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ORIGINAL RESEARCH

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Surgical outcomes for robotic-assisted single-site hysterectomy compared to multi-port hysterectomy

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Abstract

Background: Data regarding the use of single-site robotic surgery in gynecology remains limited, but the approach is anecdotally felt to be beneficial to patients. This study aims to assess the surgical outcomes of robotic-assisted single-site hysterectomy (SSH) and multi-port hysterectomy (MPH). **Methods**: Data were obtained via retrospective chart review of eligible patients from a single academic health care system who underwent surgery between October 2013–June 2022. During this time, 127 SSH and 445 MPH were performed. **Results**: 78% of SSH patients had a normal or overweight body mass index (BMI) compared to 49% of MPH patients ($p < 0.001$). 28% of SSH patients had a preoperative cancer diagnosis compared to 58% of MPH patients ($p < 0.001$). There were no differences in average number of prior abdominal surgeries ($p = 0.838$). Median operative time was 118 minutes for SSH compared to 162 minutes for MPH ($p < 0.001$). 23% of SSH patients were discharged on the day of surgery compared to 8% of MPH patients ($p < 0.001$). The plurality (47%) of SSH patients had blood loss of <50 mL compared to 50–100 mL for the plurality (36%) of MPH patients ($p < 0.001$). 7% of patients undergoing MPH experienced major complications compared to 2% of patients undergoing SSH ($p = 0.025$). Propensity score matched results using a 1:1 model were consistent with the overall analysis and prior findings, demonstrating statistically significant differences in median operative times, blood loss and lengths of postoperative stay between SSH and MPH patients. **Conclusions**: SSH has overall good outcomes, with this study demonstrating decreased operative times, decreased blood loss, lower rates of major complications and shorter lengths of postoperative stay when compared to MPH. SSH may be an alternate surgical modality with utility in risk-reducing, precancerous, or early-stage cancer in gynecologic patients.

Keywords

Robotic-assisted surgery; Single site surgery; Multi site surgery; Hysterectomy

1. Introduction

Minimally invasive surgery (MIS) has become the standard of care for many operations, with national data demonstrating an increase in cases and an association with improved perioperative outcomes when compared to laparotomy [1–4]. In gynecology, MIS approaches have well-documented advantages including faster return to normal activities, shorter hospitalizations and fewer wound infections when compared to abdominal approaches [5].

Robotic-assisted surgery was introduced to improve ergonomics and overcome limitations of laparoscopy, namely limited visibility and dexterity due to the use of rigid instruments [6–8]. In 2000, the daVinci Surgical System became the first robotic surgical platform to be approved by the United States Food and Drug Administration (FDA) for use in general laparoscopy. Robotic-assisted MIS is now considered safe and effective in gynecology, with widespread adoption following a 2005 FDA approval for the use of robotic surgery in gynecologic procedures [9–11]. The American College of Obstetricians and Gynecologists (ACOG) in collaboration with the Society of Gynecologic Surgeons (SGS) has suggested that robotic-assisted gynecologic surgery can be performed safely by experienced surgeons and has perioperative outcomes equivalent to laparoscopy and improved outcomes compared to laparotomy [7]. However, they also emphasize the ongoing need for comparative studies to further assess long-term outcomes and patient safety.

Multi-port robotic surgery remains the standard approach. In 2011, the introduction of daVinci Single-Site technology allowed surgeons to begin performing single incision surgery in the abdomen and pelvis. A 25 mm single-site port is inserted through an umbilical fascial incision, after which an 8.5 mm robotic endoscope, a 5–10 mm laparoscopic assistant trocar,

and two laparoscopic cannulas are introduced into the peritoneal cavity through the single port. The cannulas transmit interchangeable 5 mm semi-rigid instruments that cross within the trocar such that instruments operate on the contralateral side to which they are placed. The semi-rigid nature allows the instruments to curve through the cannula while maintaining enough structure to manipulate tissue and provide retraction.

Data regarding single-site robotic surgery remain limited, but the surgical approach is anecdotally thought to have additional benefits such as improved cosmesis and higher rates of patient satisfaction [12–14]. Systematic reviews by Capozzi *et al*. [15] and Arcieri *et al*. [16] have highlighted that robotic single-site surgery is a safe and technically feasible option for patients undergoing gynecologic surgery, with Arcieri *et al*. [16] focusing specifically on the single-port daVinci SP1098 Surgical System. These findings were supported by a retrospective chart review performed by Huang *et al*. [17] that found robotic single-site surgery to be a safe and acceptable alternative for the surgical treatment of endometriosis, as well as a pilot study by Lee *et al*. [18] demonstrating the feasibility of using robotic single-port myomectomies in women with symptomatic fibroids. However, data in gynecologic oncology is lacking.

In this study, we aim to better elicit the benefits of robotic-assisted single-site hysterectomy (SSH) among gynecology and gynecologic oncology patients by comparing variables and outcomes between those who underwent robotic-assisted SSH to those who underwent multi-port hysterectomy (MPH) at a single institution.

2. Materials and methods

This retrospective study was approved by the Institutional Review Board at Stanford University (Protocol #66886). Patients who underwent robotic-assisted hysterectomy at Stanford Health Care from October 2013 through June 2022 were identified using case log data from the daVinci Surgical System. All surgeries were performed by a single gynecologic oncologist as only this provider offered SSH at the study institution. All patients who underwent a robotic-assisted total hysterectomy with the designated provider during the study period were included regardless of the indication for their surgery. Exclusion criteria included patients who underwent a type of hysterectomy other than total (*i.e.*, a radical hysterectomy), who underwent non robotic-assisted surgery, or whose surgery was performed by another gynecologic oncologist at the study institution.

Robotic surgical technique was standardized across the study period and utilized the daVinci Surgical System for all cases. Port placement for MPH included an 8 mm camera port positioned 3–4 cm supraumbilically, an 8 mm right mid-clavicular port located at the mid-clavicular line and 8 cm lateral to the midline camera port, an 8 mm left lateral port located 8 cm left lateral to the right mid-clavicular port, an 8 mm right lateral port located 8 cm right lateral to the midline camera port, and a 12 mm assistant port positioned 8 cm right lateral to the right mid-clavicular port. Port placement for SSH involved a 20–25 mm incision at the umbilicus followed by placement of a single port. The same set of robotic surgical instruments was used for both MPH and SSH and included the EndoWrist monopolar cautery, EndoWrist bipolar cautery, EndoWrist grasper and EndoWrist needle driver.

Clinical data regarding the surgical technique utilized, single-site versus multi-port, were extracted from the electronic medical record along with preoperative, perioperative and postoperative variables. The decision to proceed with SSH versus MPH for each patient was determined by the primary surgeon following preoperative evaluation in the clinic. The primary factors utilized to determine whether patients would undergo SSH or MPH included body habitus with a focus on the position of the umbilicus and distribution of central adiposity and the size of the target anatomy as determined by physical exam by the primary surgeon. Prior incisions in and around the umbilicus were also taken into consideration as relative contraindications. Preoperative medical comorbidities were defined and evaluated based on the American College of Surgeons National Surgical Quality Improvement Program's Surgical Risk Calculator. As an additional metric of preoperative risk, the preoperative American Society of Anesthesiologists (ASA) classification system score for each patient was included.

The difference between single-site and multi-port was examined by Wilcoxon rank-sum test for continuous variables and Pearson Chi-square test and Fisher Exact test for categorical variables. A propensity score-matched analysis was conducted using a logistic regression, adjusting for all patients' demographics and preoperative variables. A 1:1 match was performed using nearest neighbor matching techniques without replacement. Data were then analyzed using logistic regression for binary outcomes and linear regression for continuous outcomes. The same models were applied on the entire data as a sensitivity analysis. All statistical tests were two sided and a p-value of 0.05 was considered significant. All analysis was conducted in R.

Intraoperative outcomes of interest included operative time (in minutes), which was calculated from the first skin incision to the placement of the last skin closure stitch and was inclusive of robot docking time, and estimated blood loss (in mL), which was determined based on mutual agreement between the primary surgeon and the anesthesiologist at the conclusion of the case. Postoperative outcomes were length of postoperative stay (in days) and 30-day rates of postoperative complications including both major complications (bowel injury, conversion to laparotomy, ileus, deep postoperative infection, readmission, reoperation, small bowel obstruction, urinary tract injury and vaginal cuff dehiscence) and minor complications (Emergency Department presentation without readmission and superficial postoperative infection).

3. Results

A total of 572 patients met inclusion criteria, of which 127 underwent robotic-assisted SSH and 445 underwent robotic-assisted MPH. As shown in Table 1, baseline demographic variables were compared between the two groups. Patients who underwent SSH were statistically significantly younger (median age 52) compared to those who underwent MPH (me-

TABLE 1. Baseline demographics and preoperative variables.

Variable	SSH (n = 127)	MPH (n = 445)	*p*-value
Median age (yr)	52	59	<0.001*
Race			
American Indian or Alaska Native	2 (1.6%)	1 (0.2%)	
Asian	28 (22.0%)	63 (14.2%)	
Black or African American	2 (1.6%)	12 (2.7%)	0.074
Native Hawaiian or Pacific Islander	--	6 (1.3%)	
White or Caucasian	69 (54.3%)	288 (64.7%)	
None of the Above/Unknown/Multiracial	26 (20.4%)	75 (16.9%)	
Ethnicity			
Hispanic	17 (13.4%)	103 (23.1%)	
Non-Hispanic	105 (82.7%)	324 (72.8%)	0.056
Unknown	5 (3.9%)	18 (4.0%)	
BMI (kg/m^2)			
<18.5	4 (3.1%)	11 (2.5%)	
18.5–24.9	53 (41.7%)	122 (27.4%)	
25–29.9	46 (36.2%)	94 (21.1%)	<0.001*
30–34.9	17 (13.4%)	90 (20.2%)	
35–39.9	7 (5.5%)	62 (13.9%)	
40+	--	66 (14.8%)	
Primary Language			
English	115 (90.6%)	378 (84.9%)	
Spanish	8 (6.3%)	45 (10.1%)	0.074
Other	4 (3.2%)	22 (4.8%)	
Preoperative Cancer Diagnosis	36 (28.3%)	256 (57.5%)	<0.001*
Medical Comorbidities			
Acute Renal Failure	--	--	--
CHF Exacerbation (within 30 d)	--	--	--
Current Smoker (within 1 yr)	3 (2.4%)	24 (5.4%)	0.233
Diabetes	11 (8.7%)	88 (19.8%)	0.012*
Dialysis	--	1 (0.2%)	>0.999
Dyspnea	1 (0.8%)	6 (1.3%)	>0.999
Hypertension (on medication)	31 (24.4%)	183 (41.1%)	<0.001*
Severe COPD	--	4 (0.9%)	0.580
Steroid Use (for chronic condition)	3 (2.4%)	6 (1.3%)	0.423
No Prior Abdominal Surgeries	54 (42.5%)	196 (44.0%)	0.838
ASA Class			
I	7 (5.5%)	11 (2.5%)	
II	84 (66.1%)	233 (52.4%)	0.002
III	36 (28.3%)	199 (44.7%)	
IV	--	2 (0.4%)	

**indicates statistical significance; SSH: single-site hysterectomy; MPH: multi-port hysterectomy; BMI: body mass index; ASA: American Society of Anesthesiologists; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease.*

dian age 59) ($p < 0.001$). Patients who underwent SSH were also significantly different in their body mass index (BMI) classification, with 78% being of BMI 18.5–29.9 compared to only 48% of patients who underwent MPH being of the same BMI range ($p < 0.001$). There were no differences in race between the groups, with the majority of patients self-identifying as White or Caucasian (54% SSH and 65% MPH) followed by Asian (22% SSH and 14% MPH). Similarly, there were no differences in ethnicity between the groups, with the majority of patients in both groups identifying as non-Hispanic (83% SSH and 75% MPH). Primary language was included as a surrogate marker for diversity and equitable access to care to ensure that SSH was not disproportionately being offered to English-speaking patients. While most patients in both groups were English-speaking, there was no difference in primary language spoken between the two groups ($p = 0.074$).

In addition to baseline demographic variables, we compared the preoperative diagnoses and indications for surgery between the two groups. 58% of patients who underwent MPH had a preoperative cancer diagnosis compared to only 28% in those who underwent SSH ($p < 0.001$). The most identified co-morbidities were hypertension requiring medication (24% SSH versus 41% MPH, $p < 0.001$) and diabetes (9% SSH versus 20% MPH, $p = 0.012$). Of note, there were no differences seen in the number of patients with severe medical comorbidities including recent congestive heart failure exacerbation, severe chronic obstructive pulmonary disease, acute renal failure, or a dialysis requirement (Table 1). In both groups, most patients were ASA class II, defined as patients with mild systemic disease (66% SSH versus 52% MPH); however, SSH patients had overall significantly lower ASA scores compared to MPH patients ($p = 0.002$) There were no differences in the number of prior abdominal surgeries. Additional information regarding preoperative variables can be found in Table 1.

In comparing intraoperative and perioperative variables, we found significant differences in median operative times, amounts of estimated blood loss (EBL), and lengths of postoperative stays between the groups (Table 2). Operative time was inclusive of both docking and console time, and it was specifically noted that SSH had a shorter median operative time of 118 minutes compared to 162 minutes for MPH ($p < 0.001$). 47% of SSH patients had a blood loss of <50 mL compared to 36% of MPH patients who had a blood loss of 50–100 mL ($p < 0.001$). When treated as a continuous outcome and adjusting for covariates, the EBL for MPH was 38 (95% confidence interval: 19, 57) mL greater than that of SSH ($p < 0.001$). None of the patients required blood transfusion during their surgery or postoperative admission.

Postoperative discharge criteria, which remained stable at the institution throughout the study period, included the ability to void following foley catheter removal at the end of the case, the ability to ambulate, and effective pain control with an oral regimen. 23% of SSH patients were discharged on the day of surgery compared to only 8% of MPH patients ($p < 0.001$). The maximum length of postoperative admission for SSH cases was 3 days compared to 8 days for MPH cases. The minimum length of postoperative admission for both SSH and MPH patients was 0 days (indicating same day discharge), with a mean of 0.87 days and median of 1 for SSH patients as compared to a mean of 1.32 days and median of 1 day for MPH patients. When treated as a continuous outcome and adjusting for covariates, statistical significance was maintained as the length of postoperative stay for MPH was found to be 0.45 (95% confidence interval: 0.26, 0.63) days longer than the length of postoperative stay for SSH ($p < 0.001$).

When comparing postoperative complications between the groups, no differences were detected in the rates of any individual complications occurring within 30 days of surgery, although overall incidence rates for complications were low (Table 3). As noted in Table 4, when complications were grouped together as major or minor, results demonstrated a statistically significant difference between the two groups with more than three times as many MPH patients experiencing major complications (7% MPH versus 2% SSH, $p = 0.025$). No incisional hernias were identified in any patients from both groups on short-term postoperative follow up of 30 days. Longer term follow up data were not available.

Finally, propensity score matching using a 1:1 model was utilized as a sensitivity analysis in an attempt to mitigate confounding variables and ensure that results obtained were not due to fundamental differences between the study groups. The propensity score matched model accounted for baseline demographics, BMI, number of prior abdominal surgeries, preoperative medical comorbidities including ASA class, preoperative cancer diagnoses, and ancillary procedures performed alongside the hysterectomy such as salpingectomy, oophorectomy, sentinel lymph node dissection or complete pelvic lymph node dissection. Results were consistent with overall analysis and prior findings demonstrating statistically significant shorter median operative times, lower EBL and shorter lengths of postoperative stay for SSH when compared to MPH. No differences were again detected in the rates of individual complications between the two groups (Table 4).

4. Discussion

In this single institution retrospective study, we assessed and compared the preoperative characteristics and perioperative/postoperative variables between gynecology and gynecologic oncology patients who underwent a single-site robotic assisted hysterectomy or multi-port robotic assisted hysterectomy. Our findings demonstrated that robotic-assisted SSH has overall good outcomes, including shorter patient hospital stays, shorter operative times, and lower estimated blood loss when compared to MPH performed at our institution. Therefore, it is reasonable to consider the single site platform as an alternate modality with utility in risk-reducing, precancerous, or early-stage cancer in select gynecologic patients.

The ideal candidate for this surgical modality has been evolving over time and was traditionally thought to be individuals with lower BMIs, however our observational data suggest that single-site surgery may be both safe and feasible in a larger patient population, including patients with overweight BMIs who may benefit from this approach pending their uterine size and pelvic pathology. We do acknowledge that further research is needed to validate this finding as single site surgery experience in patients with BMI over 30 is limited as demonstrated

TABLE 2. Intraoperative and postoperative variables and univariate comparison results.

Variable	SSH (n = 127)	MPH (n = 445)	*p*-value
Median Operative Time (min)	118	162	<0.001*
Estimated Blood Loss (mL)			
<50	60 (47.2%)	123 (27.6%)	
50–99	37 (29.1%)	159 (35.7%)	<0.001*
100+	10 (7.9%)	124 (27.9%)	
Length of Postoperative Stay (d)			
0–Same day discharge	29 (22.8%)	36 (8.1%)	
1–2	97 (76.4%)	372 (83.6%)	<0.001*
3+	1 (0.8%)	37 (8.3%)	

**indicates statistical significance; SSH: single-site hysterectomy; MPH: multi-port hysterectomy.*

TABLE 3. Postoperative complications within 30 days and univariate comparison results.

Variable	SSH (n = 127)	MPH (n = 445)	*p*-value
Major Complications	2 (1.6%)	30 (6.7%)	0.025*
Bowel Injury	--	3 (0.7%)	>0.999
Conversion to Laparotomy	--	6 (1.3%)	0.347
Ileus	1 (0.8%)	--	0.222
Deep Postoperative Infection	--	6 (1.3%)	0.347
Readmission	2 (1.6%)	20 (4.5%)	0.190
Reoperation	--	9 (2.0%)	0.218
Small Bowel Obstruction	--	2 (0.4%)	>0.999
Urinary Tract Injury	--	2 (0.4%)	>0.999
Vaginal Cuff Dehiscence	--	3 (0.7%)	>0.999
Minor Complications	3	18	0.592
ED Presentation (without readmission)	3 (2.4%)	16 (3.6%)	0.778
Superficial Postoperative Infection	--	9 (2.0%)	0.218

**indicates statistical significance; SSH: single-site hysterectomy; MPH: multi-port hysterectomy; ED: emergency department.*

by the fact that only 19% of our SSH patients had a BMI of 30+ compared to 49% of MPH patients.

Robotic-assisted SSH has several benefits that may make it an equal or even potentially superior surgical option in a select patient population. Given SSH requires only one small incision, typically made within the umbilicus, this results in a single scar that is less noticeable and cosmetically more appealing than multiple incisions used in MPH. This improvement in cosmetic outcomes has been demonstrated in colorectal surgery research comparing single plus one-port robotic surgery with multi-port laparoscopic surgery [19]. The single incision in SSH may also contribute to reduced postoperative pain and discomfort due to a reduction in the amount of tissue trauma, nerve damage, and muscle irritation, possibly explaining our shorter average hospital stay. Additionally, SSH may offer a faster recovery time as the procedure involves minimal tissue trauma due to the small incision, resulting in reduced blood loss and less disruption to surrounding structures. This can contribute to a quicker return to normal activities and shorter length of stays, although it is important to acknowledge that our overall rates of blood loss were relatively small and may not reflect clinical significance as none of the patients required transfusion. Finally, while the single incision used in SSH is larger than each incision used in MPH, our results showed no increase in postoperative hernias or other postoperative complications, although we acknowledge that our postoperative follow up is limited to 30 days and that our overall incidence of complications was low, therefore limiting our ability to reflect differences in complications between the two groups.

From an institutional perspective, the shorter lengths of median operative times and hospital stays for SSH may prove to be beneficial in allowing for more efficient operating room utilization and decreasing health care costs. Cost-effectiveness analysis is essential in future research to evaluate the economic implications of adopting SSH compared to MPH.

While SSH may offer the aforementioned benefits, it may not be suitable for all patients or all types of hysterectomies. Factors such as the patient's anatomy and habitus, the size of the uterus, previous abdominal surgeries, and the complexity

TABLE 4. Propensity score matched analysis for intraoperative and postoperative variables including complications within 30 days.

Variable	SSH (n = 127)	MPH (n = 127)	*p*-value
Median Operative Time (min)	118	162	<0.001*
Estimated Blood Loss (mL)			
<50	60 (47.2%)	38 (29.9%)	
50–99	37 (29.1%)	42 (33.1%)	<0.001*
100+	10 (7.9%)	33 (26.0%)	
Length of Postoperative Stay (d)			
0–Same day discharge	29 (22.8%)	14 (11.0%)	
1	87 (68.5%)	87 (68.5%)	0.004*
2	10 (7.9%)	18 (14.2%)	
3+	1 (0.8%)	8 (6.3%)	
Complications			
Conversion to Laparotomy	--	1 (0.8%)	>0.999
ED Presentation	4 (3.1%)	6 (4.7%)	0.749
Ileus or Small Bowel Obstruction	1 (0.8%)	--	>0.999
Postoperative Infection	--	3 (2.4%)	0.247
Readmission	2 (1.6%)	3 (2.4%)	>0.999
Reoperation	--	1 (0.8%)	>0.999
Urinary Tract Injury or Bowel Injury	--	--	--
Vaginal Cuff Dehiscence	--	--	--

**indicates statistical significance; SSH: single-site hysterectomy; MPH: multi-port hysterectomy.*

of the procedure may influence the surgeon's decision on the most appropriate approach. Surgeon expertise and the availability of robotic technology also play a significant role in determining the feasibility and success of either approach. A thorough evaluation by a health care professional is therefore necessary to determine the most appropriate surgical approach for each individual patient.

Our study has several limitations in addition to those already mentioned above. The primary limitation stems from the fact that this is both a single institution and a single surgeon study. As the surgeon's expertise and patient selection criteria may differ from other institutions and surgeons, our findings may be limited in their generalizability. Despite this limitation, it's important to acknowledge that the use of a single surgeon's case log data allowed us to control for surgeon skill level in this study, as we recognize that skill level and comfort with single-site surgical techniques may play a major role in surgical outcomes. Given this, it is important to note that the surgeon in our study had been performing robotic-assisted multi-port surgery since 2009 and laparoscopic single-site surgery since 2010 before beginning to perform robotic-assisted single-site surgery at the start of our study period. Our use of propensity score matching helped to control for major confounders, however the study was retrospective and lacked randomization, which introduces the potential for unmeasured confounding variables to influence the outcomes. We also recognize limitations as a result of preoperative assignment bias, as all patients were assigned to either single-site or multi-port surgery prior to the day of surgery based on a single surgeon's preoperative evaluation. Since our results demonstrated that a statistically significant higher percentage of patients who underwent MPH had a preoperative cancer diagnosis, this may indicate higher levels of surgical complexity for those cases which could contribute to the higher operative times, estimated blood loss and length of postoperative stays. This potential for preoperative assignment bias may additionally explain the higher rates of major complications found in the multi-site group.

Further research on SSH should address long-term follow-up data to evaluate the durability of outcomes beyond the immediate postoperative period of 30 days as well as patient satisfaction data. Assessing disease recurrence rates, long-term complications, and quality of life measures would provide important information for treatment decisions. Ideally, a randomized controlled trial involving proficient surgeons should be undertaken to more definitively establish the benefits of robotic single-site surgery in gynecology as compared to multi-port surgery. Future studies should also include comparisons to other minimally invasive methods, as a prior randomized trial (ROBOGYN-1004) demonstrated nonsuperiority of robotic-assisted laparoscopy compared to conventional laparoscopy with regards to severe perioperative morbidity in patients with gynecologic malignancies [20]. Data from the same trial also found that robotic-assisted laparoscopy improved perception of physical workload and effort regardless of surgical complexity compared to conventional laparoscopy [21]. As noted

in the commentary by Querleu *et al*. [22], the balance between surgeon and patient benefits needs to be further assessed, as does the impact of robotic surgery on survival outcomes in gynecologic cancers. If additional benefits are elicited, further consideration should be given to SSH as an alternate surgical modality offered to gynecologic patients as an option for route of hysterectomy. However, given the technical skills and time needed to learn a new surgical modality, future research should also assess the feasibility of incorporating robotic single-site surgery into existing gynecologic training curricula.

5. Conclusions

Robotic-assisted SSH has overall good outcomes, with this single-institution retrospective study demonstrating shorter operative times, reduced blood loss, lower rates of major complications, and shorter hospital stays when compared to MPH. In light of this, SSH may be particularly useful for patients undergoing risk-reducing, precancerous, or early-stage cancer procedures, and should be considered in the appropriate patient population. Surgical complexity and surgeon expertise should additionally play a role when determining the best surgical approach for individual patients.

The study's retrospective design, single-surgeon experience, and limited follow-up restrict generalizability and preclude assessment of long-term outcomes. Future research with extended follow-up and a focus on patient-reported outcomes is needed to validate these findings and further define the optimal role of SSH in gynecologic surgery.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

RAR—contributed to conceptualization, methodology, project administration, investigation, data curation, formal analysis, visualization and writing of both the original draft and additional edited versions based on review and feedback from the other authors. SS—contributed to conceptualization, methodology, investigation, data curation and writing of both the original draft and additional edited versions. ASM—contributed to conceptualization, validation and investigation, as well as writing, editing and review of the final manuscript. JZ—assisted with methodology, software, validation and formal analysis, as well as editing and review of the final manuscript. AK—served as the Principal Investigator for this project and contributed to conceptualization, methodology, validation, formal analysis, investigation, data curation, writing, project administration and supervision. All authors read and approved of the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by our Stanford University IRB via Protocol #66886. Given the retrospective nature of the study, this research was classified as posing minimal risk to patients and a waiver of consent was issued by the IRB.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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