and total hospital charges for admission. Perioperative complications were extracted and defined using ICD-9 codes 2-15 utilizing previously described methodology.[11,14] Intra-operative complications included surgical laceration of the bowel, ureter, nerves and/or vessels during a procedure (ICD-9 998.2). Blood-transfusion requirements were extracted using codes 99.02 and 99.04. Postoperative complications were identified and categorized using ICD-9 codes as previously described.[15]

In-hospital mortality was defined by the NIS as death occurring during admission. Length-of-stay was defined as the difference between the discharge and admission dates; it was categorized as prolonged length-of-stay if this was beyond the 75th percentile cut-off point of 2 days. Elevated hospital charges were defined as charges beyond the 75th percentile cut-off point of $37 627 (unmatched) and $39 071 (matched).

Statistical analysis

Continuous variables were summarized by a median with interquartile ranges (IQR), while categorical variables were reported in frequencies and proportions. Pearson chi-square or Mann-Whitney U tests were performed to compare categorical and continuous variables, respectively.

Propensity score matching at a 2:1 ratio was performed to account for differences in demographic characteristics between the surgical groups.[16,17] Patient variables included age, race, CCI, year of surgery and insurance status, while hospital characteristics included location, region and academic status. Trend analysis was used to determine percent change in utilization over time for each surgical group. All tests were 2-sided, with a statistical significance set at $p < 0.05$. Analyses were conducted using the R statistical package v.2.15.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

From 2009 to 2010, a nationally weighted estimate of 11 080 (82.3%) patients underwent open VVS, whereas 2381 (17.7%) underwent robot-assisted VVS. There was an increase in robot-assisted VVS utilization from 14.1% in the first quarter of 2009 to 21.8% in the fourth quarter of 2010 (Fig. 1, $p = 0.025$).

From 2009 to 2010, utilization of VVS was assessed quarterly and an increase in robot-assisted VVS was noted compared to open VVS.

Statistical differences were noted across all demographic variables (Table 1). Patients undergoing RAVVS compared to open VVS were younger. A greater proportion of robot-assisted VVS patients was white and had private insurance, while a smaller proportion of robot-assisted VVS patients had comorbidities. Robot-assisted VVS was performed at a higher proportion in teaching hospitals and urban settings. There were also noticeable regional differences in robot-assisted VVS and open VVS. Specifically, robot-assisted VVS utilization was higher in the Northeast and West. Finally, median annual caseload at hospitals where patients received RAVVS was significantly higher compared to open VVS (21 [range: 7-41] vs. 9 [range: 4-20]).

Propensity-score matching (Table 2) resulted in a cohort of 4659 open VVS (66.2%) and 2381 robot-assisted VVS (33.8%) patients, decreasing the standardized differences between the cohorts to less than 10%. The 2 hospital variables that were not used as part of the propensity matching (region and median caseload) continued to be significant-

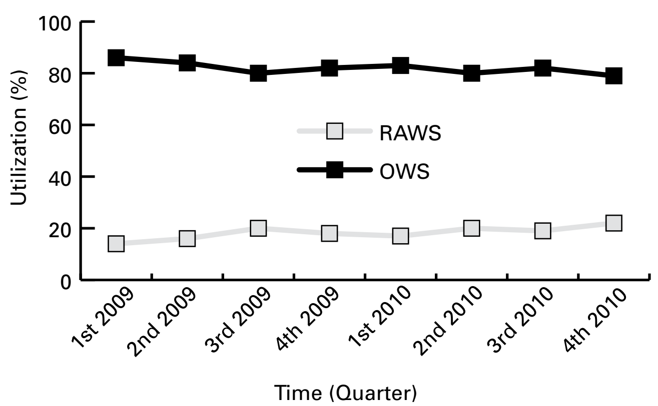

Fig. 1. Utilization of robot-assisted (RAVVS) versus open vaginal vault suspension (OVVS).

ly different between the groups, and regional differences became more noticeable.

Outcomes between the surgical groups were analyzed both in the unmatched and matched treatments (Table 3, Table 4). After propensity score matching, robot-assisted VVS had lower rates of blood transfusions and higher proportions of intraoperative complications (6.0% vs. 4.2%, $p < 0.001$). No difference in overall postoperative complications and in-hospital mortality rate was detected (Table 4).

A much higher proportion of patients undergoing open VVS stayed more than 2 days after surgery (24.2% vs. 9.3%, $p < 0.001$). However, median hospital charges were significantly lower in the open VVS population ($24 136 [IQR: $16 883-$35 413] vs. $32 402 [IQR: $22 569-$45 275]) compared to robot-assisted VVS patients and fewer experienced elevated hospital charges (21.0% vs. 37.1%).

Discussion

To date, there are 2 published studies investigating trends across the United States for POP surgeries.[2,5] Both studies are nearly 15 years old and pre-date the introduction of robotic surgery for VVS in 2004.[18] They demonstrated that the use of a vaginal approach to vault suspension is significantly higher than abdominal SCP, despite numerous studies demonstrating decreased efficacy and the increased need for repeat surgeries.[4,6,19,20]

The current literature demonstrates that the robotic approach to VVS is effective in terms of functional outcomes, such as sexual function, pelvic organ quantification scores, mesh erosion, and rates of repeat surgery as compared to open.[21-24] In addition, these studies demonstrate multiple benefits, including decreased blood loss and shorter length-of-stay. Although no prior study has been able to show significant difference in rates of transfusion, we demonstrated that a greater percentage of patients undergoing open procedures required transfusion (1.8% vs. 0.7%) and had a prolonged length-of-stay (24.2% vs. 9.3%), relative to patients receiving robotic surgery.

Siddiqui and colleagues demonstrated significant differences in wound complications (open 4.3% vs. robotic 0.0%); this is similar to our own nationally representative rates (open 1.3% vs. robotic 0.4%).[24] They also demonstrated a difference in postoperative ileus (open 11.6% vs. robotic 5.6%); similarly, we show differences in the rate of medical complications, which included ileus and bowel obstruction (open 4.2% vs. robotic 3.2%).

Our rates of intraoperative complications were higher in the robotic cohort (6.0% vs. 4.2%) compared to open group; this suggests the influence of a learning curve implicit to the growing use of the robotic approach. Many published studies have demonstrated that operative time decreases significantly with increasing case volume, indicating that initial technical challenges are overcome with practice.[8,25,26] Nonetheless, there has been no formal evaluation of the learning curve associated with robot-assisted VVS.

There are 2 analyses that studied costs associated with robotic and open approaches. Judd and colleagues presented a theoretical cost analysis demonstrating higher costs with robotic surgery compared to open surgery due to longer operating time and increased use of disposable equipment.[10] This conjecture was refuted by Elliot and colleagues.[9] They showed that on average the robotic approach can be more cost-effective due to lower than predicted time of robotic surgeries, the use of disposable equipment and the higher than predicted operative times for open cases. Their findings may not be widely applicable due to a relatively high proportion of robotic surgeries in their series. In either scenario, multiple factors may affect the cost-effectiveness of the robotic approach. We demonstrate that the robotic approach is associated with significantly higher hospital charges, but our analysis includes vaginal approaches which are often less expensive than abdominal approaches. In cases where patients undergoing abdominal SCP require an extended hospital stay, the robotic approach may mitigate much of the cost, due to decreased morbidity.

Of note, we found significant regional variation in the use of robot-assisted VVS. This finding may stem from surgeon preference or be driven by consumer demand, a recognized phenomenon in robotic surgery.[27] We also demonstrate that patients choosing robotic surgery were more likely to be white patients with private insurance.

One of the key strengths of our study arises from the large nationally representative cohort. There has been no other study yet published examining robot-assisted VVS utilization across the United States. Furthermore, we confirm many of the purported benefits and limitations of robotic surgery, including decreased rates of blood-transfusion, decreased length-of-stay, and increased hospital charges.

While we present several novel findings, there are numer-

Table 1. Demographic characteristics of patients receiving robotic-assisted versus open VVS (NIS 2009-2010)

	Open	Robot-assisted	Total	*p* value
Patient characteristics				
No. patients	11080 (82.3)	2381 (17.7)	13461	
Median age, years (IQR)	65 (57-72)	63 (57-69)	65 (57-72)	<0.001
Race, n (%)				
White	7717 (69.6)	1837 (77.2)	9554 (71.0)	<0.001
Black	405 (3.7)	62 (2.6)	467 (3.5)	
Hispanic	688 (6.2)	105 (4.4)	793 (5.9)	
Other	469 (4.2)	95 (4.0)	564 (4.2)	
Unknown	1801 (16.3)	282 (11.8)	2083 (15.5)	
CCI, n (%)				
0	8134 (73.4)	1964 (82.5)	10098 (75)	<0.001
1	2474 (22.3)	365 (15.3)	2839 (21.1)	
2	366 (3.3)	37 (1.6)	403 (3.0)	
≥3	106 (1.0)	15 (0.6)	121 (0.9)	
Insurance status, n (%)				
Medicare	5233 (47.2)	1000 (42.0)	6233 (46.3)	<0.001
Medicaid	316 (2.9)	53 (2.2)	369 (2.7)	
Private	5102 (46.0)	1257 (52.8)	6358 (47.2)	
Other	429 (3.9)	71 (3.0)	500 (3.7)	
Year of surgery, n (%)				
2009	5859 (52.9)	1142 (48.0)	7001 (52)	<0.001
2010	5221 (47.1)	1239 (52.0)	6461 (48.0)	
Hospital characteristics of patient				
Academic status, n (%)				
Nonteaching	4798 (43.3)	578 (24.3)	5371 (39.9)	<0.001
Teaching	6282 (56.7)	1803 (75.7)	8085 (60.1)	
Location, n (%)				
Rural	811 (7.3)	42 (1.8)	848 (6.3)	<0.001
Urban	10269 (92.7)	2339 (98.2)	12608 (93.7)	
Region, n (%)				
Northeast	2019 (18.2)	667 (28.0)	2686 (20.0)	<0.001
Midwest	2715 (24.5)	453 (19.0)	3168 (23.5)	
South	3907 (35.3)	702 (29.5)	4609 (34.2)	
West	2439 (22.0)	559 (23.5)	2998 (22.3)	
Median annual caseload, n (IQR)	9 (4-20)	21 (7-41)	10 (4-23)	<0.001

VVS: vaginal vault suspension; POP: pelvic organ prolapse; IQR: interquartile range; CCI: Charlson comorbidity index; NIS: Nationwide Inpatient Sample.

ous limitations associated with population-based analyses that restrict the utility of our findings. It would have been ideal to compare robotic SCP with open abdominal or vaginal SCP, but the ICD-9-CM codes do not distinguish between vaginal or abdominal approaches to vault suspension. Additionally, the NIS is unable to provide information prior to or beyond the index hospital admission; accordingly data on initial diagnoses, such as severity and type of prolapse, reasons for pursuing robotic vs. open surgical treatments, or follow-up for symptomatic improvement, are not available. Additional limitations stem from the finding that the 2 cohorts were statistically different prior to matching, but this is likely due to the very high numbers in each cohort. These differences were mitigated through propensity-score matched analysis.

Conclusion

Our analysis describes previously unpublished findings concerning the trends in utilization across the United States of robot-assisted VVS in the treatment of female POP. We demonstrate, in a nationally representative sample, consistent trends of decreased length-of-stay and decreased rates of transfusion associated with robotic surgery. We also confirm the additional associated cost. Prospective studies examin-

Table 2. Propensity-matched demographic characteristics of patients receiving robot-assisted versus open VVS, NIS 2009-2010

	Open	Robot-assisted	Total	*p* value
Patient characteristics				
No. patients (%)	4659 (66.2)	2381 (33.8)	7040	
Median age, years (IQR)	63 (57-63)	63 (57-69)	63 (57-70)	0.234
Race, n (%)				
White	3541 (76.0)	1837 (77.2)	5378 (76.4)	0.010
Black	140 (3.0)	62 (2.6)	202 (2.9)	
Hispanic	224 (4.8)	105 (4.4)	330 (4.7)	
Other	126 (2.7)	95 (4.0)	221 (3.1)	
Unknown	628 (13.5)	282 (11.8)	910 (12.9)	
CCI, n (%)				
0	3924 (84.2)	1964 (82.5)	5888 (83.6)	0.138
1	650 (14.0)	365 (15.3)	1014 (14.4)	
2	69 (1.5)	37 (1.6)	106 (1.5)	
≥3	16 (0.3)	15 (0.6)	31 (0.4)	
Insurance status, n (%)				
Medicare	2029 (43.6)	1000 (42.0)	3029 (43.0)	0.554
Medicaid	113 (2.4)	53 (2.2)	166 (2.4)	
Private	2377 (51.0)	1257 (52.8)	3632 (51.6)	
Other	140 (3.0)	71 (3.0)	211 (3.0)	
Year of surgery, n (%)				
2009	2252 (48.3)	1142 (48.0)	3394 (48.2)	0.782
2010	2407 (51.7)	1239 (52.0)	3646 (51.8)	
Hospital characteristics of patient				
Academic status, n (%)				
Nonteaching	1140 (24.5)	578 (24.3)	1717 (24.4)	0.883
Teaching	3519 (75.5)	1803 (75.7)	5322 (75.6)	
Location, n (%)				
Rural	95 (2.0)	42 (1.8)	137 (1.9)	0.466
Urban	4564 (98.0)	2339 (98.2)	6903 (98.1)	
Region, n (%)				
Northeast	1157 (24.8)	667 (28.0)	1824 (25.9)	<0.001
Midwest	1073 (23.0)	453 (19.0)	1525 (21.7)	
South	1619 (34.8)	702 (29.5)	1369 (19.4)	
West	810 (17.4)	559 (23.5)	1369 (19.4)	
Median annual caseload, n (IQR)	13 (6-24)	21 (7-41)	14 (6-29)	<0.001

VVS: vaginal vault suspension; POP: pelvic organ prolapse; IQR: interquartile range; CCI: Charlson comorbidity index; NIS: Nationwide Inpatient Sample.

ing robotic SCP long-term functional outcomes are needed and are underway.[28] We believe that these studies will support the practice of robotic surgery, which has demonstrated advantages and is growing in utilization.

Competing interests: Dr. Li, Dr. Sammon, Dr. Roghmann, Dr. Sood, Dr. Ehlert, Dr. Sun, Dr. Menon and Dr. Atiemo all declare no competing financial or personal interests. Dr. Trinh has received consultant fees from Intuitive Surgical.

This paper has been peer-reviewed.

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Table 3. Perioperative outcomes between robot-assisted versus open VVS, NIS 2009-2010

	Open	Robot-assisted	Total	*p* value
No. patients	11080	2381	13461	
Blood transfusion, n (%)	198 (1.8)	16 (0.7)	214 (1.6)	<0.001
Intraoperative complication, n (%)	465 (4.2)	143 (6.0)	608 (4.5)	<0.001
Postoperative complication, n (%)				
Overall	2148 (19.4)	427 (17.9)	2575 (19.1)	0.108
Cardiac	342 (3.1)	58 (2.4)	400 (3.0)	0.099
Vascular	76 (0.7)	5 (0.2)	81 (0.6)	0.008
Operative wound	159 (1.4)	10 (0.4)	169 (1.3)	<0.001
Genitourinary	890 (8.0)	117 (4.9)	1007 (7.5)	<0.001
Neurological	76 (0.7)	26 (1.1)	102 (0.8)	0.045
Infection	41 (0.4)	5 (0.2)	46 (0.3)	0.331
Miscellaneous medical	495 (4.5)	75 (3.2)	570 (4.2)	0.004
Miscellaneous surgical	544 (4.9)	157 (6.6)	701 (5.2)	0.001
In-hospital mortality, n (%)	4 (0.0)	5 (0.2)	9 (0.1)	0.012
Length of stay ≥2 days, n (%)	2783 (25.1)	222 (9.3)	3005 (22.3)	<0.001
Total admission charge ≥$37 627, n (%)	2430 (21.9)	883 (37.1)	3313 (24.6)	<0.001
Median annual caseload, n (IQR)	9 (4-20)	21 (7-41)	10 (4-23)	<0.001

VVS: vaginal vault suspension; POP: pelvic organ prolapse; IQR: interquartile range; CCI: Charlson comorbidity index; NIS: Nationwide Inpatient Sample.

Table 4. Propensity-matched perioperative outcomes between robot-assisted versus open VVS, NIS 2009-2010

	Open	Robot-assisted	Total	*p* value
No. patients	4660	2381	7041	
Blood transfusion, n (%)	86 (1.8)	16 (0.7)	102 (1.4)	<0.001
Intra-operative complication, n (%)	195 (4.2)	143 (6.0)	338 (4.8)	0.001
Postoperative complication, n (%)				
Overall	835 (17.9)	427 (17.9)	1262 (17.9)	1.0
Cardiac	132 (2.8)	58 (2.4)	190 (2.7)	0.352
Vascular	31 (0.7)	5 (0.2)	36 (0.5)	0.012
Operative wound	60 (1.3)	10 (0.4)	70 (1.0)	<0.001
Genitourinary	301 (6.5)	117 (4.9)	418 (5.9)	0.009
Neurological	49 (1.1)	26 (1.1)	75 (1.1)	0.903
Infection	15 (0.3)	5 (0.2)	20 (0.3)	0.485
Miscellaneous medical	195 (4.2)	75 (3.2)	270 (3.8)	0.036
Miscellaneous surgical	234 (5.0)	157 (6.6)	391 (5.6)	0.007
In-hospital mortality, n (%)	4 (0.1)	5 (0.2)	9 (0.1)	0.177
Length of stay ≥2 days, n (%)	1129 (24.2)	222 (9.3)	1351 (19.2)	<0.001
Total admission charge ≥$39 071, n (%)	977 (21.0)	883 (37.1)	1860 (26.4)	<0.001
Median annual caseload, n (IQR)	9 (4-20)	21 (7-41)	10 (4-23)	<0.001

VVS: vaginal vault suspension; NIS: Nationwide Inpatient Sample.

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Appendix 1. ICD-9 codes utilized

Patient selection	
Vaginal vault suspension	70.77, 70.78
Robot-assisted modifier	17.4x
Minimally-invasive modifier	54.21
Intraoperative complications	998.2
Blood-transfusion	99.02, 99.04

ICD: International Classification of Diseases.
All other ICD-9 codes can be found in Hu et al.[14]