

Vaginal self-lubrication following peritoneal, penile inversion, and colonic gender-affirming vaginoplasty: a physiologic, anatomic, and histologic review

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Abstract

Introduction: Vaginal self-lubrication is central to the sexual satisfaction and healthy genitourinary function of patients who have undergone gender-affirming vaginoplasty (GAV). Secretory capacities of different neovaginal lining tissues have been variably described in the literature, with little evidence-based consensus on their success in providing a functionally self-lubricating neovagina. We review the existing neovaginal lubrication data and the anatomy, histology, and physiology of penile and scrotal skin, colon, and peritoneum to better characterize their capacity to be functionally self-lubricating when used as neovaginal lining.

Objectives: The study sought to review and compare the merits of penile and scrotal skin grafts, spatulated urethra, colon, and peritoneal flaps to produce functional lubrication analogous to that of the natal vagina in the setting of GAV.

Methods: We conducted a systematic review following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Medline, EMBASE, [ClinicalTrials.gov](https://www.clinicaltrials.gov), and the Cochrane Library databases were searched for peer-reviewed studies published prior to December 12, 2022, that (1) included data specific to transfeminine individuals; (2) were full-text randomized controlled studies, case reports, case series, retrospective cohort studies, prospective cohort studies, qualitative studies, and cross-sectional studies; and (3) included specific discussion of vaginal lubrication or fluid secretion following GAV utilizing penile skin, colonic tissue, or peritoneum.

Results: We identified 580 studies, of which 28 met our inclusion criteria. Data on neovaginal lubrication were limited to qualitative clinician observations, patient-reported outcomes, and satisfaction measures. No studies quantifying neovaginal secretions were identified for any GAV graft or flap technique. Anatomically, penile and scrotal skin have no self-lubricating potential, though penile inversion vaginoplasty may produce some sexually responsive secretory fluid when urethral tissue is incorporated and lubricating genitourinary accessory glands are retained. Colonic and peritoneal tissues both have secretory capacity, but fluid production by these tissues is continuous, nonresponsive to sexual arousal, and likely inappropriate in volume, and so may not meet the needs or expectations of some patients. The impact of surgical tissue translocation on their innate secretory function has not been documented.

Conclusions: None of penile/scrotal skin, colon, or peritoneum provides functional neovaginal lubrication comparable to that of the adult natal vagina. Each tissue has limitations, particularly with respect to inappropriate volume and/or chronicity of secretions. The existing evidence does not support recommending one GAV technique over others based on lubrication outcomes. Finally, difficulty distinguishing between physiologic and pathologic neovaginal fluid secretion may confound the assessment of neovaginal self-lubrication, as many pathologies of the neovagina present with symptomatic discharge.

Keywords: transgender health; gender-affirming health care; gender-affirming surgery; vaginal lubrication; vaginoplasty.

Introduction

Gender-affirming vaginoplasty (GAV) involves surgical reconstruction of the penis and perineum to achieve a vulva and vagina with sexual and urinary functioning. It is an important transition step for some transfeminine people, which helps alleviate gender incongruence and is associated with improved mental health and quality of life.^{1,2} Essential to the functional characteristics of the neovagina is the choice of tissue used to line the neovaginal cavity. Penile skin, scrotal skin, colon, or peritoneum are the main tissues used to line the neovaginal cavity for GAV. The ideal lining tissue should functionally mimic the properties of the estrogenized natal vagina, be available in adequate supply, and be reasonably safe to harvest.

Of major functional concern following GAV is the ability for the neovagina to secrete lubricating fluid. The Female Sexual Function Index (FSFI)³ is a measure of sexual function and screening tool for sexual dysfunction utilized in much of the literature on neovaginal lubrication. It assesses sexual function across various domains, including desire, arousal, lubrication, orgasm, satisfaction, and pain, with a maximum score in each domain of 6.0. Lower scores suggest a greater degree of dysfunction in the assessed domain. The FSFI is validated for use in cis women only; however, it is used widely in evaluating GAV outcomes.

In a retrospective study of 49 transgender women following penile inversion vaginoplasty (PIV), Buncamper et al⁴ found

that despite high levels of self-reported overall functional satisfaction, FSFI scores for lubrication and comfort were lowest among all measures, largely contributing to over half (56%) of participants meeting the criteria for sexual dysfunction. Similarly, Zavlin et al⁵ noted that satisfaction with vaginal lubrication was the lowest of all functional measures in a sample of transgender patients who had undergone PIV (N = 39).

The absence of vaginal self-lubrication has functional and health implications for GAV patients. Without adequate endogenous vaginal self-lubrication, patients must rely on exogenous lubricant use for dilation or for receptive sexual intercourse. Though not rigorously studied, inadequate vaginal lubrication poses the risk of friction-related skin tears and possible associated infections. It could reasonably also result in an elevated risk of vaginal infection due to lack of mucinous protection of the vaginal walls and lack of secretions washing postcoital ejaculate and other possible antigens out of the vaginal canal.⁶ Finally, the dependence on exogenous lubricant may be a source of dysphoria for some transfeminine patients.

Having identified vaginal self-lubrication to be desirable and beneficial for patients, we set out to understand if any of the main GAV techniques provides functional neovaginal fluid secretion. We systematically review the literature to identify existing data of functional lubrication outcomes in patients post-GAV. Further, we review the anatomy, histology, and physiology of penile and scrotal skin, colon, and peritoneum to better characterize their capacity to be functionally self-lubricating when used as neovaginal lining. We compare neovaginal lubrication to the basal and responsive self-lubricating physiology of the natal vagina to better understand to what extent each vaginoplasty technique meets the needs of patients undergoing GAV.

Anatomy and physiology of self-lubrication

To understand the strengths and limitations of each GAV technique, we summarize self-lubricating physiology of the adult natal vagina. We also outline the self-lubricating function of adult natal penile anatomy, which may be partially retained and integrated to provide some self-lubrication post-GAV. We use “natal” as a descriptor for anatomy that has not undergone medical or surgical intervention and is free from functional pathology.

Self-lubrication in the natal vagina

The natal vagina is composed of 3 layers: mucosa, muscularis, and adventitia. The vaginal mucosa lines the lumen and is composed of thick, nonkeratinized, stratified squamous epithelium that contains large deposits of glycogen, and an underlying lamina propria.⁷

Mucosa is defined in some sources as surface epithelial tissue and supporting lamina propria that lines body cavities that are continuous with the outside world. The epithelium may or may not contain glands.⁷ Other sources provide a narrower definition of mucosa, identifying it as cavity-lining epithelium with mucus-secreting and absorptive functions.⁸ In the context of discussing vaginal lubrication, it bears noting that vaginal mucosa adheres to the former definition: the vaginal epithelium contains no glands, despite its characterization as mucosal tissue.⁹

Vaginal lubrication in the natal vagina is divided into basal, nonaroused, secretions as well as responsive, sexually aroused,

secretions. Basal vaginal lubrication provides the continuous moisture that prevents adhesion of the vaginal walls. This basal moisture is partially responsible for the vaginal lining’s characterization as a mucosal tissue, despite the absence of glands. Basal vaginal fluid is actually a combination of secretions into the vaginal lumen from the pelvic peritoneal space, uterine tubes, uterus, cervix, vaginal walls, and vestibular glands.¹⁰ Fluid contribution from the vagina arises from a low level of plasma transudate that leaks from the capillary beds of the lamina propria through the mucosa into the lumen to mix with secretions from the cervix and superior structures.¹⁰ Sodium reabsorption by the vaginal epithelium osmotically draws fluid out of the vaginal lumen, limiting the amount of basal fluid accumulation within the vagina.¹⁰ This results in the production of about 6 mL/d of high-potassium, low-sodium, acidic (pH 4.7) moisturizing fluid.¹¹ This basal volume of vaginal fluid is not generally adequate to provide lubrication for painless, penetrative sex.¹⁰

Sexually responsive vaginal lubrication is also a combination of secretions from several sources within the genital tract. Upon arousal, the nitric oxide signaling pathway rapidly promotes relaxation of vascular smooth muscle cells, resulting in vasocongestion in the vulva and vagina.¹² The elevated hydrostatic pressure in the vaginal walls causes increased transudation into the vaginal lumen. This transudate production overwhelms the sodium reabsorption that regulates basal vaginal fluid secretion, resulting in accumulation of fluid with increased sodium and chloride concentrations, when compared with the basal vaginal fluid.^{10,11} Transudative fluid is combined with contributions from cervical mucus, and mucins secreted by the Bartholin’s, Skene’s, and minor vestibular glands at the introitus, to form a slippery, lubricating fluid that facilitates penetrative sexual activity.¹³ The relative contributions of vaginal transudate, glandular secretions, and cervical mucus to erogenous lubrication are not well quantified, and research attempting to measure the total volume of vaginal secretion during sexual arousal is limited.¹⁴ However, total fluid secretion into the vagina during sexual arousal has been estimated at 0.7 mL/15 min, an approximately 10-fold increase from basal fluid production.¹⁵

In short, vaginal lubrication is produced by transudative processes in the vaginal lining tissue, with contribution from accessory reproductive structures. The healthy vaginal environment is maintained through a basal rate of secretion, but fluid production must rapidly and appropriately increase early in the sexual response cycle to facilitate intercourse. Ideally, GAV should similarly provide both basal and sexually responsive lubrication in appropriate volume and consistency to meet patients’ functional needs.

Sexually responsive fluid production in natal penile anatomy

Despite individual variations in presurgical patient anatomy, each GAV technique is broadly premeditated on reconstructing natal penile and scrotal anatomy to form the neovagina. Therefore, the extent to which the secretory structures of the natal male genitourinary system are retained and incorporated into the neovagina is consequential to understanding the self-lubricating potential of each technique.

In the natal male reproductive tract, several accessory glands contribute to lubricating pre-ejaculatory fluid and ejaculate. Cowper’s glands (ie, bulbourethral glands) secrete alkaline, clear, mucinous lubricating fluid into the urethra to

prepare for the passage of ejaculate during sexual arousal.¹⁶ Numerous periurethral Littre glands also contribute to this pre-ejaculatory lubrication. The volume of pre-ejaculate fluid secretion from the Cowper's glands and Littre glands varies between individuals, but averages 0.2 mL to 5 mL per sexual response cycle.^{16,17} Furthermore, the prostate gland contributes a thin, alkaline fluid to the ejaculate, directly after the Cowper's glands emit their secretions.¹⁶ The seminal vesicles provide the majority of the fluid volume of ejaculate, which is released at the time of orgasm.

The prostate gland, seminal vesicles, Cowper's glands, and some Littre glands are generally retained in all major GAV techniques.^{18,19} The Bartholin's gland, Skene's gland, and minor vestibular glands of the natal vaginal anatomy are embryologically analogous to the Cowper's glands, prostate gland, and Littre glands in the natal penile anatomy, respectively.¹³ Thus, these glands may, in theory, provide a similar source of sexually responsive lubrication to the neovagina. Indeed, subjective accounts of neovaginal fluid secretion following PIV are reported in multiple studies and has been postulated to derive from the retained Cowper's glands.²⁰⁻²²

However, the adequacy of accessory gland secretions in providing functional self-lubrication was not clearly demonstrated in the literature. Multiple studies found that exogenous lubricant was needed for some PIV and colon vaginoplasty patients.²³⁻²⁶ The inadequacy of glandular secretions may be explained by the observation that natal vaginal lubrication occurs early in the sexual response cycle in order to facilitate ensuing intercourse. In contrast, secretions from the prostate and seminal vesicles primarily contribute to ejaculate and are released late in the sexual response cycle, thus making the chronicity of these fluids unsuitable for functional neovaginal lubrication.²⁷ Additionally, androgens are key regulators in the development and functioning of the sexual accessory glands, so their capacity for fluid production is likely reduced by both gender-affirming orchiectomy and androgen suppressing medications in this patient population.²⁸ As such, it is difficult to estimate the volume and adequacy of lubricating fluid that is secreted from retained accessory structures or compare this with the volume of lubricating fluid produced in the natal vaginal sexual response. To our knowledge, no data have been published on the function of the accessory glands following GAV.

Methods

Search strategy

We conducted a systematic literature review following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (PROSPERO CRD42022367947). Medline, EMBASE, [ClinicalTrials.gov](https://www.clinicaltrials.gov/), and the Cochrane Library databases were searched for English-language studies with the following protocol string: “transgender*” OR “transsexual*” OR “gender-affirming” OR “male-to-female” OR “feminizing” OR “transfeminine” OR “non-binary” AND “vaginoplasty” OR “neovagina” AND “lubrication” OR “secretion*” OR “fluid” OR “mucus” OR “mucous” OR “outcome*” OR “complication*”. We had no date restrictions on publication year because all previous work addressing neovaginal lubrication following GAV was considered relevant. The last search was performed on December 12, 2022.

Eligibility criteria and study selection

Our inclusion criteria consisted of peer-reviewed studies that (1) included data specific to transfeminine individuals; (2) were full-text randomized controlled studies, case reports, case series, retrospective cohort studies, prospective cohort studies, qualitative studies, and cross-sectional studies; and (3) included specific discussion of vaginal lubrication or fluid secretion following GAV utilizing penile skin, colonic tissue, or peritoneum. We excluded articles that were reviews, research letters, and editorials; not involving human subjects; or not written in English.

After de-duplication, full texts were screened by 2 authors (CO and SK) using a keyword search for relevant terms, and articles containing primary data pertaining to vaginal lubrication outcomes were identified. Disagreements on inclusion of papers were resolved by a third author (AK). Data extraction included authors' name(s), publication year, study design and/or methodology, surgical technique, participants, and key findings relating to neovaginal lubrication following GAV.

Assessment of level of evidence

Studies included in this review were graded using the Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.²⁹ Level 1 indicates the highest form of evidence; that is, systematic reviews of randomized trials or evidence-based clinical practice guidelines. Level 2 indicates individual randomized clinical trials with consistently applied reference standard and blinding. Level 3 includes cohort studies, non-consecutive studies, or studies without consistently applied reference standards. Level 4 includes case-control studies, case series, poor-quality prognostic cohort studies, or studies with poor reference standards. Level 5 is the lowest form of evidence, that is, mechanism-based reasoning. The Oxford Centre for Evidence-Based Medicine Levels of Evidence take into account bias within research methodology and the type of evidence likely to provide the strongest support for the research question.

Results

We identified 580 studies that met our search criteria from EMBASE and Medline. There were no new studies identified with published data from [ClinicalTrials.gov](https://www.clinicaltrials.gov/) or the Cochrane Library. After full-text keyword search, 428 articles were excluded. After reading the remaining 152 articles in full, 124 more were excluded as they did not include relevant data, yielding the final set of 28 studies included in this review ([Figure 1](#)).

Of the 28 studies identified, 19 included data on neovaginal secretion in GAV techniques that utilized penile skin with or without scrotal skin, and/or a spatulated urethra. Fewer studies included data on neovaginal lubrication in GAV techniques that utilized colonic tissue or peritoneum ($n = 10$ and 2, respectively). No studies attempted to quantify the volume or rate of neovaginal fluid secretion either at baseline or during sexual arousal. Instead, data comprised patient-reported outcomes including satisfaction measures via the FSFI or other satisfaction scales, functional markers such as use of exogenous lubricant, subjective patient experiences of vaginal moisture, and direct observations of moisture or fluid secretions by clinicians ([Table 1](#)).

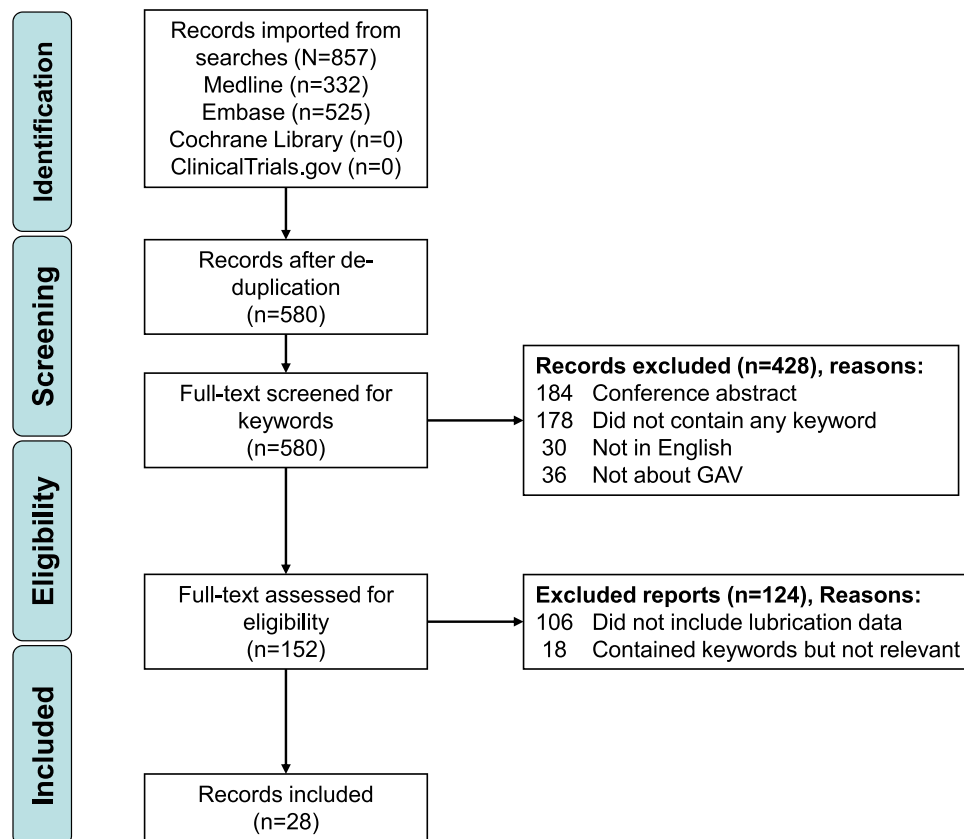


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

Nineteen studies discussed neovaginal lubrication in patients who had undergone PIV. Results were mixed: for most studies, mean FSFI scores for lubrication were low, ranging from 2.39 to 2.83 out of 6.^{4,30–33} The exceptions were one small study that found a mean FSFI lubrication score of 3.7 (N=10)³⁴ and a case control study that found a mean FSFI lubrication score of 4.02 (n=65) for transfeminine patients, significantly lower than their cis female counterparts who reported a mean score of 5.02 (n=57).³⁵ Five studies suggested that a majority of their sample experienced some degree of neovaginal lubrication upon sexual arousal.^{20–22,36} One study noted that 82.4% (n=41) of patients who underwent PIV without incorporation of spatulated urethra reported never or almost never achieving neovaginal lubrication during sexual activity; however, 62.5% (n=26) of patients who had had PIV with spatulated urethra reported achieving neovaginal lubrication during sexual activity always or most of the time.³⁷ Whether or not scrotal tissue and/or spatulated urethra was utilized was not clearly indicated in all studies.

Ten studies provided data on neovaginal lubrication following colonic GAV. No studies specifically reported any patients that did not experience neovaginal discharge, but 3 studies noted the need for exogenous lubricant during sexual activity for some patients.^{23–25} Mean FSFI lubrication scores ranged from 2.7 to 5.8,^{31,38,39} generally higher than those reported for PIV. Six studies reported inconvenient, excessive, or undesirable neovaginal mucorrhea.^{23–25,40–42}

Only 2 small studies encompassing a total of 15 participants included data pertaining to neovaginal lubrication following peritoneal vaginoplasty. A case series of 5 patients reported that researchers observed “a good lubricated... vaginal

surface” at 6 months postoperatively but provided no functional data supporting neovaginal lubrication outcomes.⁴³ A cross-sectional survey and retrospective chart review of 10 patients reported that 70% (N=10) reported occasional to frequent sensation of increased neovaginal wetness with sexual arousal.⁴⁴ No FSFI lubrication data were reported for peritoneal GAV patients.

Penile inversion vaginoplasty

PIV is the most widely used technique for GAV.⁴⁵ In PIV, the neovaginal cavity is lined by the tubularized inverted penile skin flap. If the amount of penile tissue is not adequate to construct a neovagina of satisfactory width and depth, scrotal skin grafts may be used in conjunction with penile tissue to line the neovaginal apex. Spatulated urethral grafts may also be integrated into the neovaginal lining.

The structure of penile and scrotal skin reflects its primary role as a homeostatic barrier from the outside environment. The thin skin is composed of keratinized, stratified squamous epithelium with loose connective tissue and bundles of smooth muscle in the underlying stroma. The proximal penile and scrotal epithelium contains numerous sweat glands—which secrete thin, watery fluid—and sebaceous glands—which secrete waxy, cholesterol-rich oils.⁷ These glands provide thermoregulation and an evaporative barrier, respectively; however, they play a little role in reducing surface friction.^{9,46} As such, when used as a neovaginal lining, the penile and scrotal skin does not have secretory capacity functionally similar to the natal vagina and cannot provide vaginal lubrication in response to erogenous arousal or otherwise (Table 2).^{47,48}

Table 1. Studies assessing neovaginal lubrication in PIV, colonic, or peritoneal tissue techniques.

Author (year)	Study design	Vaginoplasty tissue	n	Main lubrication findings	Level of evidence
De Cuypere <i>et al.</i> (2005) ²⁰	Cross-sectional patient survey	PIV	32	64.3% of patients reported neovaginal secretion during sexual excitation	3
Lawrence (2006) ⁷⁸	Cross-sectional patient survey	PIV	232	Mean satisfaction with neovaginal lubrication was 4.4 (0-10 scale), among lowest scores for satisfaction domains	3
Selvaggi <i>et al.</i> (2007) ²¹	Cross-sectional patient interview	PIV	30	More than two-thirds of patients who underwent GAV reported secretion of neovaginal fluid during sexual excitation, even before orgasm	3
Imbimbo <i>et al.</i> (2009) ⁷⁹	Cross-sectional patient survey	PIV (with and without scrotal flap), colonic	139; 47 underwent PIV without scrotal flap, 85 underwent PIV with scrotal flap, 7 underwent colonic vaginoplasty	41% of patients complained of lack of lubrication	3
Weyers <i>et al.</i> (2009) ³⁰	Cross-sectional patient survey	PIV	50	Mean FSFI lubrication score = 2.39 ± 2.29	3
Amend <i>et al.</i> (2013) ⁸⁰	Retrospective database review	PIV with spatulated urethra	24	All sexually active patients denied the need for additional lubricant during intercourse; all individuals reported use of a lubricant with vaginal dilator	3
Bucci <i>et al.</i> (2014) ⁵¹	Retrospective chart review	PIV with spatulated urethra	282	3 cases of neovaginal prolapse were attributed to sexual intercourse without exogenous lubrication	3
Buncamper <i>et al.</i> (2015) ⁴	Cross-sectional patient survey	PIV	49	Mean FSFI lubrication score = 2.8 ± 2.4	3
Reed <i>et al.</i> (2015) ³⁴	Retrospective case review and cross-sectional patient survey	Revision of PIV, abdominal skin flap vaginoplasty	10; 9 underwent PIV, 1 underwent abdominal skin flap vaginoplasty	Mean FSFI lubrication score = 3.7	3
van der Sluis <i>et al.</i> (2016) ³¹	Cross-sectional patient survey	PIV	49	Mean FSFI lubrication score = 2.8 ± 2.4	3
Buncamper <i>et al.</i> (2017) ³²	Prospective cohort survey	PIV	100	Mean FSFI lubrication score = 2.4 ± 2.1	3
LeBreton <i>et al.</i> (2017) ²²	Prospective cohort	PIV	28	Most participants reported experiencing natural lubrication (quantitative data not published)	3
Zavlin <i>et al.</i> (2018) ⁵	Prospective cohort	PIV with spatulated urethra	39	Mean satisfaction with neovaginal lubrication = 6.72 ± 2.48 (0 = very unsatisfied, 10 = very satisfied)	3
Cristofari <i>et al.</i> (2019) ²⁶	Retrospective chart review	PIV	189	58% of patients reported needing additional lubrication for sexual intercourse	3
Gentile <i>et al.</i> (2020) ³⁷	Retrospective cohort	PIV	41	82.4% reported never or almost never achieving spontaneous vaginal lubrication during sexual activity	3
		PIV with spatulated urethra	26	62.5% reported spontaneous vaginal lubrication during sexual activity always or most of the time; 12.5% reported sexual lubrication never or almost never	3
Vedovo <i>et al.</i> (2021) ³⁵	Case-control cohort	PIV with and without scrotal flap	122, 65 transfeminine patients and 57 cis female patients (case controls)	Mean FSFI lubrication score for transfeminine patients = 4.02 ± 1.27 ; mean FSFI lubrication score for cis female control subjects = 5.02 ± 1.0	3
Canale <i>et al.</i> (2022) ⁸¹	Cross-sectional patient survey	PIV	6	Lowest scores among FSFI domains were for lubrication and pain	3
Thammapiwan <i>et al.</i> (2021) ³³	Cross-sectional patient survey	PIV	69	Mean FSFI lubrication score = 2.83 ± 1.36	3
Toolenaar <i>et al.</i> (1993) ²³	Cross-sectional patient survey	Colonic	11	All sexually active participants used exogenous lubrication; 8 of 11 transfeminine patients complained of white, sticky discharge	3
Liguori <i>et al.</i> (2001) ⁴⁰	Case report	Colonic	1	A case report of mucus production and accumulation due to neovaginal stenosis resulting in rupture and peritonitis	4
Kim <i>et al.</i> (2003) ²⁴	Cross-sectional patient survey	Colonic	28	3 of 28 patients reported excessive discharge more than 1 y postoperatively; 1 of 28 patients reported using lubricant with intercourse	3

(Continued)

Table 1. Continued.

Author (year)	Study design	Vaginoplasty tissue	n	Main lubrication findings	Level of evidence
Morrison <i>et al.</i> (2015) ²⁵	Retrospective chart review and cross-sectional patient survey	Colonic	83, incomplete data for some patients	7 of 27 patients reported need for exogenous lubricant; 10 of 35 reported mucorrhea, all resolved by 1 y postoperatively	3
Bouman <i>et al.</i> (2016) ³⁸	Cross-sectional patient survey	Colonic	31	Mean FSFI lubrication score = 2.7 ± 2.6	3
Manrique <i>et al.</i> (2018) ³⁹	Retrospective chart review	Colonic	15	Mean FSFI lubrication score = 5.8	3
van der Sluis <i>et al.</i> (2016) ⁴¹	Prospective observational	Colonic	34; 32 transfeminine patients, 2 cisgender patients	38% of patients reported inconvenient neovaginal discharge at mean postoperative time of 23 mo	3
van der Sluis <i>et al.</i> (2016) ³¹	Cross-sectional patient survey	Colonic	9	Mean FSFI lubrication score = 4.0 ± 2.6	3
Kaushik <i>et al.</i> (2019) ⁴²	Retrospective cohort	Colonic	386	Mucorrhea was reported by 6.2% of patients, which resolved after 9 mo	3
Sachan <i>et al.</i> (2022) ⁴³	Consecutive case series	Peritoneal	5	Vaginotomy at mean follow-up of 6 mo postoperatively showed “a good lubricated and healthy vaginal surface”	4
Smith <i>et al.</i> (2022) ⁴⁴	Retrospective chart review and cross-sectional patient survey	Peritoneal	10	70% reported occasional to frequent sensation of increased vaginal wetness with sexual arousal; 2 of 5 patients who had previously had PIV reported the same or less vaginal moisture after peritoneal vaginoplasty, 3 of 5 patients reported they had more moisture after peritoneal vaginoplasty	3

Levels of Evidence are based on the Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.²⁹ Abbreviations: FSFI, Female Sexual Function Index; GAV, gender-affirming vaginoplasty; PIV, penile inversion vaginoplasty.

Table 2. Fluid secretion characteristics across gender-affirming vaginoplasty techniques.

GAV technique	Lining tissue	Mode of fluid production	Basal fluid secretion (rate)	Responsive fluid secretion (rate)	Retention of GU accessory glands	Limitations
Natal vagina	Vaginal mucosa	Transudative	Yes	Yes (0.7 mL/15 min)	Yes, all	N/A
PIV	Penile ± scrotal epithelium	None	No	No	Yes, some	No fluid production
	Penile ± scrotal epithelium + spatulated urethra	Glandular secretion (Littre glands)	Minimal	Yes	Yes, some	Small volume
Colonic	Full thickness colon	Glandular secretion (crypts of Lieberkühn)	Yes	No	Yes, some	Non-sexually responsive; excessive production; malodor
Peritoneal	Peritoneum	Transudative	Yes (estimated 0.001 mL/min)	No	Yes, some	Small volume; non-sexually responsive

Abbreviations: GAV: gender-affirming vaginoplasty; GU: genitourinary.

In some cases, a spatulated urethral graft is integrated into the neovaginal lining of PIV. The function and histology of the penile urethra is quite distinct from penile and scrotal skin. The penile urethra is lined by stratified columnar epithelium, interspersed with areas of pseudostratified columnar and nonkeratinized, stratified squamous epithelium at the terminal end of the urethra (ie, the navicular fossa). The underlying lamina propria contains highly vascularized, loose, fibroelastic connective tissue with numerous mucus-secreting Littre glands. Mucus from the Littre glands provides lubrication and protection to the urethra from urine and ejaculate.⁹

The prostatic, membranous and proximal bulbar urethra are commonly retained in PIV, meaning that Littre glands

within these portions may continue to secrete some lubricating fluid. However, the Littre glands are most densely abundant within the penile portion of the urethra (ie, spongy urethra), which is generally truncated during urethral reconstruction in vaginoplasty.⁴⁹ Increased secretory action from the Littre glands is stimulated by sexual arousal.^{16,50}

The incorporation of penile urethra into the vaginal lining theoretically provides a promising source of self-lubricating fluid for the neovagina that responds to sexual stimulation in a manner analogous to the natal vagina. One study (N = 67) did suggest that sexually responsive self-lubrication was more often achieved in patients who underwent PIV with urethral graft compared with those who underwent

PIV without.³⁷ While this outcome appears promising, we cannot conclude that the relatively small area of the neovaginal canal lined by urethral tissue provides functionally meaningful lubrication. One retrospective chart review of patients who had PIV with urethral graft noted 3 cases of neovaginal prolapse attributed to sexual intercourse without adequate lubrication.⁵¹ Another study of 39 patients who had undergone PIV with urethral graft showed that patient satisfaction with lubrication was lowest among all functional measures, suggesting that any contribution of the urethra to vaginal lubrication remains functionally unsatisfactory for many patients.⁵

Colonic vaginoplasty

Colonic vaginoplasty (also referred to as intestinal, sigmoid, or bowel vaginoplasty) utilizes a pedicled segment of large intestine to form the vaginal canal. To harvest the bowel segment, the abdominal cavity is accessed, and a 12- to 15-cm full-thickness segment of sigmoid bowel is transected. The transected bowel segment and its supplying vasculature are released, such that the tissue pedicle can be translocated through the pelvic peritoneum and into the vaginal cavity without tension. The bowel segment is then joined with the inverted penile tissue of the vaginal introitus to form the vaginal canal and the remaining ends of the transected large bowel are anastomosed.^{52,53}

The histology of the colon reflects its normal physiological functions of water, vitamin and electrolytes absorption, and transportation of fecal waste toward the rectum. The colon is composed of 4 major tissue layers: mucosa, submucosa, muscularis, and serosa. The mucosa is comprised of a simple columnar epithelium arranged into numerous tubular glands that extend into the lamina propria called crypts of Lieberkühn. The crypts of Lieberkühn contain absorptive cells and mucin-producing Goblet cells. This epithelium will come to form the exposed surface of the neovaginal walls in colonic vaginoplasty.⁹

Similar to the natal vagina, the large intestine is also lined by a mucosal surface. However, in contrast to the glandless vaginal mucosa, the intestinal mucosa contains abundant glands, crypts of Lieberkühn, which produce its own lubricating mucus.^{53,54} The Goblet cells of the colonic tissue produce a bilayer of thick, transparent, gel-like mucus that functions to defend the epithelium of the large intestine from pathogens, protect against autodigestion, and aid the movement of intestinal contents.⁵⁵

This mucus-producing capacity of the colon may be considered advantageous in the setting of vaginoplasty, as it could provide a possible source for self-lubrication in the neovagina. Indeed, one retrospective chart review demonstrated a mean FSFI lubrication score of 5.8, approaching the maximum score of 6.³⁹ However, several other studies pointed to problematic overproduction of mucus secretions for some patients,^{24,25} and one study noted inconvenient neovaginal discharge in as many as 38% of their patient cohort (N = 34).⁴¹ Unlike urethral secretions, the secretions of the large intestine are not responsive to sexual arousal and are therefore continuously, and in some cases copiously, produced (Table 2).

Malodor of colonic vaginoplasty secretions was also a concern for patients: 10.7% (N = 28) patients in one study and 20.6% (N = 34) in another reported concerns over malodorous discharge.^{24,41} While sigmoid vaginoplasty may succeed in providing adequate neovaginal lubrication for sexual

penetration in some patients, constant, profuse, and malodorous mucus production is likely not practical or desirable for many patients.

Peritoneal vaginoplasty

Peritoneal vaginoplasty utilizes a pedicled flap of pelvic peritoneum to line some or all of the neovaginal vault. There is variation in the techniques used across centers, including open, laparoscopic, and robot-assisted peritoneal vaginoplasty.^{56,57} In peritoneal GAV, pelvic peritoneum is located and grasped through the dissected neovaginal cavity between the bladder and rectum. The peritoneum is opened and drained via a small incision in the rectovesicular pouch. The incision is then enlarged and the pelvic peritoneum is pulled caudally through the neovaginal canal and sutured to the vaginal introitus to form the neovaginal lining. Alternatively, the peritoneum may be joined to penile skin lining a portion of the canal more proximal to the introitus. The cuff of the peritoneum-lined neovaginal cavity is then closed, sealing the vaginal cavity from the peritoneal space.⁵⁸

The peritoneum is a thin, serous membrane composed of 2 layers that are functionally similar to that of other serosal cavities of the body (eg, pericardium, pleura).⁵⁹ Under histological examination, each peritoneal layer is composed of 3 sublayers: mesothelium, basal lamina, and underlying submesothelial stroma. The mesothelium is composed of simple squamous (mesothelial) cells with apical microvilli containing embedded lamellar bodies. Peritoneal lamellar bodies produce lipid-containing emissions that may reduce friction at the tissue surface.⁶⁰ In addition to the lamellar secretions, the apical aspect of the mesothelial layer is coated in a glycocalyx formed of hydrophilic proteoglycans and glycosaminoglycans. This traps fluid and produces a lubricating surface that reduces friction between the peritoneum and abdominal structures.⁶⁰

The semipermeable membrane of the peritoneum selectively allows the passage of solutes and solvent across it.⁶¹ Under normal conditions, the peritoneum secretes a small amount of transudative fluid into the space between its visceral and parietal layers and tightly regulates the volume of peritoneal fluid accumulation to approximately 5 to 20 mL.⁶² This fluid is transported from the capillary beds in the submesothelial stroma, through the mesothelial lining, and into the peritoneal potential space. Peritoneal fluid leaves the cavity via lymphatic drainage through stomata, small lymphatic channels in the mesothelium. The secretion and the drainage of peritoneal fluid is meticulously balanced to prevent accumulation in the peritoneal cavity. In disease states, this process may become disrupted, forming transudative ascites when serum protein content is disrupted and exudative ascites when the damaged mesothelium permits proteins and other particles to leak into the peritoneal cavity.⁶²

Some literature suggests that the transudative properties of peritoneal tissue may allow for the secretion of lubricating fluid in the peritoneal neovagina.^{56,63,64} Despite claims that peritoneal vaginoplasty may provide a self-lubricating neovagina, the evidence remains extremely limited. In one case series of 5 patients, Sachan et al⁴³ described the appearance of a good lubricated and healthy vaginal surface at a mean postoperative interval of 6 months. Another small study reported that 70% (N = 10) of peritoneal GAV patients had occasional to frequent sensation of increased neovaginal wetness on arousal.⁴⁴ Overall, robust clinical data discussing vaginal lubrication following gender-affirming peritoneal

vaginoplasty are lacking. Similarly, self-lubricating from peritoneal tissue appears to be consistent with continuous lubrication and is difficult to distinguish from fluid from retained sexual accessory glands during sexual arousal (Table 2).

Given the limited evidence specific to transfeminine patients, it is possible that research on cis women who underwent peritoneal vaginoplasty for vaginal agenesis has contributed to the notion that peritoneal vaginoplasty provides self-lubrication. In one comparison of outcomes between peritoneal and sigmoid vaginoplasty, cis women reported similar FSFI scores for postoperative lubrication.⁶⁵ This suggests that peritoneal vaginoplasty lubrication had similar satisfaction to colonic vaginoplasty, the latter having been well established to provide some degree of lubrication. Another study found no significant difference in FSFI lubrication scores between cis women who had undergone peritoneal vaginoplasty compared with control subjects without any gynecological pathology.⁶⁶ While it may be appropriate to draw some parallels between peritoneal vaginoplasty outcomes in cis women to transfeminine or gender-diverse populations, physiological differences between these patient populations and their possible impact on surgical outcomes must not be overlooked. More population-specific evidence is needed to support the assertion that peritoneal GAV provides any functional self-lubrication for transfeminine and gender-diverse patients.

Without robust clinical data, it is also difficult to evaluate to what degree transudative peritoneal fluid secretion persists in the long term following translocation of the peritoneal flap to line the neovagina. One advantage of peritoneal flap use in vaginoplasty is that the tissue is not severed from its vascular and lymphatic pedicle. Thus, it is plausible that the transudative process stemming from the hydrostatic pressure within the peritoneal capillary beds may be retained following vaginoplasty. However, physiological peritoneal fluid production is quite small, with a total filtration rate of fluid into the peritoneal cavity of 0.1 mL/min.⁶⁷ The entire peritoneal membrane measures approximately 1.8 m² but only a small percentage of this surface area is utilized to form the neovaginal lining.⁶⁰ Using mean neovaginal depth and circumference measurements of 15 × 12 cm,⁴⁴ this would suggest an almost negligible secretion rate of 0.001 mL/min into the neovagina. It is difficult to compare peritoneal secretion volume to erogenous secretory volume of the natal vagina, as no method of objectively measuring vaginal lubrication volume has been validated for use.¹⁴ Still, our estimated peritoneal neovaginal secretory rate of 0.001 mL/min (0.015 mL/15 min) is nowhere near the existing estimate of 0.7 mL/15 minutes of fluid secreted into the natal vagina during arousal.¹⁵ At best, any peritoneal fluid production could emulate some of the basal moisture produced in the natal vagina, since this peritoneal fluid would be continuously produced, nonresponsive to sexual arousal, and of very low volume.

Another plausible source of neovaginal lubrication arises from the secretions of the lamellar bodies and the maintenance of the peritoneal glycocalyx. Nevertheless, it cannot be assumed that these tissue processes would remain unimpacted by the surgical disruption and relocation of peritoneal tissue to form the neovagina. The peritoneum has been demonstrated to undergo spontaneous squamous epithelial metaplasia when grafted to the urogenital introitus and exposed to the external environment.⁶⁵ Although data specific to transfeminine and

gender-diverse patients is absent, we agree with Salibian et al's⁴⁸ assertion that the rapid cellular transformation of the peritoneal vaginal lining in cis patients casts doubt on the likelihood that the peritoneal neovagina retains adequate self-lubricating properties for peritoneal GAV patients in the longer term. In cis women who underwent peritoneal vaginoplasty, their peritoneal neovaginal flap underwent metaplastic squamous epithelization within the first 6 months.^{68,69} Moreover, Herman et al⁷⁰ took biopsy specimen of cis women who underwent peritoneal vaginoplasty and showed complete replacement of mesothelium with stratified squamous epithelium starting as early as 3 months postoperatively. Evidence of glandular cells within this metaplastic squamous epithelium was seen in a subset of cis female patients with vaginal agenesis, but these mucinous glands possessed histological and histochemical features of Müllerian (paramesonephric) origin.⁷⁰ Unfortunately, no similar data have been published in the transfeminine or gender-diverse population to date. More patient reported outcomes data are needed to better characterize neovaginal lubrication following gender-affirming peritoneal vaginoplasty in the medium and long terms.

Although peritoneum demonstrates both transudative function and cellular surface lubrication in situ, little evidence supports the persistence of these processes in the neovaginal lining of peritoneal GAV. Additionally, these possible sources of fluid, if persistent, are nonresponsive to sexual stimulus and likely limited in volume. No glands are identified in the microanatomical structures of the peritoneum, and therefore there are no other obvious sources of fluid to provide lubrication to the peritoneum-derived neovagina. Overall, the transudative physiology of the peritoneum shares promising similarity with natal vaginal fluid secretion; however, the capacity for peritoneal vaginoplasty to provide functionally significant basal or responsive self-lubrication is not born out in the existing evidence.

Pathologic and other contributions to Neovaginal fluid

Some complications associated with GAV may present with fluid leakage from the neovagina. Additionally, the requirement for regular vaginal douching and lubrication use for dilation may result in retained moisture or lubricant in the vaginal canal. Taken together, these factors make assessment of presence and quantity of endogenous nonpathologic neovaginal fluid production more difficult.

Vaginal voiding and hygiene

Shortening of the urethra in GAV may result in altered voiding habits and hygiene. The proximity of the neourethral meatus to the neovaginal introitus may allow the urinary stream to be deflected into the vaginal canal resulting in retention of fluid within the vagina. This is particularly true when patients experience urinary incontinence as a complication of GAV. One study comparing surgical outcomes following gender-affirming PIV across multiple studies found that 8% to 33% experienced dribbling of urine.⁷¹ Inadequate hygiene after micturition could further contribute to moisture in the vaginal canal and vulva.

Granulation tissue

A common postoperative complication of all vaginoplasty techniques is granulation tissue deposition. Granulation tissue

within the neovagina presents with discharge and varying degrees of bleeding from the granulation site.⁷² Incidence of granulation tissue formation following PIV has been reported at 7% to 26% of patients postoperatively.⁷³ One study of transwomen who underwent peritoneal vaginoplasty found that 20% developed hypergranulation.⁷⁴ It may be difficult to distinguish weeping or discharge from hypergranulation tissue from other, desirable secretions from the neovagina. Given the prevalence of granulation tissue formation following vaginoplasty, this symptomatology may confound the perception of lubrication after GAV.

Fistula

Fistula formation between the neovaginal cavity and the surrounding structures is a relatively rare, but serious, complication of vaginoplasty. Rectovaginal fistula, occurring in 0.8% of primary vaginoplasties at one large center,⁷⁵ and urethrovaginal fistula, occurring in 0.8% to 3.9% of cases,⁷² are most commonly reported, though vesicovaginal and peritoneal-vaginal fistulas are also possible. A study of single-center PIV and colonic vaginoplasty outcomes reported a 2.3% (N = 1082) overall incidence of fistulae.⁷⁵ The overall fistula rate associated with peritoneal vaginoplasty is difficult to estimate due to limited data, but a recent systematic review identified just 1 instance of urethrovaginal fistula in 49 gender-affirming peritoneal vaginoplasty cases.⁴⁸ Leakage of urine or peritoneal fluid into the neovagina could be mistaken for neovaginal lubrication, resulting in possible underdiagnosis of fistulae and mischaracterization of the neovagina as self-lubricating.

Peritoneal fluid is perhaps the most difficult to identify and therefore is most easily misattributed as nonpathological neovaginal secretion. In peritoneal vaginoplasty, the possibility of incomplete closure of the vaginal cuff could result in peritoneal-vaginal fistula, resulting in leakage of peritoneal fluid into the vaginal canal. At present, this complication is theoretical, as no cases of peritoneal-vaginal fistula relating to vaginoplasty have been reported in the literature. Perforation or fistulas between the rectovesicular pouch with any GAV technique could also result in peritoneal-vaginal fistula. This has been reported for 1 patient who underwent PIV.⁷⁵

Hair and foreign materials

Another source of possible complications is the possibility of hair growth within the neovaginal vault. Hair follicles are completely absent in natal vaginal tissue, but some tissues used to line the neovagina do contain hair follicles. Hair growth within the neovagina may be associated with several adverse outcomes, including possible discomfort with dilation or intercourse, infection, hair bezoar formation, concretions, and calculi.^{72,73} These sources of irritation within the neovagina may promote inflammation and associated fluid discharge.

Although penile and scrotal skin are the most widely used flap/graft tissues for GAV, they both contain hair follicles and have the propensity for growing hair within the vaginal vault following vaginoplasty. To reduce the risks associated with hair growth, some centers encourage or require patients to undergo genital hair removal via laser or electrolysis before undergoing PIV. Other centers manually cauterize hair follicles during the PIV surgery. No study has demonstrated the effectiveness of either hair-removal technique in improving hair growth-associated outcomes following PIV. Regardless, the presence of hair follicles within penile and scrotal tissue

presents a disadvantage in their use for GAV and may increase the risk of pathological discharge in these patients.

In contrast, colonic, peritoneal, and urethral tissues have the benefit of being innately hairless, which removes the risk of hair growth in the vaginal canal.⁶³ These tissue options eliminate the need for painful and costly presurgical hair removal and reduce the risk of hair-associated inflammation.

Patients of GAV, regardless of technique, may still experience inflammation and discharge associated with foreign bodies retained in the neovagina, such as undissolved sutures or particulates introduced into the neovaginal vault through dilation, sex, or other activities.

Infection and other causes

Van der Sluis et al⁷⁶ identified pathologic neovaginal discharge as a concern for patients post-GAV and proposed an algorithm to help health professionals diagnose and treat such conditions. Other possible etiologies for symptomatic vaginal discharge that they identified include sexually transmitted infection, neovaginal dysbiosis, neovaginal candidiasis, neovaginal malignancy, neovaginal inflammatory bowel disease (in colonic vaginoplasty), and diversion neovaginitis in colonic vaginoplasty.⁷⁶

Conclusions

We review here the functional capacity for neovaginal self-lubrication in PIV, colonic and peritoneal GAV to support evidence-based decision making for clinicians and patients. Neovaginal lubrication following GAV arises from the total fluid production from the neovaginal lining, the preserved glands of the reconstructed vulva, and exogenous or pathologic sources (eg, retained lube, vaginal voiding, inflammatory fluid production). However, none of the GAV techniques reviewed convincingly provide a level of functional self-lubrication similar to that of the natal vagina.

The only identified source of sexually responsive lubrication is from the retention of genitourinary glands, particularly Cowper's glands and Littre glands. The retention of these glands is generally consistent across PIV, colonic, and peritoneal GAV and thus has little bearing when comparing techniques. Despite the retention of these glands, data consistently demonstrate that sexual lubrication following GAV is unsatisfactory to many patients. This is likely reflective of insufficient volume of secretions, noting that the contribution of glandular fluids to natal vaginal lubrication in both the basal and responsive states makes up only a fraction of lubricating fluid, with vaginal wall transudate, cervical, and uterine fluid also contributing in phenotypical cis women.

The epithelial vaginal lining of PIV has no functional secretory capacity, neither basal nor responsive. In fact, the cornified epithelium acts as a barrier to fluid passage across its surface. Any fluid in the neovaginal vault arises from secretions from the preserved genitourinary glands or is secondary to retained exogenous fluid or pathological fluid production.

Colonic vaginoplasty produces a constant basal rate of fluid secretion from colonic mucosa that is not responsive to sexual arousal. It is also distinct from natal vaginal fluid in that it is mucinous and glandular, rather than largely transudative. The properties of this colonic mucinous fluid include constant, sometimes excessive and malodorous, production. Any degree of self-lubrication may be considered a benefit by some

individuals, but others may find that the continuous secretion outside of arousal is unhelpful and requires increased hygiene measures.

Peritoneum, in situ, shares a similar capacity to produce transudative fluid to the natal vagina and thus provides promise in its use for lining the neovaginal cavity. Despite its theoretical suitability in GAV, data fail to demonstrate superior satisfaction with functional lubrication compared with PIV, whose epithelial lining provides no contribution to fluid production. Perhaps this is because peritoneal fluid production is also nonresponsive to sexual stimulus, being produced at a relatively constant basal rate, and suboptimal in volume. It is likely that the volume of any fluid produced by the peritoneal vaginal lining is nonsignificant to function and that the transudative gradient may be disrupted by the translocation of peritoneal tissue. Additionally, some evidence suggests that metaplastic changes to the tissue following surgery impede continued fluid production in the neovagina.

Finally, pathologic sources of fluid may develop in all surgical approaches and may be more problematic than beneficial in terms of contributing to neovaginal lubrication. The retention of exogenous lubricant used for dilation or penetrative intercourse, the risk of inflammatory fluid production due to granulation tissue formation or infection, and the presence of other bodily fluids entering the neovagina via fistula are present across techniques. Fluids arising from these processes must be excluded when assessing healthy neovaginal self-lubrication.

This review was limited by the sparse availability and specificity of published data. No studies provided objective or quantitative measures of neovaginal fluid volumes. Existing literature also did not provide data on the sexual practices or specific functional needs of their participants. Patients who engage in receptive penetrative intercourse may have different requirements with respect to neovaginal self-lubrication than those who do not. Further, patients who engage in penis-in-vagina sex may have different self-lubrication needs compared with those incorporating toys or other objects into their sexual activities, affecting their self-reported satisfaction. Additionally, FSFI measures were widely used to assess neovaginal lubrication, despite lack of demonstrated validity in transfeminine or gender-diverse populations. More broadly, the fact that no pre- or postsurgical sexual function measures are validated for transfeminine and gender-diverse patients limits all studies of sexual functioning for these patients.⁷⁷ Finally, small sample sizes limit the appropriateness of extrapolating beyond the specific populations included in this review.

At this time, no GAV approach has been demonstrated to provide appropriate basal and sexually responsive self-lubrication comparable to that of the natal vagina. To support the health of GAV patients, clinicians must be transparent about the limitations of each GAV technique. No technique can be recommended over others with respect to providing functional self-lubrication. Each has been shown to lack adequate self-lubrication for most patients. Thus, patients should be counseled to use exogenous lubricant for penetrative sexual activities and dilation to avoid injury. In order to provide evidence-based guidance to patients choosing between GAV techniques, and to set appropriate expectations regarding GAV outcomes, more clinical data are needed to accurately characterize the volume and chronicity of basal and sexually responsive self-lubrication of PIV, colonic, and peritoneal GAV.

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