Bulletin of Pioneering Researches of Medical and Clinical Science

Bulletin of Pioneering Researches of Medical and Clinical Science

Available online: https://bprmcs.com
2026 | Volume 6 | Issue 1 | Page: 22-29

Minimally Invasive Pelvic Reconstruction Using a Robotic Rectus Abdominis Flap: A Single-Center Study

Lucas Meyer[1]*, Anna Schmid[2], Stefan Braun[1]

[1]Department of Medical Research Systems, ETH Zurich, Zurich, Switzerland.
[2]Department of Clinical Investigation Sciences, University of Bern, Bern, Switzerland.

Abstract

Robotic surgery has seen rapid and widespread uptake among gynecologic surgeons, largely because of its proven capacity to lower patient morbidity. Plastic surgeons must therefore update their reconstructive strategies to fully leverage the advantages of robotic-assisted procedures. This paper describes our clinical outcomes using robotic-assisted rectus abdominis muscle flaps for posterior vaginal wall reconstruction. It includes a review of the existing literature on robotic-assisted reconstructive pelvic surgery. Following IRB approval, we conducted a retrospective analysis of all patients who received robotic pelvic reconstruction at a single institution from 2016 to 2024. Those who specifically underwent posterior vaginal wall reconstruction with a robotic-assisted rectus abdominis muscle (RRAM) flap were included in the final evaluation.

Thirty-two patients underwent pelvic reconstruction employing robotic surgical methods. Of these, five (mean age = 56.2 years, range = 32–72 years; mean BMI = 30.0, range = 24–39.9) received posterior vaginal wall reconstruction using an RRAM flap. Two patients (40%) experienced minor wound complications, while one patient (20%) developed vaginal stenosis eight years postoperatively. No major complications occurred that required return to the operating room or hospital readmission. All patients ultimately achieved complete and successful healing. Published studies indicate that robotic-assisted surgery offers important benefits, including lower morbidity through reduced intraoperative blood loss, decreased pain, quicker recovery times, and shorter hospital stays. The RRAM flap proves to be well tolerated for pelvic reconstruction even in patients with significant comorbidities, while still preserving the minimally invasive nature of the original extirpative procedure. As robotic technology continues to gain broader acceptance, plastic surgeons should actively incorporate these techniques into their surgical repertoire.

Keywords: Robotic rectus abdominis flap, Robotic surgery, Plastic surgery, Reconstructive surgery

Corresponding author: Lucas Meyer
E-mail: lucas.meyer@gmail.com

Received: 01 September 2025
Revised: 15 January 2026
Accepted: 16 January 2026

How to Cite This Article: Meyer L, Schmid A, Braun S. Minimally Invasive Pelvic Reconstruction Using a Robotic Rectus Abdominis Flap: A Single-Center Study. Bull Pioneer Res Med Clin Sci. 2026;6(1):22-9. https://doi.org/10.51847/ax4HeIIqLk

Introduction

The National Aeronautics and Space Administration (NASA) and the United States military originally funded the development of robotic-assisted surgical systems in pursuit of "telepresence" surgery, which would allow surgeons to operate without being physically present at the patient's side [1, 2]. Due to existing technological limitations at the time, the project was handed over to Intuitive Surgical for further advancement of the DaVinci platform. A key priority in contemporary surgery has been minimizing the invasiveness of procedures, and robotic technology has been instrumental in driving this transformation. Robotic-assisted methods have delivered clear advantages to both surgeons and patients by providing improved dexterity, greater precision, and motion scaling for the operator [1-6]. Numerous investigations have documented reduced patient morbidity, including less intraoperative blood loss, shorter hospitalizations, decreased postoperative pain, and accelerated recovery. Moreover, the availability of three-dimensional visualization and magnified operative fields has made more intricate operations feasible.

The Food and Drug Administration approved the DaVinci system for gynecologic surgery in 2005 [7]. Since that approval, robotic-assisted laparoscopic surgery has experienced steady growth in adoption. Between 2007 and 2010, the percentage of hysterectomies performed with robotic assistance rose sharply from 0.5% to nearly 10% [8]. Robotic-assisted laparoscopic techniques are now firmly established for managing benign gynecologic disorders [8-11]. Procedures such as myomectomies and hysterectomies have shown notably lower blood loss compared with traditional vaginal or open approaches. The DaVinci platform is especially beneficial for obese patients, individuals with extensive prior adhesions, and those suffering from severe endometriosis. Robotic assistance has also significantly reduced the conversion rate from laparoscopy to laparotomy. Sacrocolpopexies and sacrohysteropexies particularly benefit from the superior precision and wrist-like articulation offered by robotic systems when compared with standard laparoscopy [12, 13]. Operative suturing times are often reduced, and the management of mesh- or suture-related complications from sling procedures has been enhanced with robotic assistance.

Additionally, robotic techniques have been linked to fewer conversions to open surgery in endometrial and cervical cancer cases [14-16]. Reports have also indicated lower overall complication rates and fewer bladder injuries. The ability to work effectively across multiple abdominal quadrants makes robotics especially valuable in complex gynecologic procedures.

Our institution, the University of Nevada, Las Vegas, previously reported one of the largest series on robotic rectus abdominis flaps for perineal reconstruction [17]. That work illustrated that minimally invasive repair remains effective even when substantial dead space is present or when vaginal reconstruction is required. A statistically non-significant rise in minor complications (specifically wound dehiscence) was noted among patients treated with open flaps. No meaningful differences emerged regarding major complications, total operative time, or hospital length of stay when comparing RRAM to traditional open techniques in that earlier cohort, which extended through 2021. Importantly, eliminating the skin paddle and associated subcutaneous fat bulk — typically seen with vertical rectus abdominis myocutaneous flaps — appeared to decrease the incidence of vaginal stenosis when using the RRAM flap. Furthermore, the peritoneum covering the deep aspect of the harvested RRAM flap demonstrated comparable strength and pliability to native vaginal tissue in vaginectomy defects.

The present study seeks to expand on the existing literature by detailing our more recent experience and long-term outcomes with robotic-assisted rectus abdominis muscle flap harvest for vaginal wall reconstruction.

Materials and Methods

Following IRB approval, a retrospective analysis was conducted on every robotic rectus abdominis muscle (RRAM) flap raised for perineal reconstruction by a single surgeon at a single center using the da Vinci Surgical System from 2014 to 2024. 32 patients met the inclusion criteria (mean age = 59.9 years; number of females = 12). From this group, those who specifically received posterior vaginal wall reconstruction via RRAM methods were chosen for detailed qualitative review and descriptive statistical evaluation.

Results and Discussion

Case 1

The patient was diagnosed with biopsy-verified invasive rectal adenocarcinoma. She completed preoperative chemoradiation therapy, underwent low anterior resection, and finished adjuvant chemotherapy afterward. One year later, a rectovaginal fistula developed, prompting the creation of a diverting colostomy. She subsequently had a primary repair of the vaginal fistula using a coloanal flap in addition to another low anterior resection with formation of an end colostomy. Rectal recurrence was later identified. Consequently, she proceeded with abdominoperineal resection combined with vaginal reconstruction employing a robotic rectus (RRAM) flap. Extensive scar tissue resulting from earlier operations and radiation was evident. To enhance visibility amid the dense scarring, lateral port placement was required. Harvest of the muscle proceeded from superior to inferior, with the rectus sheath divided down to the vascular pedicle. The posterior rectus sheath, together with the peritoneum, was anchored to the vaginal wall borders using interrupted sutures. Speculum examination afterward confirmed satisfactory tissue alignment and secure closure. No immediate wound issues arose; however, adenocarcinoma recurred along the vaginal wall, necessitating repeated courses of chemotherapy and further vaginal brachytherapy. Vaginal stenosis became apparent eight years following the RRAM operation.

Case 2

The patient presented with Bartholin gland carcinoma that had spread through the posterior vaginal wall, rectum, and anus. An abdominoperineal resection was performed jointly by colorectal surgery and gynecologic oncology teams. Plastic surgery employed an RRAM flap for reconstruction of the posterior vaginal wall, obliteration of the fresh pelvic cavity, support of the rectal vault, and final perineal closure. Extra ports were inserted in the left lateral abdominal wall to locate the deep inferior epigastric artery pedicle situated in the right lower quadrant. Division of the falciform ligament was also performed to secure greater RRAM flap length reaching above the costal margin. Overall closure length measured 16 cm. The patient recovered satisfactorily after surgery, though she experienced superficial perineal wound separation managed with packing for one month and hypergranulation tissue addressed with gentian violet application.

Case 3

This patient developed a rectovaginal fistula following an earlier low anterior resection for rectal cancer after completing both chemotherapy and radiation. Radiation-related soft tissue injury was present in the region. Following initial adhesiolysis and rectovaginal fistula repair with rectal stump closure performed by colorectal surgery, an RRAM flap was elevated. Two additional ports were introduced, the pedicle was carefully isolated, and a myoperitoneal flap measuring 7 × 8 cm² was used to provide robust vascularized coverage over the repair in a previously irradiated field. Biologic mesh reinforcement was applied at the anterior repair site. The patient tolerated the reconstruction without difficulty and had no wound-related problems. Hospitalization was extended because of a left ureter injury that occurred during adhesiolysis, requiring both an indwelling Foley catheter and nephrostomy tube placement.

Case 4

Plastic surgery was asked to assist with pelvic floor reconstruction in a patient suffering from recurrent adenocarcinoma at the rectosigmoid junction. She had already received a low anterior resection with loop ileostomy creation, followed by ostomy reversal once chemoradiation was completed. She then underwent robot-assisted laparoscopic abdominoperineal resection with subsequent reconstruction of the perineum and posterior vaginal wall using a right-sided RRAM flap and abdominal wall support with Strattice mesh. **Figure 1** demonstrates reinforcement with the biological mesh. Her recovery after surgery proceeded without complications.

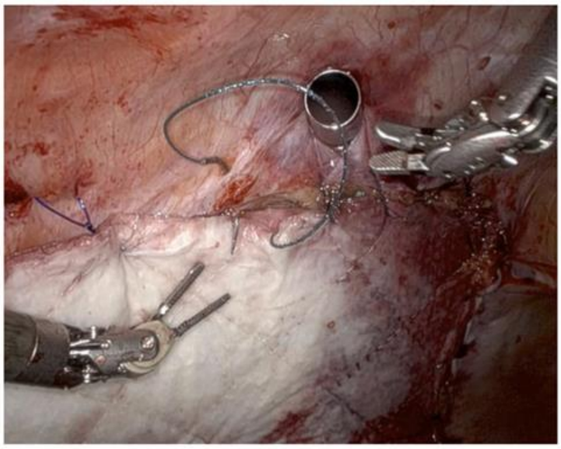

Figure 1. Reinforcement of the repair with a Strattice mesh using a barbed suture.

Case 5

The patient was scheduled for a joint procedure involving both colorectal and plastic surgery teams. She had a documented history of squamous cell carcinoma of the anal canal that persisted despite chemotherapy and radiation, in addition to a previous low anterior resection. The recurrent tumor had invaded the rectum and posterior vaginal wall. She subsequently underwent robot-assisted laparoscopic abdominoperineal resection, followed by reconstruction performed with a robotic rectus abdominis flap. Postoperative imaging revealed no intra-abdominal abscess or signs of disease recurrence, and the remaining recovery period proceeded without issues.

Dead space is an unoccupied cavity that results from tissue loss due to injury, infection, or surgical removal. This space increases the likelihood of serious problems, most notably hernia formation and fluid buildup, which may become a breeding ground for infection and progress to deep-space abscesses [18, 19]. Pelvic exenteration carried out for advanced or recurrent gynecologic malignancies generates sizable cavities in the effort to obtain clear oncologic margins. Reconstructive efforts are often undertaken simultaneously with intricate urogynecologic operations to restore typical anatomy and shrink these cavities. Such reconstruction can also correct issues, including pelvic organ prolapse, congenital absence of the vagina, and various fistulas.

Flap procedures represent a cornerstone of reconstruction after major gynecologic interventions and can even reinstate the functional role of pelvic structures such as the vaginal canal, perineum, and vulva [20-23]. A flap involves moving tissue from a donor area to a recipient site to replace lost skin, fat, muscle, or bone. While nearby tissue can sometimes be advanced, pedicled or free flaps permit relocation across greater distances and are frequently selected by plastic and reconstructive surgeons when dealing with extensive pelvic cavities [22]. Perforator flaps are supplied by vessels that travel through the underlying muscle or fascia before reaching the subcutaneous layer and skin [24]. Pedicled flaps allow repair of defects without severing the original blood supply. Free flaps are completely detached from their source vessels and require reconnection of the vessels at the target location. Options regularly chosen for pelvic coverage and volume restoration include gracilis, omental, rectus abdominis, gluteus maximus, and anterolateral thigh flaps [22]. With gynecologic surgeons increasingly favoring minimally invasive methods to lessen overall patient harm, a parallel demand has emerged for flap elevation to follow the same minimally invasive pathway. Adding robotic assistance to gynecologic and pelvic reconstruction helps unify the surgical process, lower complications at the donor site, and better maintain the advantages of minimal access surgery.

The rectus abdominis flap remains a dependable mainstay for abdominal and pelvic reconstruction. Its primary strength lies in reliably filling dead space, a central tenet of successful pelvic repair. The standard rectus abdominis flap (VRAM) is traditionally raised through an open incision incorporating a vertical skin island and requiring direct exposure of the muscle [17, 25-34]. This flap is highly adaptable thanks to its dual vascular input from the superior and inferior epigastric arteries [17, 25]. **Figure 2** shows an intra-abdominal view of the inferior epigastric pedicle during rectus abdominis flap elevation. Even so, the added morbidity of open harvesting can counteract the gains achieved by minimally invasive tumor removal in the pelvis.

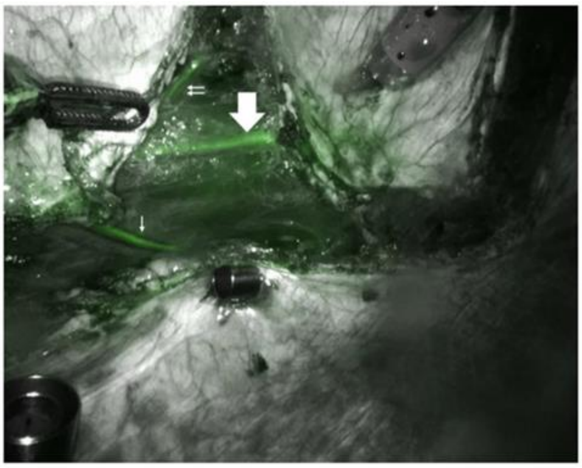

Figure 2. Intra-operative photo of indocyanine green used for the identification of the deep inferior epigastric pedicle for the flap. The white arrow is the vessel (highlighted pedicle).

As colorectal surgeons and gynecologic oncologists increasingly adopt minimally invasive techniques, the cavities left behind are typically smaller than those resulting from conventional open laparotomy. Enhanced visualization frequently enables precise isolation of tumors lying close to the vaginal wall. In earlier years, when resections were more radical, the skin paddle included with VRAM flaps provided useful bulk. However, the vaginal lining is hairless and differs markedly in microscopic structure from cutaneous tissue. Drs. Wu and Song at the University of Chicago documented five patients treated between 2003 and 2005 who received a rectus abdominis myoperitoneal flap for vaginal wall repair [35]. Their series confirmed the reliability of these flaps and noted that the peritoneum had successfully merged with the vaginal lining by two months after surgery. The RRAM approach preserves the peritoneal layer, which experimental work in rats and swine has shown to promote improved healing [36]. In one model, the myoperitoneal flap developed uroepithelial metaplasia as early as two weeks postoperatively [3]. A further study using an open rectus abdominis myoperitoneal flap for vaginal reconstruction reported that the peritoneum was histologically nearly identical to native vaginal mucosa [35, 37].

The intraperitoneal robotic harvest of the rectus abdominis muscle has become increasingly popular among surgeons involved in pelvic reconstruction over the last 20 years. This shift is driven by multiple factors that extend well past simply upholding the minimally invasive character of the primary tumor removal. Key benefits include fewer incision-related complications and hernias, closer alignment with natural gynecologic anatomy, and enhanced cosmetic outcomes at the donor site [24-34].

The RRAM approach relies on a three-port method combined with Airseal (Conmed, Largo, FL, USA) to maintain proper pneumoperitoneum. Once the pedicle—originating from the external iliac artery and vein—is traced through the peritoneum, the posterior fascia is opened with electrocautery. A barbed suture is then used to attach the mesh to the posterior fascial opening. Off the console, the posterior rectus fascia and its attached peritoneum are shaped to rebuild the pelvic floor. Our team has already provided a full technical description of this RRAM harvesting process in an earlier report [17].

Since 2014, our center has carried out thirty-two RRAM operations for pelvic reconstruction. Among them, five patients (mean age = 56.2 years, range = 32–72 years; mean BMI = 30.0, range = 24–39.9) underwent posterior vaginal wall reconstruction using an RRAM flap, as previously described. Patient demographics are summarized in **Table 1**. Every patient in this group had undergone preoperative neoadjuvant chemoradiation. No major adverse events occurred that necessitated a return to the operating room or inpatient readmission. Complete and successful healing was observed in all cases.

Table 1. Demographic overview of patients receiving robotic rectus abdominis flap for vaginal wall reconstruction.

Case	Age	Diagnosis	Associated procedure	BMI (kg/m²)	Postoperative outcome
Case 1	32	Rectovaginal fistula associated with rectal carcinoma	Abdominoperineal resection	24.0	Vaginal stenosis
Case 2	33	Carcinoma of the Bartholin gland	Abdominoperineal resection	39.9	Minor wound issues managed with topical therapy
Case 3	66	Rectovaginal fistula secondary to rectal carcinoma	Surgical takedown of rectovaginal fistula	26	No flap-related complications (ureteric injury occurred during initial fistula surgery)
Case 4	72	Adenocarcinoma at the rectosigmoid junction	Abdominoperineal resection	20.9	No reported complications
Case 5	78	Anal squamous cell carcinoma	Abdominoperineal resection	39.9	No reported complications

One individual developed vaginal stenosis eight years following the procedure. Notably, this patient had needed adjuvant brachytherapy and suffered a direct recurrence involving the vaginal wall. While radiation therapy effectively targets cancer cells by triggering apoptosis and halting progression at the G1/S phase in fast-dividing cells, it simultaneously inflicts considerable harm on nearby healthy tissues [38, 39]. It disrupts blood vessels and prevents new vessel growth, thereby undermining tissue strength and quality. Radiation-induced vaginal stenosis represents a recognized consequence of pelvic radiation treatment. The mechanism involves overproduction of scar tissue due to collagen accumulation in the vaginal connective tissue, leading to fibrosis and tissue hardening [40].

Two of the five patients (⅖) experienced minor wound-related issues. Existing studies report wound complication rates for VRAM flaps during abdominoperineal reconstruction ranging from 25% to 79%. In our previous analysis involving 16 RRAM flaps, the minor wound complication rate was 31%, compared with 55% in the corresponding VRAM cohort. These outcomes are partly attributable to radiation effects, especially since 92% of individuals receiving VRAM flaps also undergo radiation therapy as part of their care.

The current series is modest in size (n = 5), making qualitative assessment more appropriate than statistical generalization. Although limited patient numbers limit broad inferences, the results clearly demonstrate that plastic surgeons can reliably perform flap harvest, defect repair, and tissue inset.

Investigators at Mayo Clinic Arizona reviewed six cases in which the rectus abdominis muscle was harvested for pelvic floor repair [32]. The patients presented with diverse conditions ranging from complex pelvic organ prolapse and vesicovaginal fistula to gynecologic malignancies requiring exenteration, vaginectomy, vulvectomy, or abdominoperineal resection. Even with multiple underlying health problems and compromised tissue quality, all six achieved satisfactory pelvic wound healing. A separate Mayo Clinic report described a female patient with a persistent vesicovaginal fistula after uterine cancer treatment. Earlier conservative management and a robotic attempt later converted to open surgery had proven unsuccessful [41]. Interposition of a robotic rectus abdominis flap between the vagina and bladder ultimately secured reliable fistula closure.

Emerging techniques now include robotically procured peritoneal flaps for constructing the upper portion of a neo-vagina in gender-affirming vaginoplasty procedures. A team from New York University documented an extra 5 cm of vaginal canal depth in their series, with no complications reported [42].

Conclusion

Robotic surgery offers a range of substantial benefits. The robotic arms facilitate precise dissection in complex areas, remove hand tremors, and enable deep pelvic work without the usual constraints of surgeon posture and reach [17, 25-34]. In addition, the camera system of the DaVinci platform delivers outstanding clarity and magnification that would be difficult to achieve in traditional open or standard laparoscopic procedures. Superior visualization is one of the robotic platform’s greatest strengths, proving especially valuable during pelvic operations. Greater instrument dexterity is particularly useful in confined anatomical spaces. Reports also indicate quicker patient recovery linked to smaller incisions and less overall tissue disruption. These reduced incisions often yield improved cosmetic results.

Despite its strengths, robotic surgery has notable drawbacks. Surgeons and operating room teams face a demanding initial learning period that involves mastering robot docking, console operation, and various setup requirements [6]. Consequently, early procedures may take longer while the team builds proficiency with the technology. Dissection efficiency tends to improve markedly with accumulated experience. Another obstacle is the wide variation in robot credentialing policies across different hospitals, which can limit surgeon access [1]. From a technical perspective, the absence of haptic feedback — a feature available in conventional laparoscopy — remains a limitation. Robotic procedures are typically more expensive due to specialized instruments and potentially longer operating room time at the outset.

Nevertheless, multiple long-term investigations in other minimally invasive specialties have shown that these higher upfront costs are often offset by shorter postoperative hospital stays [43]. At present, relatively few studies address the specific application of robotics in reconstructive surgery. Much of the existing evidence consists of case reports or small series, which makes it challenging to draw firm general conclusions.

Robotic technology continues to evolve beyond current platforms, with ongoing innovations aimed at integrating robotics into microsurgery and enhancing fine motor control. The fifth-generation DaVinci system now includes haptic feedback, addressing one of the main earlier criticisms of robotic surgery [44]. The Medtronic Hugo system introduces a novel modular intracorporeal robotic platform that may challenge Intuitive's longstanding dominance in this field [45]. The Musa-3 platform, developed specifically for microsurgeons, shows considerable promise for performing vascular anastomoses in vivo [46]. Ongoing efforts to refine ergonomics could also extend surgeons' professional longevity.

In summary, robotic-assisted techniques have proven to be both feasible and safe when used by plastic and reconstructive surgeons following robotic pelvic procedures. Available literature indicates that methods such as the robotic rectus abdominis muscle (RRAM) flap achieve outcomes at least as good as those of conventional open approaches. Once the learning curve is surmounted, robotic techniques may even surpass open surgery in selected aspects. Additional well-designed studies are needed to confirm these advantages and to establish clear, evidence-based benefits of incorporating robotic methods into plastic and reconstructive surgery.

Acknowledgments: None

Conflict of interest: None

Financial support: The publication fees for this article were supported by the Graduate Medical Education Open Article Fund of the University of Nevada, Las Vegas.

Ethics statement: "The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of University Medical Center (protocol code UMC-2017-111 and date of approval 7 November 2017)." for studies involving humans.

Patient consent was waived as this was a retrospective review.

References

1. Selber J, editor. Preface. In: Robotics in plastic and reconstructive surgery. Berlin: Springer Nature; 2021. p. 7.
2. Morrell ALG, Morrell-Junior AC, Morrell AG, Mendes JMF, Tustumi F, De-Oliveira-E-Silva LG, et al. The history of robotic surgery and its evolution: when illusion becomes reality. Rev Col Bras Cir. 2021;48:e20202798.
3. Handa A, Gaidhane A, Choudhari SG. Role of robotic-assisted surgery in public health: its advantages and challenges. Cureus. 2024;16(6):e62958.
4. Rivero-Moreno Y, Echevarria S, Vidal-Valderrama C, Pianetti L, Cordova-Guilarte J, Navarro-Gonzalez J, et al. Robotic surgery: a comprehensive review of the literature and current trends. Cureus. 2023;15:e42370.
5. Hussain A, Malik A, Halim MU, Ali AM. The use of robotics in surgery: a review. Int J Clin Pract. 2014;68(10):1376–82.
6. Awad L, Reed B, Bollen E, Langridge BJ, Jasionowska S, Butler PEM, et al. The emerging role of robotics in plastic and reconstructive surgery: a systematic review and meta-analysis. J Robot Surg. 2024;18(2):254.
7. Sinha R, Sanjay M, Rupa B, Kumari S. Robotic surgery in gynecology. J Minim Access Surg. 2015;11(1):50–9.
8. Wright JD, Ananth CV, Lewin SN, Burke WM, Lu YS, Neugut AI, et al. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. JAMA. 2013;309(7):689–98.
9. Weinberg L, Rao S, Escobar PF. Robotic surgery in gynecology: an updated systematic review. Obstet Gynecol Int. 2011;2011:852061.
10. Capozzi VA, Scarpelli E, Armano G, Monfardini L, Celardo A, Munno GM, et al. Update of robotic surgery in benign gynecological pathology: systematic review. Medicina. 2022;58(3):552.
11. Asmar J, Even M, Carbonnel M, Goetgheluck J, Revaux A, Ayoubi JM. Myomectomy by robotically assisted laparoscopic surgery: results at Foch Hospital, Paris. Front Surg. 2015;2(2):40.
12. Sassani JC, Glass Clark S, McGough CE, Shepherd JP, Bonidie M. Sacrocolpopexy experience with a novel robotic surgical platform. Int Urogynecol J. 2022;33(10):3255–60.
13. Hudson CO, Northington GM, Lyles RH, Karp DR. Outcomes of robotic sacrocolpopexy: a systematic review and meta-analysis. Female Pelvic Med Reconstr Surg. 2014;20(4):252–60.

14. Jones N, Fleming ND, Nick AM, Munsell MF, Rallapalli V, Westin SN, et al. Conversion from robotic surgery to laparotomy: a case-control study. Gynecol Oncol. 2014;134(2):238–42.
15. Dinoi G, Tarantino V, Bizzarri N, Perrone E, Capasso I, Giannarelli D, et al. Robotic-assisted versus conventional laparoscopic surgery in obese patients with early endometrial cancer. Int J Gynecol Cancer. 2024;34(5):773–6.
16. Magrina JF, Zanagnolo V, Giles D, Noble BN, Kho RM, Magtibay PM. Robotic surgery for endometrial cancer: perioperative outcomes and recurrence. Eur J Gynaecol Oncol. 2011;32(4):476–80.
17. Davila AA, Goldman J, Kleban S, Lyons M, Brosious J, Bardakcioglu O, et al. Reducing complications and expanding use of robotic rectus abdominis muscle harvest. Plast Reconstr Surg. 2022;150(1):190–5.
18. Bocková M, Hoch J, Kestlerová A, Amler E. The dead space after extirpation of rectum. Physiol Res. 2019;68(Suppl 4):S509–15.
19. Mori GA, Tiernan JP. Management of perineal wounds following pelvic surgery. Clin Colon Rectal Surg. 2022;35(3):212–20.
20. Pusic AL, Mehrara BJ. Vaginal reconstruction: an algorithm approach to defect classification and flap reconstruction. J Surg Oncol. 2006;94(6):515–21.
21. Arcieri M, Restaino S, Rosati A, Granese R, Martinelli C, Caretto AA, et al. Primary flap closure of perineal defects after pelvic exenteration. Eur J Surg Oncol. 2024;50(2):107278.
22. Salgado CJ, Chim H, Skowronski PP, Oeltjen J, Rodriguez M, Mardini S. Reconstruction of acquired defects of the vagina and perineum. Semin Plast Surg. 2011;25(2):155–62.
23. Maciel-Miranda A, Morris SF, Hallock GG. Local flaps, including pedicled perforator flaps. Plast Reconstr Surg. 2013;131(4):896e–911e.
24. Raposio E, Moioli M, Raposio G, Spinacih S, Cagnacci A. Perforator flaps for vulvar reconstruction. Acta Biomed. 2022;93(5):e2022076.
25. Haverland R, Yi J, Rebecca AM. Rectus abdominis pedicled flap: robotic approach. J Minim Invasive Gynecol. 2019;26(7):S9.
26. Appel R, Shih L, Gimenez A, Bay C, Chai CY, Maricevich M. Robotic rectus abdominis harvest for pelvic reconstruction. Semin Plast Surg. 2023;37(2):188–92.
27. Taylor JP, Stem M, Althumairi AA, Gearhart SL, Safar B, Fang SH, et al. Minimally invasive proctectomy for rectal cancer. World J Surg. 2020;44(9):3130–40.
28. Hawkins AT, Albutt K, Wise PE, Alavi K, Sudan R, Kaiser AM, et al. Abdominoperineal resection in the 21st century. J Gastrointest Surg. 2018;22(8):1477–87.
29. Ibrahim AE, Sarhane KA, Pederson JC, Selber JC. Robotic harvest of rectus abdominis muscle. Semin Plast Surg. 2014;28(1):26–31.
30. Patel NV, Pedersen JC. Robotic harvest of rectus abdominis muscle. J Reconstr Microsurg. 2012;28(7):477–80.
31. Pedersen J, Song DH, Selber JC. Robotic intraperitoneal harvest of rectus abdominis muscle. Plast Reconstr Surg. 2014;134(6):1057–63.
32. Haverland R, Rebecca AM, Hammond J, Yi J. Robot-assisted rectus abdominis flap harvest: case series. J Minim Invasive Gynecol. 2021;28:245–8.
33. Singh P, Teng E, Cannon LM, Bello BL, Song DH, Umanskiy K. Tandem robotic technique for pelvic floor closure. Dis Colon Rectum. 2015;58(9):885–91.
34. Hammond JB, Howarth AL, Haverland RA, Rebecca AM, Yi J, Bryant LA, et al. Robotic harvest of rectus abdominis flap. Dis Colon Rectum. 2020;63(10):1334–7.
35. Wu LC, Song DH. Rectus abdominis musculoperitoneal flap for vaginal reconstruction. Plast Reconstr Surg. 2005;115(2):559–62.
36. Büyükünal SN, Kaner G, Celayir S. Rectus abdominis flap in bladder exstrophy model. J Pediatr Surg. 1989;24(6):586–9.
37. Niazi ZB, Kutty M, Petro JA, Kogan S, Chuang L. Vaginal reconstruction with rectus abdominis flap. Ann Plast Surg. 2001;46(6):563–8.
38. Jiao Y, Cao F, Liu H. Radiation-induced cell death mechanisms. Health Phys. 2022;123:376–86.
39. Bouten RM, Young EF, Selwyn R, Iacono D, Rittase WB, Day RM. Effects of radiation on vascular integrity. In: Gorbunov NV, editor. Tissue barriers in disease, injury and regeneration. Amsterdam: Elsevier; 2021. p. 43–94.
40. Morris L, Do V, Chard J, Brand AH. Radiation-induced vaginal stenosis. Int J Womens Health. 2017;9:273–9.
41. Nunez R, Rebecca A, Khan A, Wolter C. Robot-assisted vesicovaginal fistula repair. ICS; 1970. Available from: https://www.ics.org/2017/abstract/735
42. Jacoby A, Maliha S, Granieri MA, Cohen O, Dy GW, Bluebond-Langner R, et al. Robotic Davydov vaginoplasty. J Urol. 2019;201(6):1171–6.
43. Sabbatini F, La Regina D, Murgante Testa N, Senatore AM, Saporito A, Pini R, et al. Hospital costs of robotic-assisted hernia repair. Sci Rep. 2024;14(1):11523.
44. Intuitive. Da Vinci 5 has force feedback [Internet]. n.d. Available from: https://www.intuitive.com/en-us/about-us/newsroom/Force%20Feedback

45. Surgical Robotics Technology. Medtronic announces clinical studies for Hugo™ RAS system [Internet]. 2024 May 23. Available from: https://www.surgicalroboticstechnology.com/news/medtronic-announces-clinical-studies-for-hugo-ras-system/

46. Microsure. Microsure secures €38 million for Musa-3 robot [Internet]. 2023 Oct 4. Available from: https://www.prnewswire.com/news-releases/microsure-secures-38-million-to-advance-its-microsurgical-robot-musa-3-301946937.html