Weinstein *et al. Plast Aesthet Res* 2023;10:61
DOI: 10.20517/2347-9264.2023.41

Plastic and Aesthetic Research

Review

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Robotics in genital gender-affirming surgery

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How to cite this article: Weinstein B, Govekar H, Cherullo E, Jacobs KM, Schechter L. Robotics in genital gender-affirming surgery. *Plast Aesthet Res* 2023;10:61. https://dx.doi.org/10.20517/2347-9264.2023.41

Received: 10 May 2023 **First decision:** 29 Aug 2023 **Revised:** 15 Sep 2023 **Accepted:** 20 Oct 2023 **Published:** 27 Oct 2023

Academic Editors: Gennaro Selvaggi, Xiao Long **Copy Editor:** Yanbing Bai **Production Editor:** Yanbing Bai

Abstract

Gender-affirming genital surgery includes a constellation of pelvic procedures that can help feminize or masculinize the genitalia. Technological advances in robotic surgery can aid surgical access to and visualization of the pelvis, thereby facilitating certain procedures. In this scoping review, we will discuss the developing role of the robot in genital affirming genital surgery. Indications, techniques, and outcomes using the robot in both feminizing and masculinizing genital procedures will be reviewed.

Keywords: Robotic surgery, gender affirming surgery, vaginoplasty, peritoneal vaginoplasty, intestinal vaginoplasty, metoidioplasty, colpectomy, vaginectomy, phalloplasty

INTRODUCTION

Gender-affirming genital surgery is a personalized series of procedures that help alleviate gender incongruence. Feminizing genital procedures include vaginoplasty and masculinizing procedures include metoidioplasty or phalloplasty combined with hysterectomy and colpectomy with colpocleisis. These complex procedures require specialized care, and the robot may facilitate access to and visualization of the pelvic structures.

This scoping review will discuss the developing role of the robot in gender-affirming genital surgery. Through evaluation of peer-reviewed literature, we provide an overview of robotic surgery, with potential benefits and limitations in gender-affirming genital surgery. We focus on three vaginoplasty techniques performed with a robot, namely peritoneal vaginoplasty, intestinal vaginoplasty, and revision vaginoplasty. Additionally, we review the use of the robot for hysterectomy and colpectomy with colpocleisis as components of phalloplasty and metoidioplasty procedures. Indications, an overview of techniques, and outcomes will be discussed.

ASSESSMENT

Prospective patients for gender affirming surgery are evaluated in a comprehensive process according to guidelines established by the World Professional Association for Transgender Health, *Standards of Care*, Version 8[1]. Care is an individualized process that focuses on patient goals balanced with potential risks, and the informed consent process is one of shared decision making between the patient and provider. Preoperative assessment includes an assessment by mental/behavioral health professionals, medical optimization including pelvic floor physical therapy[2] when appropriate, and social work/case management evaluation to develop postoperative recovery plans and address social determinants of health. Anesthetic risk is considered and evaluated by institutional protocols. Additional specific risk factors that should be noted are bleeding or clotting disorders, hip or lower extremity concerns (lithotomy).

When gender-affirming genital surgery is performed with a robot, coordination and communication among surgical disciplines are required. This may include urology, gynecology, and/or colorectal surgery. As with other complex surgical procedures, patient education and a multidisciplinary team help optimize outcomes.

The use of the robot in colorectal, gynecological, urologic, plastic surgery, and other fields has expanded in recent years. Robotic surgery employs a surgical device with multiple arms capable of interchangeable tools for surgical access. The software platform permits surgeons to utilize a three-dimensional viewing dock while manipulating the remote instruments, improving visualization and facilitating dissection. Reported benefits include decreased biochemical oncologic recurrence of prostate cancer, improved pain for prostatectomy, improved sexual and urologic function for prostatectomy, and decreased conversion to open surgery in endometrial cancer[3]. As compared to open or laparoscopic surgery, the robotic platform provides improved surgeon ergonomics[4].

The robot can be particularly useful in the pelvis, where visualization can be difficult due to the narrow, non-distensible space obscured by complex musculoskeletal anatomy. Prior to the robot, urologic and gynecologic organs, as well as bowel, were only accessible through transabdominal, perineal, or laparoscopic approaches. After growth during the early adaptation period, robotic surgery has been relatively constant from 2018 to 2020 in general surgery, urology, and gynecology[5]. The decision making process to use robotic assistance is largely based on patient goals, anatomy, and risk factors. The characteristics that may favor the use of robots are outlined in each procedural section.

Limitations of the robot are related to the technology barrier (cost, learning curve, access) and the complexities of cases requiring both robotic and open approaches. The Da Vinci (Intuitive Surgical, Sunnydale, California) robot itself is expensive, but financing options are available. Other robotic platforms are available but are not well reported in the gender-affirming peer-reviewed literature. Robotic training in General Surgery, Urology and Obstetrics/Gynecology residency programs has improved, although standardization is lacking[6]. The learning curve for robotic colorectal surgery is faster than laparoscopic surgery, with fewer complications[7], and requires 31 cases to reach the maturation phase[8]. Many tertiary and academic facilities have access to robotic surgery, but smaller institutions or resource-constrained institutions may still lack the technology. Robotic surgery is safe; however, conversion to an open approach may be required in certain circumstances (i.e., bleeding). Surgical familiarity with open approaches is still required.

GENDER AFFIRMING VAGINOPLASTY

Proponents of the robot in gender affirming vaginoplasty (GAV) describe advantages in vaginal canal dissection and harvest of peritoneum or intestine when needed, for canal lining[9-11]. These techniques may be of particular benefit for revision vaginoplasty or vaginoplasty in patients with limited penile and/or scrotal tissue. Primary GAV utilizes homologous genital tissues to construct the clitorovulvar structures. The clitoris is constructed from the glans penis, the labia minora are created from the penile shaft skin and urethra, and the labia majora are fashioned from the scrotum. Penile skin flap may be used to line the introitus and distal vaginal canal but rarely provides sufficient tissue for desired vaginal depth. Vaginal lining may be derived from three sources: skin grafts (scrotal skin or non-genital full-thickness skin grafts), peritoneal tissue, or intestine (typically sigmoid colon)[9]. Each of these tissues may be used for either primary or revision vaginoplasty. Technical challenges in the procedure focus on the dissection of the vaginal canal. The senior author's preferred technique entails the identification of Denonvillier's fascia under direct vision. The fascial layer is incised, and the vaginal canal is developed bluntly, superior to Denonvillier's fascia. In addition to harvesting peritoneal flaps or an intestinal conduit, the robot may be helpful in developing the vaginal canal, especially in revision cases.

ROBOT PERITONEAL VAGINOPLASTY

The peritoneum consists of a layer of mesothelial cells that line the abdominal cavity. Peritoneal flaps provide additional tissue for vaginal lining, which may be necessary in cases of penile and scrotal insufficiency or revision vaginoplasty (i.e., vaginal stenosis or loss of depth). Dissection of these flaps is facilitated with the use of the robot. Peritoneal tissue may be used to augment vaginal depth, providing an apical cap to the vaginal canal. The use of peritoneum may limit scars from remote donor sites (i.e., skin graft donor sites from the flank or abdomen)[10]. In the senior author's practice, peritoneum is most often used for patients with insufficient local graft or revision surgery to facilitate dissection and provide tissue.

The procedure is performed simultaneously by the plastic and urologic surgeons. The perineal dissection is conducted by the plastic surgeon and the abdominal dissection by the urologist. The robot is docked, and the abdomen is entered. The peritoneum is incised beneath the vas deferens, under the seminal vesicles, and into the retrovesical pouch. The space between the rectum and bladder is identified [Figure 1]. Superiorly based flaps, 6-8 cm in length, are elevated off the anterior rectum and posterior bladder[11]. The flaps are perfused by an extensive network of submesothelial blood vessels supplied by the major splanchnic vessels[12]. Once the flaps are dissected, they are advanced distally and sutured to the intravaginal skin grafts. The peritoneum is closed with locking sutures to prevent hernia. The vagina is packed and a bolster dressing on the clitorovulvar structures is placed.

The primary advantage of the robotic approach, especially in revision cases, is the visualization of surrounding structures (rectum, bladder, urethra). This may facilitate the dissection of the vaginal canal. Operative times are reported to be 4.2 h for the Da Vinci Xi system and 3.7 h for the Single Port System[13]. In cases of limited penoscrotal tissue, the use of peritoneum provides additional tissue for vaginal lining. Studies are limited regarding the potential benefits of lubrication following peritoneal vaginoplasty. Similar to skin-graft-lined vaginas, lubrication for intercourse or dilation is recommended. For people with genital hypoplasia, outcomes are similar with regard to depth and dilator use[9,10]. Intra-abdominal complications

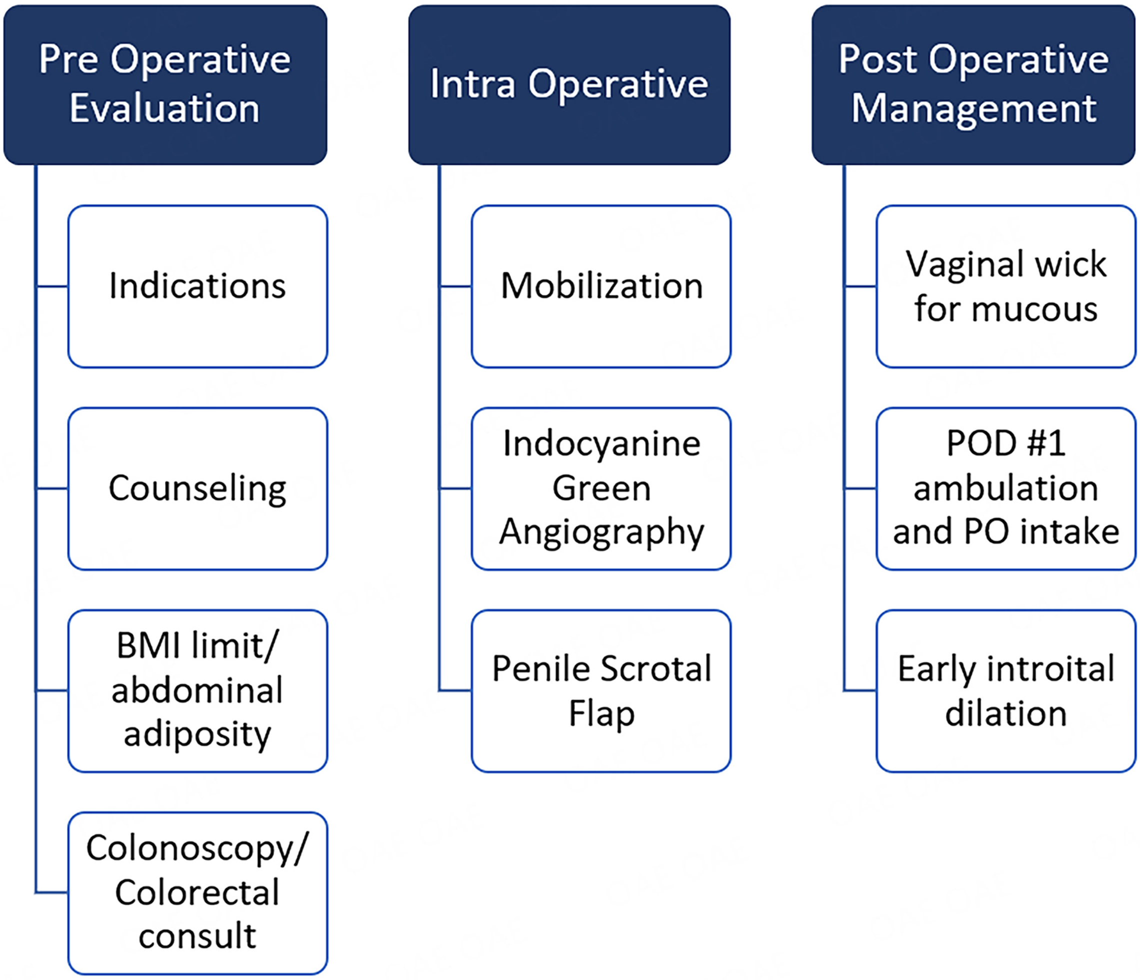

Figure 1. Algorithm for perioperative management of intestinal vaginoplasty.

are rare and may include bowel obstruction (2%), pelvic abscess (1%), and rectovaginal fistula (1%)[13].

ROBOTIC INTESTINAL VAGINOPLASTY

Intestinal vaginoplasty utilizes bowel, most commonly sigmoid colon, to create the vaginal canal [Figure 2]. It is typically used for revision surgery, but can be used as the primary approach. The robot may facilitate the harvest of the intestinal conduit and dissection of the vaginal canal[14]. Preoperatively, patients require consultation with colorectal surgery and a preoperative colonoscopy. Colonoscopy is performed in all intestinal vaginoplasty patients, regardless of oncologic risk. Abdominal imaging may be indicated based on the patient's surgical history. Obesity limits the ability to mobilize the intestinal conduit, and preoperative weight loss may be required. Additional risks include intestinal obstruction, anastomotic leak, and loss of graft vasculature.

As with the peritoneal vaginoplasty, the colorectal and plastic surgeon work simultaneously during the procedure. The robot is docked, and the abdomen is entered. The sigmoid and left colon are mobilized, including the splenic flexure. The sigmoid colon is supplied by the inferior mesenteric artery (IMA), and the rectosigmoid is supplied by the superior rectal artery from the IMA, internal iliac, middle and inferior rectal arteries. The rectosigmoid junction is identified as the distal transection site. The proximal transection

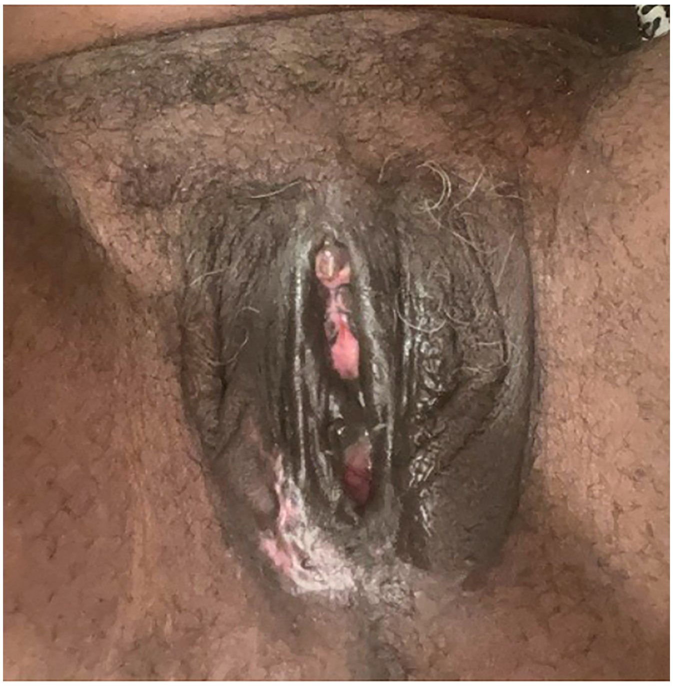

Figure 2. Patient external genitalia three months status post primary intestinal vaginoplasty. Posteriorly based flap, with the aim to prevent a cicatricial scar at the introitus, is well healed.

depends upon the vascular supply and length of the intestine required. The intestinal segment may be evaluated with indocyanine green (ICG) fluorescence to ensure adequate perfusion. A stapled colorectal anastomosis is performed to restore intestinal continuity. If necessary, a Pfannenstiel incision may be made to assist with the passage of the intestinal segment into position in the perineum. The proximal portion of the sigmoid is fixed to the presacral fascia [Figure 2].

Robotic assist improves visualization and facilitates dissection, which, in turn, decreases morbidity when used for rectal cancer[15]. Data suggest that robotic, as compared to laparoscopic rectal cancer surgery, reduces operative time, significantly lowering conversion of the procedure to open surgery, shortening the duration of hospital stay, lowering the risk of urinary retention, and improving survival to hospital discharge or 30-day overall survival rate[15]. Minimally invasive techniques decrease blood loss and, in turn, morbidity and mortality of colorectal surgery[16]. While a Pfannenstiel incision may be necessary, this scar may be more aesthetic and more easily concealed with clothing compared with the midline incision of open surgery.

Complications following intestinal vaginoplasty include intraabdominal complications, infection (including necrotizing fasciitis), and excess vaginal secretions[17]. Additionally, while stenosis of the vaginal canal is uncommon, introital stenosis may occur (0%-79%)[18]. This may require subsequent scar release. To reduce this and to avoid a circular anastomosis, a scrotoperineal flap is inset into the posterior wall of the sigmoid conduit. It is difficult to predict the volume of secretions following this procedure. While the large bowel is non-secretory, mucus production from goblet cells can be significant. This may require the use of a pad within the underwear on a permanent basis. Other complications specific to intestinal vaginoplasty are prolapse of the vaginal mucosa and/or anastomotic leak[19]. Long-term postoperative considerations include the possibility of diversion colitis and the requirement of annual vaginal exams including cancer surveillance of the mucosa. Long-term satisfaction of intestinal vaginoplasty demonstrates high self-ratings for functionality (7.3/10) and appearance (7.4/10)[20].

ROBOTIC REVISION VAGINOPLASTY

Some patients seek revision vaginoplasty for aesthetic or functional reasons. Complications, including delayed wound healing, may compromise the surgical result, interfere with postoperative vaginal dilation, and lead to vaginal stenosis (0%-12%)[21]. Stenosis can occur at the introitus, or within the vaginal canal and may be partial or complete. If complete stenosis, revision vaginoplasty requires re-dissection of the vaginal canal and resurfacing vaginal lining. For patients requiring full canal revision, full-thickness skin graft with or without peritoneum, allograft, or intestine may be used[21]. For patients needing additional depth, peritoneal flaps may be an option. The robotic approach aids both in the complex re-dissection of the vaginal canal and potentially in the harvest of peritoneum or intestine for canal lining.

Revision vaginoplasty performed for stenosis of the vaginal canal presents additional challenges as compared to primary vaginoplasty. Scar and tissue distortion may obscure the identification of the appropriate dissection planes and anatomic landmarks. The robot assists with the identification of these surrounding structures (i.e., rectum, bladder, urethra). Following dissection of the canal, dissected scar tissue is released (primarily along the lateral sidewalls), and prior skin graft may be removed, if necessary. Reconstruction of the vaginal canal is then performed with either skin grafts, peritoneum, or intestine [Figure 3]. Wound matrix products may be used, such as cadaveric allograft, for lining when other tissues are not amendable to use[22].

In the senior author's practice, revision vaginoplasty is most often performed for people seeking increased vaginal depth. A study of 24 patients with revision peritoneal vaginoplasty demonstrated long-term patency with a mean depth of 13.6 cm and width of 3.6 cm over 3 years[23]. In patients with secondary intestinal vaginoplasty, long-term patient-reported outcomes demonstrate satisfaction with function (7.3/10) and appearance (7.4/10) with their vagina[20]. A long-term study from The Netherlands presented 12.5% of patients with secondary intestinal vaginoplasty had their revised vagina removed, one for acute complications and two for recurrent long-term stenosis (60 and 77 months). All went on to have successful tertiary vaginoplasty with skin graft and/or peritoneum[20].

ROBOTICS IN MASCULINIZING GENDER-AFFIRMING GENITAL SURGERY

Masculinizing gender-affirming genital surgery comprises several procedures that may be performed alone or concomitantly to achieve individualized patient goals. Some of these procedures, such as hysterectomy, bilateral salpingo-oophorectomy, and vaginal closure (vaginectomy/colpectomy/colpocleisis), may benefit from a robotic-assisted approach.

According to the American College of Obstetrics and Gynecology, the choice to utilize the robotic platform for hysterectomy and BSO "should be selected based on the likelihood of improved outcomes compared with other surgical approaches due to the complexity of the case or patient factors, with appropriate consideration to costs"[24]. Regarding low-risk, low-complexity hysterectomy, there is not an apparent benefit of the robot over traditional laparoscopy[25]. Approximately 21% of transmasculine people will undergo gender-affirming hysterectomy[26] and evidence exists to suggest that this patient population may have a higher baseline risk of pelvic pathology. A study by Ferrando *et al.* found the incidence of endometriosis to be nearly 27% in transmasculine patients undergoing hysterectomy[27], which is more than double the incidence of endometriosis in cis-gender individuals[28]. Thus, the robotic approach may facilitate improved dissection and decrease conversion to laparotomy[29]. Similar to cis-gender individuals, single-site robotic hysterectomy may be possible[30].

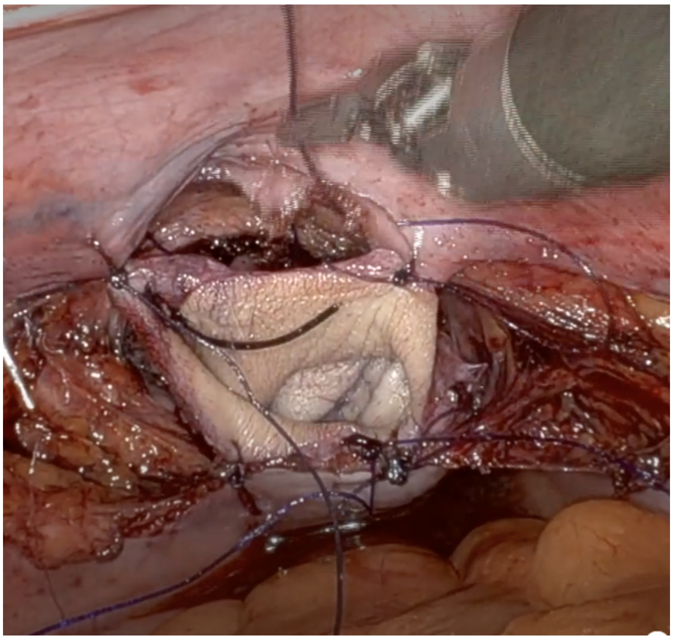

Figure 3. Full-thickness skin graft with peritoneal fixation for revision vaginoplasty.

Vaginal canal closure (vaginectomy/colpectomy/colpocleisis) is often requested in conjunction with hysterectomy as a stand-alone procedure or concomitantly with additional masculinizing genital procedures. In our practice, vaginal closure is performed for patients undergoing metoidioplasty with urethral lengthening to reduce fistula formation[31]. Various techniques have been proposed to perform vaginal canal closure, with the two most common being: (1) excision of the vaginal epithelium followed by suture ligation and (2) electrocautery destruction of the vaginal epithelium and suture ligation. Remnants of vaginal epithelium have been linked to incomplete electrocautery destruction, making the excision approach seemingly more favorable. Challenges, however, exist with excision of the vaginal epithelium and closure of the canal. In transmasculine people, the vaginal canal may be long, narrow, and friable. These characteristics make visualization and direct excision difficult via the transvaginal route. Furthermore, the vaginal canal directly abuts the bladder, ureters, and rectum. Historically, vaginal canal closure has been associated with a high rate of minor and major complications, including up to a 30% transfusion rate[32]. Some have found the robotic approach for vaginal closure to be safe, feasible, and reduced both minor and major complications[33,34]. Thus, it is our practice to utilize the robotic platform for vaginal closure when performed at the time of hysterectomy for most nulliparous patients.

CONCLUSION

Robotic surgery for gender-affirming patients continues to evolve. In feminizing procedures, robotic surgery can facilitate access to the vaginal canal and improve the harvesting of tissue for lining the vagina. In masculinizing procedures, the robot can be used for hysterectomy and BSO and facilitate dissection of the colpectomy. Issues of cost and availability continue to be addressed and improved. Additional research is needed to better understand the benefits and potential drawbacks of robotic surgery, specifically in gender-affirming genital surgery. Ultimately, a shared decision-making process between the multidisciplinary team and the patient will optimize the use of the robotic surgical approach.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study: Weinstein B, Govekar H, Cherullo H, Jacobs KM, Schechter L

Made substantial contributions in writing the manuscript: Weinstein B, Govekar B, Cherullo E, Jacobs KM, Schechter L

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

All patients provide photo consent. Informed consent was obtained from the patients involved in this manuscript.

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