

# Laser Angiography to Assess the Vaginal Cuff During Robotic Hysterectomy

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## ABSTRACT

**Background and Objectives:** Vaginal cuff dehiscence may be a vascular-mediated event, and reports show a higher incidence after robot-assisted total laparoscopic hysterectomy (RATLH), when compared with other surgical routes. This study was conducted to determine the feasibility of using laser angiography to assess vaginal cuff perfusion during RATLH.

**Methods:** This was a pilot feasibility trial incorporating 20 women who underwent RATLH for benign disease. Colpotomy was made with ultrasonic or monopolar instruments, whereas barbed or nonbarbed suture was used for cuff closure. Time of instrument activation during colpotomy was recorded. Images were captured of vaginal cuff perfusion before and after cuff closure. Reviewers evaluated these images and determined areas of adequate cuff perfusion.

**Results:** Indocyanine green (ICG) was visible at the vaginal cuff in all participants. Optimal dosage was determined to be 7.5 mg of ICG per intravenous dose. Mean time to appearance for ICG was  $18.4 \pm 7.3$  s (mean  $\pm$  SD) before closure and  $19.0 \pm 8.7$  s after closure. No significant difference ( $P = .19$ ) was noted in judged perfusion in

open cuffs after colpotomy with a monopolar ( $48.9 \pm 26.0\%$ ; mean  $\pm$  SD) or ultrasonic ( $40.2 \pm 14.1\%$ ) device. No difference was seen after cuff closure ( $P = .36$ ) when a monopolar ( $70.9 \pm 21.1\%$ ) or ultrasonic ( $70.5 \pm 20.5\%$ ) device was used. The use of barbed ( $74.1 \pm 20.1\%$ ) or nonbarbed ( $66.4 \pm 20.9\%$ ) sutures did not significantly affect estimated closed cuff perfusion ( $P = .19$ ). Decreased cuff perfusion was observed with longer instrument activation times in open cuffs ( $R^2 = 0.3175$ ).

**Conclusion:** Laser angiography during RATLH allows visualization of vascular perfusion of the vaginal cuff. The technology remains limited by the lack of quantifiable fluorescence and knowledge of clinically significant levels of fluorescence.

**Key Words:** Hysterectomy, Indocyanine green, Laser angiography, Robotic surgery, Vaginal cuff.

## INTRODUCTION

Vaginal cuff dehiscence is a morbid, potentially fatal complication that can occur after total hysterectomy from any approach. During the 20th century, very few cases were reported, and 95% occurred after total abdominal or vaginal hysterectomy, before the advent of laparoscopic hysterectomy.<sup>1</sup> Since the start of the 21st century, with the increased adoption of laparoscopic hysterectomy, vaginal cuff dehiscence has had an increased incidence. The condition is especially pronounced after robot-assisted total laparoscopic hysterectomy (RATLH), with numerous reports demonstrating an increased incidence of vaginal cuff dehiscence.<sup>2-7</sup> Reported rates of vaginal cuff dehiscence based on surgical approach to hysterectomy are 0.60% after abdominal, 0.32% after vaginal, 1.05% after laparoscopic, and 3.16% after robotic-assisted, according to one study.<sup>5</sup> Trials examining the contribution of electrosurgical energy use on the vaginal cuff reveal conflicting results, with a review article quoting no difference based on selected energy method.<sup>5</sup> In early reports, elevated rates of incidence after RATLH may have been due to poor electrosurgical energy choice, as monopolar instrumentation with coagulation waveform was used in 2 studies,<sup>3,4</sup>

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but use of monopolar instrumentation with pure cut waveform in a later report showed rates comparable to abdominal and vaginal approaches.<sup>8</sup> Further, the approach of suturing for cuff closure during laparoscopic hysterectomy was analyzed and showed reduced rates of cuff dehiscence after transvaginal cuff closure versus laparoscopic approaches when hysterectomies were otherwise performed similarly.<sup>7</sup>

Although no definite conclusion has been made regarding the pathogenesis of vaginal cuff dehiscence after laparoscopic hysterectomy, our team has trialed use of laser angiography during conventional total laparoscopic hysterectomy in hopes of allowing prospective analysis of colpotomy energy method and suturing methods.<sup>9</sup> Laser angiography has guided surgical decision-making during left-side colectomy and anterior resection, with reduced anastomotic leak rates,<sup>10</sup> and could perhaps offer similar guidance during vaginal cuff closure after total hysterectomy. The da Vinci Si surgical system (Intuitive Surgical, Sunnyvale, California, USA) contains an optional built-in laser angiography system (FireFly vision technology). The purpose of our study was to assess vaginal cuff perfusion during RATLH, using the FireFly system (Intuitive Surgical).

## MATERIALS AND METHODS

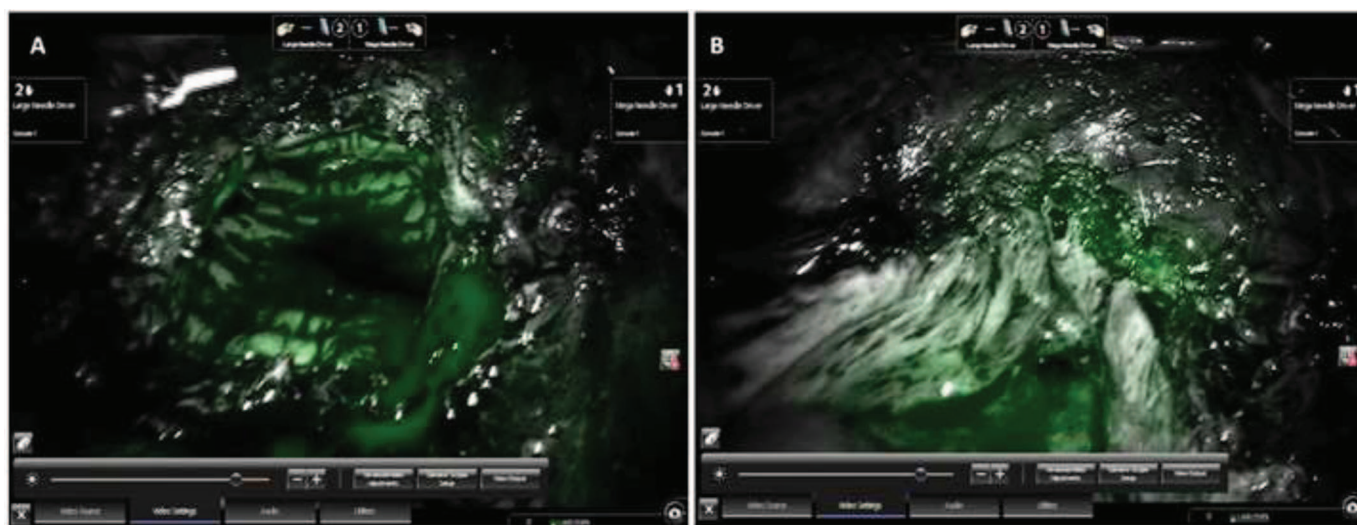
The Cleveland Clinic Foundation Institutional Review Board provided approval for this prospective single-center trial. The protocol was adapted from our team's previous trial in which we used conventional laparoscopy.<sup>9</sup> Inclusion criteria were adult patients (age, 18–65 years) scheduled for RATLH for benign indications. One surgeon had a high volume of procedures for benign gynecologic conditions, and the other a high volume of oncologic surgeries. Exclusion criteria included hypersensitivity to indocyanine green (ICG) or iodine, lactation or pregnancy, infected surgical field, extensive concomitant surgery (ie, bowel resection), and any prior pelvic radiation therapy or current chemotherapy treatment.

Under a factorial design, participants were randomly allocated to 1 of 4 groups based on 2 criteria after enrollment. The first criterion was electro-surgical energy device used for colpotomy, either monopolar or ultrasonic, and the second was suture type used for cuff closure: barbed (0 V-Loc 180, Medtronic, Minneapolis, Minnesota, USA) or nonbarbed (0 Polysorb or 0 Maxon; Medtronic, per surgeon preference). An online randomization tool (Sealed Envelope, [www.sealedenvelope.com](http://www.sealedenvelope.com)) was used create a

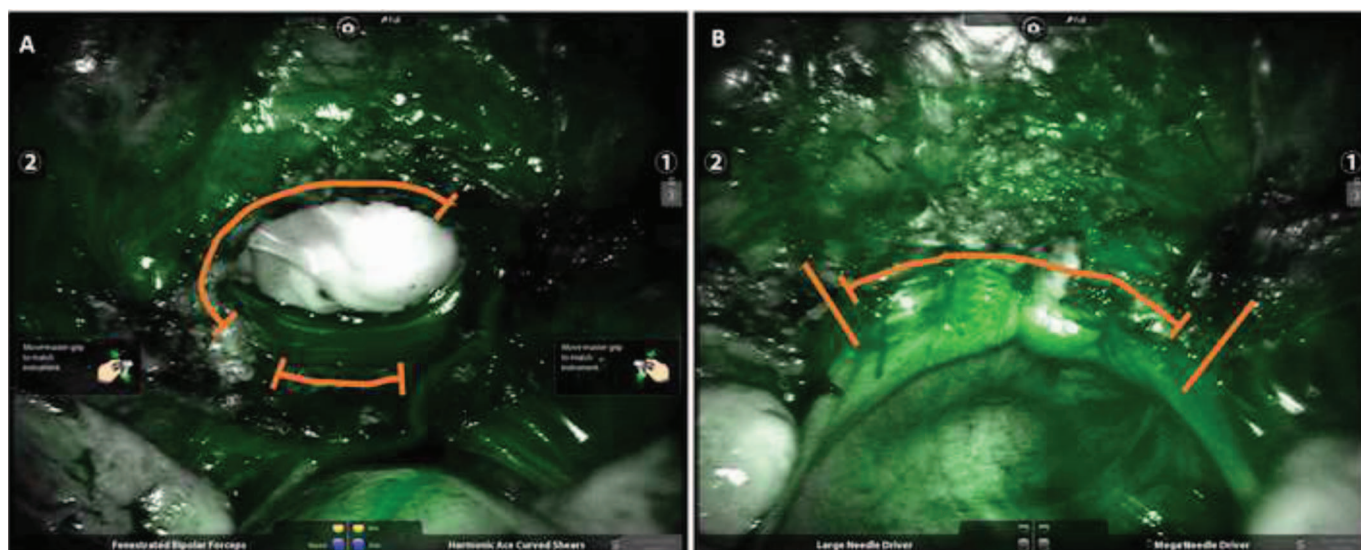
random list using blocks of 4, which was then concealed in sealed opaque envelopes. Each participant's allocation was revealed to the surgical team when the operating room was opened, to allow setup of proper instrumentation. The monopolar electrode was scissors (HotShear; Intuitive Surgical) attached to an electro-surgical unit (ValleyLab ForceTriad; Medtronic) at a 50-W pure cut waveform. Harmonic ACE curved shears (Ethicon, Somerville, New Jersey, USA) for the Da Vinci system were used for ultrasonic energy groups in maximum power mode for colpotomy. Each patient had an appropriately sized uterine manipulator (V-Care; ConMed, Utica, New York, USA) placed at the beginning of surgery, and, beyond the colpotomy energy method and suture for cuff closure, the hysterectomies were performed according to surgeon preference. Surgeries were performed by fellows in minimally invasive gynecologic surgery under the supervision of the experienced gynecologic surgeons. Port configuration used 4 or 5 ports in an inverted-U or linear pattern. Vaginal cuff sutures were placed using the Mega needle driver (Intuitive Surgical).

Audio recordings were made of instrument activation during colpotomy for later processing and determination of time of energy application to cuff tissue. ICG was prepared based on standard packaging for a final concentration of 2.5 mg/mL. The laser angiography system (FireFly vision technology for Da Vinci Si; Intuitive Surgical) was activated, and ICG was administered intravenously by the anesthesia team. Each dose (2.5–10.0 mg) was followed by a 10-mL saline flush. Time from administration until appearance within the pelvis was noted, and digital images were captured of the resultant fluorescence (**Figure 1**). After cuff closure under white light, the steps of ICG administration and laser angiography image capture were repeated. Patients had same-day discharge and were followed in the clinic with routine visits at 2, 6, and 12 weeks after surgery.

Three members (fellows in minimally invasive gynecologic surgery) of the research team independently reviewed printed laser angiographic images and individually marked the areas they thought had adequate perfusion (**Figure 2**). Each reviewer marked images of all cuffs, and a mean value was calculated. Areas of adequate perfusion were reported as a percentage of open-cuff perimeter or closed-cuff length. Audio recordings of colpotomy instrument activation were analyzed to determine total time of activation, assuming constant contact with tissue during activation. These times were corrected to colpotomy circumference as judged by known uterine manipulator cervical cup circumference. Only large bleed-



**Figure 1.** Laparoscopic images of the vaginal cuff during robot-assisted total laparoscopic hysterectomy with laser angiography with ICG with FireFly vision technology before (A) and after (B) cuff closure. The green overlay represents detected fluorescence from intravenous ICG.



**Figure 2.** Representative images showing markings (orange lines) placed by evaluators in areas judged to have adequate perfusion before (A) and after (B) cuff closure. The long perpendicular bars in (B) define the total length of the closed cuff.

ing points along the cuff were controlled, with additional judicious energy application via monopolar or bipolar electro-surgical instruments, whereas small areas of bleeding were controlled with suture hemostasis during cuff closure. These additional instrument activation signals were not included in the data analysis, as they were identifiable by unique tones. Intergroup comparisons were performed with unpaired *t* test and linear regression. Research Electronic Data Capture (REDCap)<sup>11</sup> was used to

collect and manage study data, and statistical analyses were performed with Excel (Microsoft Office 2013, Microsoft, Redmond, Washington, USA).

## RESULTS

Twenty patients were enrolled in the study from February 2016 to March 2017. **Table 1** lists patient characteristics.



**Table 1.**  
Patient Characteristics and Operative Data

Characteristics	Data
<i>N</i>	20
Age, years (range)	45 (31–64)
Race/ethnicity, n (%)	
White	10 (50%)
Black	5 (25%)
Hispanic/Latino	5 (25%)
Gravidity, n (%)	3 (1–7)
Parity, n (%)	2 (0–3)
BMI (kg/m <sup>2</sup> )	28.0 (21.1–43.6)
Anesthetic Risk, n (%)	
ASA 1	2 (10%)
ASA 2	16 (80%)
ASA 3	2 (10%)
Diabetes mellitus, n (%)	4 (20%)
Smoking status, n (%)	
Never	15 (75%)
Quit	4 (20%)
Current	1 (5%)
Primary surgical indication, n (%)	
AUB-L	9 (45%)
AUB	1 (5%)
Pelvic pain	5 (25%)
Cervical dysplasia	3 (15%)
Lynch syndrome	1 (5%)
Postmenopausal bleeding	1 (5%)
Estimated blood loss, mL (range)	62.5 (25–400)
Change in hemoglobin, mg/dL (range)	–0.6 (–3.1 to +0.5)
Data are expressed as median (range) or number (%)	
BMI, body mass index; ASA, American Society of Anesthesiologists; AUB-L, abnormal uterine bleeding–leiomyoma; AUB, abnormal uterine bleeding–unspecified.	

No patients had vasculopathy or chronic steroid use, and all final pathology was benign.

Fluorescence obtained by laser angiography with ICG was visible at the vaginal cuff in all patients, both before and after cuff closure. Technical difficulties caused a fault in storing images for 3 patients before and after cuff closure (2 ultrasonic/nonbarbed group, 1 ultrasonic/barbed group), 1 patient before cuff closure only (monopolar/barbed group), and 1 patient after

cuff closure only (monopolar/nonbarbed group). No complications were caused by administration of ICG.

ICG fluorescence appeared in the pelvis as soon as 7 s after saline flush, with a mean of 18.4 s (SD ±7.3) before cuff closure and 19.0 s (SD ±8.7) after cuff closure. The initial 2 patients received doses of 2.5 mg (1 mL) at each ICG administration, but it was thought to be poorly visible. The next 8 patients received 5 (2 mL), 7.5 (3 mL), or 10 (4 mL) mg for each dose, with the research team eventually settling on 7.5 mg (3 mL) for the final 10 patients, which provided sufficient visualization of the pelvis without oversaturating the screen with fluorescence. The dose after cuff closure was given 21.9 ± 6.1 minutes (mean ± SD) after precuff closure dose, and ICG fluorescence remained visible in all except 3 patients. Regardless, all patients received the second dose of ICG after cuff closure, and all demonstrated new or further fluorescence at the vaginal cuff.

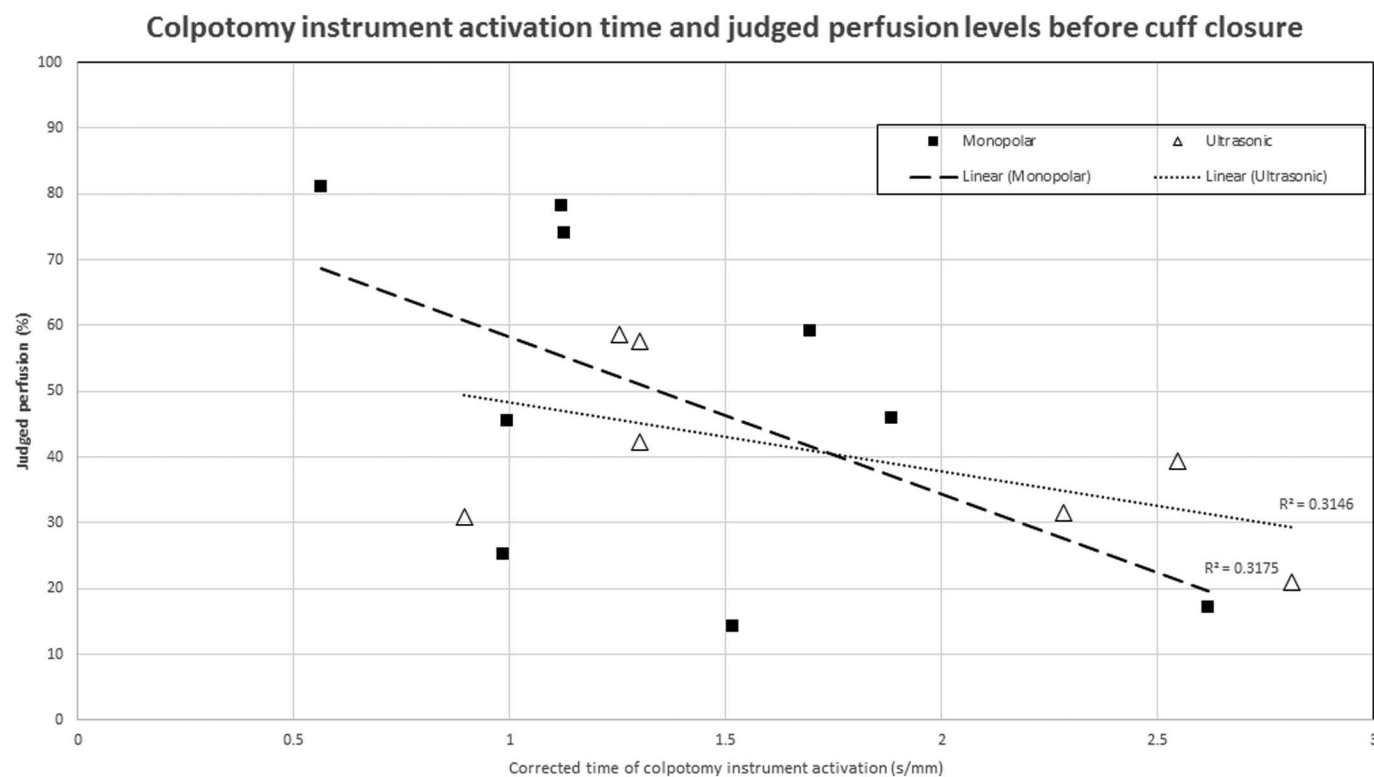
**Table 2** lists results of corrected time of colpotomy instrument activation and the composite estimated perfusion percentages. No difference was noted in judged perfusion between monopolar or ultrasonic colpotomy instrumentation, before ( $P = .19$ ) or after ( $P = .36$ ) cuff closure. Also, no difference was noted after cuff closure among the groups with barbed suture or nonbarbed suture ( $P = .19$ ). With increased corrected time of colpotomy instrument activation we noticed a trend toward decreased estimated perfusion for both monopolar and ultrasonic instrumentation, although neither trend showed a strong association (**Figure 3**).

No complications occurred during surgery, beyond an intraoperative blood transfusion for 1 patient (monopolar/nonbarbed group) who had pre-existing anemia. All patients completed a 2-week postoperative visit: 1 (5%) had granulation tissue (monopolar/nonbarbed group) and 1 (5%) reported vaginal bleeding (ultrasonic/barbed group). No patients had cuff separation, dehiscence, or infection during the 12 weeks of study follow-up. Sixteen patients (80%) completed a 6-week follow-up, with 1 patient (6.3%) reporting vaginal bleeding (ultrasonic/nonbarbed group) and none reporting cuff separation, dehiscence, granulation tissue, or infection. Only 7 of 20 (35%) of patients completed the 12-week visit, with no evidence of bleeding, cuff separation, dehiscence, granulation tissue, or infection on examination.

**Table 2.**  
Results of Colpotomy Instrument Activation and Judged Perfusion Based on Group Assignment

Group	Corrected Time of Colpotomy Instrument Activation (s/mm)	Judged Perfusion Before Cuff Closure (%)	Judged Perfusion After Cuff Closure (%)
Monopolar	1.37 (±0.58)	49.0 (±26.0)	70.9 (±21.1)
Ultrasonographic	1.79 (±0.62)	40.2 (±14.1)	70.5 (±20.5)
Barbed			
Monopolar	1.36 (±0.33)		74.4 (±27.3)
Ultrasonographic	1.92 (±0.71)		73.7 (±9.2)
Nonbarbed			
Monopolar	1.37 (±0.81)		66.5 (±12.0)
Ultrasonographic	1.67 (±0.57)		66.3 (±33.0)

All data are means (±SD).



**Figure 3.** Trend of the relation between corrected time of colpotomy instrument activation and judged perfusion. Monopolar instrumentation: filled squares, long dashes. Ultrasonic instrumentation: hollow triangles, short dashes.

## DISCUSSION

We have demonstrated the feasibility of using laser angiography with ICG for evaluating vaginal cuff perfusion during RATLH in this study, based on the appearance of ICG fluorescence at the vaginal cuff in all

patients. Although clinical utility in gynecology remains uncertain for this technology, a foundation has been provided for dose of ICG and developing measurable outcomes. We found that the FireFly vision technology did not afford good views of the entire pelvis, requiring

close zooming in to the tissue of interest to maximize fluorescence contrast. This may have occurred because the FireFly technology presents normal anatomy as black and white with ICG fluorescence as a green overlay. When using these close views, along with our optimal ICG dose of 7.5 mg per administration, satisfactory fluorescence was consistently seen. This result contrasts with those in our prior report<sup>9</sup> with the Pin-Point endoscopic fluorescence imaging system (Novadaq, Mississauga, Ontario, Canada), which allowed full pelvic views, use of only 5 mg ICG per dose, and better contrast, with its Spy mode presenting normal tissue as black and ICG fluorescence as a white overlay.

A similar critique of the 2 technologies is the lack of quantifiable fluorescence measurements. This hindrance led us to devise our method of objectively reporting the visualized fluorescence as a percentage of the open cuff perimeter or closed cuff length. The trichromatic FireFly images made the evaluator's analysis of cuff images more difficult than the dichromatic PinPoint Spy mode images. Although our method did not reveal any significant difference in cuff perfusion between instrumentation used for colpotomy creation or suture used for cuff closure, it did reveal a parallel trend with time of colpotomy instrument activation. Tissue application of electrosurgical energy should be used judiciously, as increased time of activated contact increases unintended tissue effects through increased lateral thermal spread. As prior reports evaluated only type of electrosurgical energy, we chose to analyze time of electrosurgical energy application. Our study may show that laser angiography can verify this concept in real-time, as estimated perfusion was found to decrease with increasing corrected times of colpotomy instrument activation (**Figure 3**). This effect was seen only in open cuffs, not closed cuffs, which may suggest that reperfusion can occur during the time of cuff closure or that the areas of minimal perfusion are buried within the cuff closure and no can longer be visualized laparoscopically. Improving the quantification process of robot-assisted laparoscopic fluorescence imaging should enable improvement of these techniques.

This study was limited by a small enrollment, given that it was intended for feasibility and contribution toward future research design. The slow rate of enrollment matches our practice's distribution of robotic versus conventional laparoscopy resulting from limited access to the robotic system. A larger patient sample may have allowed the trends seen in our study to gain statistical significance, but conversely could reveal them as false.

We caution against change in practice patterns based on the result of this study alone. The minor postoperative complications (vaginal bleeding and granulation tissue) cannot be definitively commented on because of the small sample size. Unfortunately, during our study, in the operating room with the robotic surgery hardware, there were multiple changes to the digital recording device, causing technical errors that led to missing images, further limiting the results from our small sample. Although most patients completed at least 6 weeks of follow-up, there was a high loss at the 12-week mark, as patients did not respond to reminders to schedule these visits, which required examinations and therefore could not be performed by telephone.

A full cost-benefit analysis cannot be performed, as the clinical benefits of the technology remain unproven, but laser angiography with ICG has an advantage of low increased cost of utilization. ICG can be obtained for a nominal charge for each patient,<sup>9</sup> ICG has few contraindications, and many existing laparoscopic and robot platforms have laser angiography capabilities. In addition, for women undergoing hysterectomy for benign indications, tolerance and safety are high with the exclusion of those with iodine allergies.

## CONCLUSION

Vaginal cuff perfusion during RATLH can be evaluated by using laser angiography with ICG, because fluorescence is consistently seen at the vaginal cuff. Development of improved methods for quantification of fluorescence could allow for more widespread research leading to clinical utility.

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