

Phalloplasty: A Review of Techniques and Outcomes

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Background: Acquired or congenital absence of the penis can lead to severe physical limitations and psychological outcomes. Phallic reconstruction can restore various functional aspects of the penis and reduce psychosocial sequelae. Moreover, some female-to-male transsexuals desire creation of a phallus as part of their gender transition. Because of the complexity of phalloplasty, there is not an ideal technique for every patient. This review sets out to identify and critically appraise the current literature on phalloplasty techniques and outcomes.

Methods: A comprehensive literature search of the MEDLINE, PubMed, and Google Scholar databases was conducted for studies published through July of 2015 with multiple search terms related to phalloplasty. Data on techniques, outcomes, complications, and patient satisfaction were collected.

Results: A total of 248 articles were selected and reviewed from the 790 identified. Articles covered a variety of techniques on phalloplasty. Three thousand two hundred thirty-eight patients underwent phalloplasty, with a total of 1753 complications reported, although many articles did not explicitly comment on complications. One hundred four patients underwent penile replantation and two underwent penile transplantation. Satisfaction was high, although most studies did not use validated or quantified approaches to address satisfaction.

Conclusions: Phalloplasty techniques are evolving to include a number of different flaps, and most techniques have high reported satisfaction rates. Penile replantation and transplantation are also options for amputation or loss of phallus. Further studies are required to better compare different techniques to more robustly establish best practices. However, based on these studies, it appears that phalloplasty is highly efficacious and beneficial to patients. (*Plast. Reconstr. Surg.* 138: 594, 2016.)

Malformation or absence of the penis, whether acquired or congenital, can lead to dire health issues for male patients. Physical abnormality of the genitalia, coupled with the physiologic changes including inability to micturate in the standing position and engage in penetrative sexual intercourse, can translate into severe psychological distress. Patients with congenital anomalies of the genitalia, penile cancer, and traumatic penile injury are all at risk

of developing major physical and psychological sequelae.¹⁻⁸ Moreover, gender dysphoric patients, who lie on the transsexual spectrum, often present

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A Video Discussion by William M. Kuzon Jr. M.D., Ph.D., accompanies this article. Go to PRSJJournal.com and click on "Video Discussions" in the "Videos" tab to watch.

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with similar symptoms, especially if not appropriately placed on the correct trajectory for gender transition.^{2,3,6,9–12}

Over the past century, plastic surgeons and urologists have sought to treat such patients through innovative advances in phalloplasty. However, reconstruction of the penis has proven to be extraordinarily complex, as there are yet no suitable replacements for erectile and urethral tissue.¹³ Numerous techniques ranging from hormone treatment to local pedicled and distant free flaps to penile epithesis to transplants have been used in attempts to create or reconstruct the penis, but creation of a fully functional phallus remains elusive.^{7–9,11,13–16} Ideally, reconstruction of the penis should be completed in a single procedure, be aesthetically acceptable, retain erogenous and tactile sensation, enable micturition while standing, and allow for penetrative sexual intercourse.^{14,17,18}

With the numerous techniques being advocated because of their risk-to-benefit profiles, a singular reference that collects available data on phalloplasty techniques and outcomes is necessary to aid in choosing the most appropriate treatment for a given patient. This review collects available data on total phalloplasty, replantation, and transplantation techniques and outcomes in both natal and, when applicable, transsexual male patients, and aggregates them into a solitary reference for providers, patients, and others within the health care system.

PATIENTS AND METHODS

A comprehensive literature search of the PubMed, MEDLINE, and Google Scholar databases was conducted for studies published through July of 2015 for techniques and outcomes of total phalloplasty with the terms “penile reconstruction,” “penis reconstruction,” or “phalloplasty” and Medical Subject Headings terms “penis/surgery” or “phalloplasty” or “penis allotransplant” or “penile replantation” or “penile allotransplant.” Three independent reviewers screened the titles, abstracts, and full texts of the articles identified. Additional articles were selected after reviewing references of identified articles. Disagreement between the reviewers was resolved by discussion and consensus. The search strategy was designed to include primary evidence and all articles that discuss outcomes, defined broadly, in the reconstruction of greater than or equal to the distal two-thirds of the phallus. Exclusion criteria consisted of review articles, reconstruction less than

two-thirds of the distal shaft, scrotal or urethral reconstruction without concomitant reconstruction of the penile shaft, buried penis reconstruction, and articles that did not specifically comment on the technique of reconstruction. Articles published in the English language and any journals were considered. Non-human studies and cadaver studies were excluded. Data on techniques, outcomes, complications, and patient satisfaction were collected.

RESULTS

A total of 790 titles of potentially relevant publications were identified from the initial query. Based on abstract review, 269 articles were excluded. The full texts of the 521 articles were reviewed in detail. Of these, 273 were excluded for the following reasons: they were reviews, letters, editorials, or commentaries; the procedure reported was not total phalloplasty or reconstruction of at least the distal two-thirds of penis; only urethroplasty, scrotoplasty, or skin reconstruction was performed; augmentation or lengthening procedures were reported; reductive phalloplasty or removal of erectile tissue only was reported; articles did not report outcomes data or reported outcomes data that were not stratified by type of phalloplasty; behavioral, psychological, or analgesic studies; duplicate articles; partial reconstruction for hypospadias, chordee, exstrophy, or epispadias; and articles on penile splinting or prosthesis only. The final number of articles that met inclusion criteria and did not have any of the exclusion criteria was 248.

Of these 248 articles, data from 121 that reported on the following types of phalloplasty were aggregated: metoidioplasty, abdominal flaps, latissimus dorsi flaps, groin flaps, gracilis flaps, anterolateral thigh flaps, fibula flaps, and radial forearm flaps, as these are the most common techniques (Fig. 1). (See **Table, Supplemental Digital Content 1**, which shows the list of publications by flap type from which data were gathered, <http://links.lww.com/PRS/B795>.) Fifty articles reporting on other forms of reconstruction are reported in the supplemental section. (See **Table, Supplemental Digital Content 2**, which shows the list of publications by flap type from which supplementary data were gathered, <http://links.lww.com/PRS/B796>.) Of the remaining 77 articles, 74 reported on penis replantation and three reported on penis transplantation. (See **Table, Supplemental Digital Content 3**, which shows the list of publications about penile replantation from which data

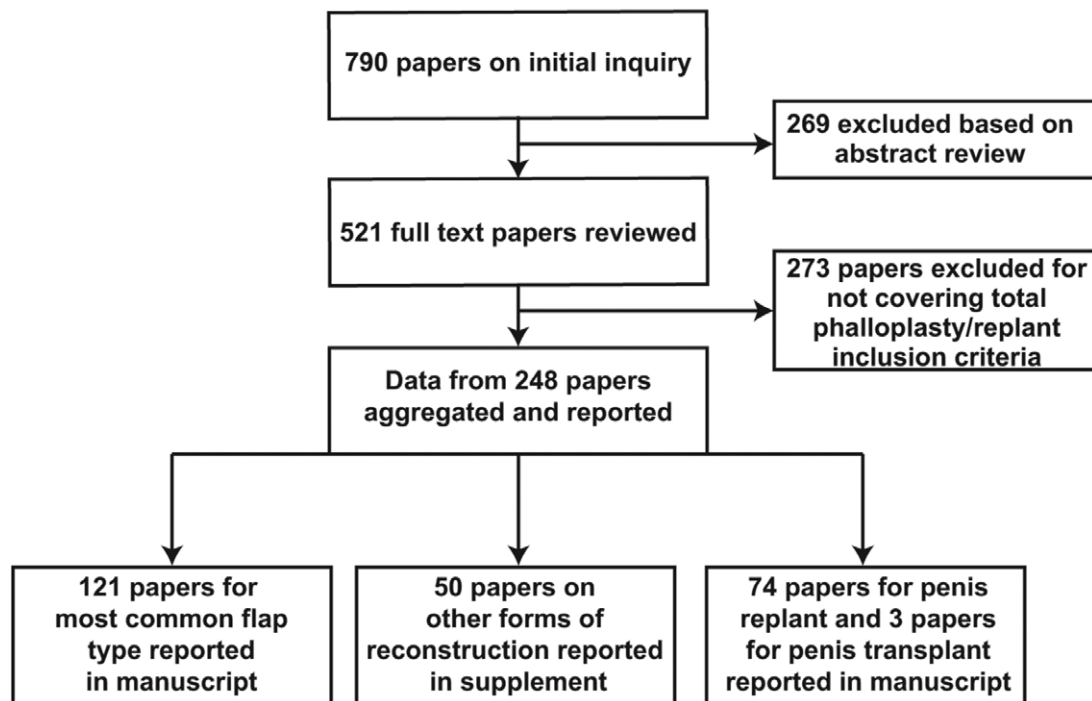


Fig. 1. Schematic of comprehensive literature search.

were gathered, <http://links.lww.com/PRS/B797>.) Three thousand two hundred thirty-eight patients underwent phalloplasty, with a total of 1753 complications reported, although many articles did not explicitly comment on complications. One hundred four patients underwent penile replantation, with 107 complications reported.

Satisfaction was high, although most studies did not use validated or quantifiable approaches to address satisfaction. As such, drawing specific conclusions about patient satisfaction is not possible.

For flap-based phalloplasty, procedures, number of patients, follow-up [see Table, Supplemental Digital Content 4, which shows the summary by flap types reported. “Mixed” refers to publications that reported on multiple flap type reconstructions but did not stratify their results by type of flap. “Other” refers to reconstruction methods not fitting into a single flap category (e.g., corporal mobilization, vascularized appendix transfer for neourethra, transfer of testis and spermatic cord into penile skin), <http://links.lww.com/PRS/B798>], aggregated results (Table 1) (see Table, Supplemental Digital Content 5, which shows the aggregated results by flap types, <http://links.lww.com/PRS/B799>), aggregated complications (Table 2) (see Table, Supplemental Digital Content 6, which shows the aggregated complications by flap type, <http://links.lww.com/PRS/B800>),

information on implants (see Table, Supplemental Digital Content 7, which shows the implants/prostheses, <http://links.lww.com/PRS/B801>), and satisfaction (Table 3) (see Table, Supplemental Digital Content 8, which shows the patient-reported satisfaction, <http://links.lww.com/PRS/B802>) are presented. For penile replantation, number of patients, follow-up results, complications, and satisfaction are reported. (See Table, Supplemental Digital Content 9, which shows the aggregated results for penile replantation, <http://links.lww.com/PRS/B803>.)

Metoidioplasty

One of the initial techniques used for phalloplasty in the female-to-male transsexual population was metoidioplasty, in which the clitoris is hypertrophied with the use of systemic testosterone.^{19–21} In general, a relatively small phallus is produced (4 to 10 cm) that often is not acceptable for penetrative intercourse.²² However, metoidioplasty does have some advantages to flap-based techniques, including maintaining erogenous sensitivity without neurotomy, shorter hospitalization, and minimization of scarring outside the genital area. Its cost is also substantially lower than that of phalloplasty.¹³ In addition, micturition in the standing position is possible with mobilization of the clitoris and chordee to the ventral position and extension of the urethra with a vaginal

epithelial flap or a combined buccal mucosal graft with labia minora flap.^{9,23} Without surgical castration in the setting of metoidioplasty, systemic administration of testosterone has led to rare reports of ovarian carcinoma, breast cancer, and vaginal cancer.^{6,24}

Studies have shown that the average length of the urethra and phallus after metoidioplasty are 9.1 to 14.2 cm and 4 to 10 cm, respectively. Most patients (94.1 percent) experienced adequate urinary function in standing position, and 100 percent reported having erections following reconstruction (Table 1). The most common complications were related to urethral reconstruction, including fistula formation (16.9 percent) and stricture/stenosis (9.1 percent), but other

postoperative complications (4.5 percent) and total flap loss (4.5 percent) were also reported (Table 2). Patient satisfaction was generally high, with 93.1 percent reporting overall satisfaction (Table 3).^{22,23,25–29} In one study, 24 percent of patients underwent further phalloplasty.²²

Abdominal Flaps

Abdominally based flaps using the epigastric vessels were more common before free flap–based reconstruction. Drawbacks include diminished sensation because of absence of neurotomy, variability in vascular anatomy potentially requiring preoperative imaging, atrophy of the neophallus, limited ability to urinate in the standing position, and inability to engage in

Table 1. Aggregated Results by Main Flap Types Reported

Flap Type	Dimensions	Results (%)	Urinary Function (%)	Sexual Function (%)
Metoidioplasty	Neourethra length, 9.1–14.2 cm ¹ Neophallus length, 4–10 cm ¹	<ul style="list-style-type: none"> • 82 (100) with tactile sensation² • 5 (22.7) required reoperation for unsatisfying results³ 	<ul style="list-style-type: none"> • 348 (94.1) can void while standing⁴ • 23 (6.2) dribbling/spraying while urinating⁴ 	<ul style="list-style-type: none"> • 82 (100) with erections⁵
Abdominal flap	Length, 3.7–16 cm ⁶ Diameter, 9.5–12 cm ⁷	<ul style="list-style-type: none"> • 3 (75) with tactile sensation⁸ • 1 (25) no sensation⁸ 	<ul style="list-style-type: none"> • 41 (37.3) can void while standing⁹ • 1 (0.9) with dribbling on urination⁹ • 1 (0.9) diminished flow of urine⁹ • 61 (55.5) with leakage, dilation, stenting, awaiting further reconstruction⁹ • 1 (0.9) voids by means of scrotal urethrostomy⁹ • 17 (100) can void¹⁵ 	<ul style="list-style-type: none"> • 20 (19.6) able to have intercourse¹⁰ • 2 (2) with erections¹⁰ • 1 (1) no erections or erotic thought¹⁰ • 2 (2) reported orgasms¹⁰
Latissimus dorsi flap	Length, 7–17 cm ¹¹ Circumference, 10–20 cm ¹² Diameter, 3.5 cm ¹³	<ul style="list-style-type: none"> • 17 (100) with tactile sensation¹⁴ 	<ul style="list-style-type: none"> • 17 (100) can void¹⁵ 	<ul style="list-style-type: none"> • 9 (14.8) able to have intercourse¹⁶ • 3 (4.9) unable to have intercourse¹⁶ • 2 (3.3) partially able to have intercourse¹⁶ • 4 (6.6) did not try enough or did not have opportunity to have intercourse¹⁶ • 8 (13.1) able to achieve enough muscle contraction and neophallus stiffness for intercourse¹⁶ • 2 (3.3) able to penetrate but not keep penis inside because of short length¹⁶ • 6 (9.8) reported penis too wide, too short, or too soft for successful penetration¹⁶

(Continued)

Table 1. (Continued)

Flap Type	Dimensions	Results (%)	Urinary Function (%)	Sexual Function (%)
Groin flap	Length, 7.5–15 cm ¹⁷ Diameter, 4–5 cm ¹⁸	• 2 (100) with tactile sensation ¹⁹	• 9 (100) can void while standing ²⁰	• 5 (100) able to have intercourse ²¹ • 1 (20) got wife pregnant ²¹
Anterolateral thigh flap	Length, 10 cm ²² Diameter, 3.5 cm ²²	• 4 (75) with tactile sensation ²³ • 1 (25) temperature and vibratory sense intact ²³	• 2 (66.7) can void while standing ²⁴ • 1 (33.3) voids sitting (no urethroplasty) ²⁴	• 3 (60) able to have intercourse ²⁵ • 3 (60) with erogenous sensation ²⁵
Gracilis	Length, 4–15 cm ²⁶ Width, 6–10 cm ²⁷ Circumference, 12 cm ²⁸	• 1 (100) with tactile sensation ²⁹	• 3 (100) can void while standing ³⁰	• 1 (100) able to have intercourse ³¹
Fibula flap	None reported	• 1 (100) with tactile sensation ³² • 5 (100) with bulbocavernosus reflex intact ³³	• 9 (90) can void while standing ³⁴ • 1 (10) without urethroplasty able to void from posterior scrotum ³⁴	• 15 (51.7) able to have intercourse ³⁵ • 1 (3.4) reports erection transmitted to fibula by means of corpora ³⁵ • 5 (17.4) went on to have children ³⁵
Radial forearm flap	Length, 7.5–14 cm ³⁶	• 611 (98.4) with tactile sensation ³⁷	• 704 (97.5) can void while standing ³⁸	• 115 (21.1) able to have intercourse ³⁹ • 5 (0.9) with erections ³⁹ • 389 (71.4) with return of erogenous sensation ³⁹

¹Total of 327 patients who underwent metoidioplasty reported neourethral and neophallus length.

²Total of 82 patients who underwent metoidioplasty for whom sensory function was reported.

³Total of 22 patients who underwent metoidioplasty for whom rate of reoperation was reported.

⁴Total of 370 patients who underwent metoidioplasty for whom urinary function was reported.

⁵Total of 82 patients who underwent metoidioplasty for whom sexual function was reported.

⁶Total of 32 patients who underwent abdominal flap reconstruction reported neophallus length.

⁷Total of 24 patients who underwent abdominal flap reconstruction reported neophallus diameter.

⁸Total of four patients who underwent abdominal flap reconstruction for whom sensory function was reported.

⁹Total of 110 patients who underwent abdominal flap reconstruction for whom urinary function was reported.

¹⁰Total of 102 patients who underwent abdominal flap reconstruction for whom sexual function was reported.

¹¹Total of 31 patients who underwent latissimus dorsi flap reconstruction reported neophallus length.

¹²Total of 30 patients who underwent latissimus dorsi flap reconstruction reported neophallus circumference.

¹³Total of one patient who underwent latissimus dorsi flap reconstruction reported neophallus diameter.

¹⁴Total of 17 patients who underwent latissimus dorsi flap reconstruction for whom sensory function was reported.

¹⁵Total of 17 patients who underwent latissimus dorsi flap reconstruction for whom urinary function was reported.

¹⁶Total of 61 patients who underwent latissimus dorsi flap reconstruction for whom sexual function was reported.

¹⁷Total of five patients who underwent groin flap reconstruction reported neophallus length.

¹⁸Total of four patients who underwent groin flap reconstruction reported neophallus diameter.

¹⁹Total of two patients who underwent groin flap reconstruction for whom sensory function was reported.

²⁰Total of nine patients who underwent groin flap reconstruction for whom urinary function was reported.

²¹Total of five patients who underwent groin flap reconstruction for whom sexual function was reported.

²²Total of one patient who underwent anterolateral thigh flap reconstruction reported neophallus length and diameter.

²³Total of four patients who underwent anterolateral thigh flap reconstruction for whom sensory function was reported.

²⁴Total of three patients who underwent anterolateral thigh flap reconstruction for whom urinary function was reported.

²⁵Total of five patients who underwent anterolateral thigh flap reconstruction for whom sexual function was reported.

²⁶Total of eight patients who underwent gracilis flap reconstruction reported neophallus length.

²⁷Total of seven patients who underwent gracilis flap reconstruction reported neophallus width.

²⁸Total of one patient who underwent gracilis flap reconstruction reported neophallus circumference.

²⁹Total of one patient who underwent gracilis flap reconstruction for whom sensory function was reported.

³⁰Total of three patients who underwent gracilis flap reconstruction for whom urinary function was reported.

³¹Total of one patient who underwent gracilis flap reconstruction for whom sexual function was reported.

³²Total of one patient who underwent fibula flap reconstruction for whom sensory function was reported.

³³Total of five patients who underwent fibula flap reconstruction for whom reflexes were reported.

³⁴Total of 10 patients who underwent fibula flap reconstruction for whom urinary function was reported.

³⁵Total of 29 patients who underwent fibula flap reconstruction for whom sexual function was reported.

³⁶Total of 15 patients who underwent radial forearm flap reconstruction reported neophallus length.

³⁷Total of 621 patients who underwent radial forearm flap reconstruction for whom sensory function was reported.

³⁸Total of 722 patients who underwent radial forearm flap reconstruction for whom urinary function was reported.

³⁹Total of 545 patients who underwent radial forearm flap reconstruction for whom sexual function was reported.

Table 2. Aggregated Complications by Main Flap Types Reported

Flap Type	General Complications (%)	Urethral Complications (%)	Flap Complications (%)	Donor-Site Complications (%)
Metoidioplasty ¹	<ul style="list-style-type: none"> 23 (4.5) unspecified postoperative complications (e.g., hematoma, infection, UTI, urinary retention) 	<ul style="list-style-type: none"> 86 (16.9) fistula 46 (9.1) stricture/stenosis 	<ul style="list-style-type: none"> 6 (1.2) hematoma 23 (4.5) total flap loss 	<ul style="list-style-type: none"> None reported
Abdominal flap ²	<ul style="list-style-type: none"> 11 (2.2) cystitis 2 (0.4) bleeding 1 (0.5) contraction at base of penis and ulcer at ureteral orifice 20 (9.9) wound infection 2 (1) abscess 18 (8.9) shearing sutures 2 (1) with perforation or abscess after TE placement 1 (0.5) failure of intercourse after initial success 	<ul style="list-style-type: none"> 44 (21.8) fistula 54 (26.7) stricture 5 (2.5) urinary stones 1 (0.5) urethral obstruction 60 (29.7) unspecified urethral complications 1 (0.5) urinary retention 1 (0.5) multiple perforations along original suture lines because of hair growth in neourethra 	<ul style="list-style-type: none"> 5 (2.5) hematoma 4 (2) total flap loss/necrosis 3 (1.5) distal loss/necrosis 15 (7.4) graft loss requiring regraft 9 (4.5) tube dehiscence 4 (2) wound dehiscence 1 (0.5) cartilage explant because of infection 1 (0.5) cartilage fracture 	<ul style="list-style-type: none"> 1 (0.5) donor-site bulging
Latissimus dorsi flap ³	<ul style="list-style-type: none"> None reported 	<ul style="list-style-type: none"> 7 (13.2) fistula 	<ul style="list-style-type: none"> 7 (13.2) hematoma 1 (1.9) partial loss/necrosis 2 (3.8) vascular thrombosis 3 (5.7) excessive swelling of neophallus 	<ul style="list-style-type: none"> 1 (1.9) skin graft loss
Groin flap ⁴	<ul style="list-style-type: none"> 7 (4.2) infection 4 (2.4) lymphorrhagia 	<ul style="list-style-type: none"> 9 (5.5) fistula 2 (1.2) stricture/stenosis 1 (0.6) urethral recon necrosis 1 (0.6) recurrent UTIs 	<ul style="list-style-type: none"> 4 (2.4) hematoma 5 (3) total flap loss/necrosis 1 (0.6) flap failure because of late hemorrhage 2 (1.2) partial necrosis 26 (15.8) distal necrosis 2 (1.2) skin necrosis 14 (8.5) edema/venous congestion 1 (0.6) leak because of infection 1 (0.6) with penile localization toward pedicle side 	<ul style="list-style-type: none"> 3 (1.8) partial dehiscence
Anterolateral thigh flap ⁵	<ul style="list-style-type: none"> None reported 	<ul style="list-style-type: none"> 10 (22.2) fistulas 3 (6.7) stricture/stenosis 1 (2.2) delayed closure of neourethra requiring cystostomy drainage 	<ul style="list-style-type: none"> 1 (2.2) partial flap loss/necrosis 1 (2.2) failed free inlay graft for neourethra 	<ul style="list-style-type: none"> 1 (2.2) partial graft loss
Gracilis ⁶	<ul style="list-style-type: none"> 1 (9.1) wound dehiscence 	<ul style="list-style-type: none"> 1 (9.1) fistula 	<ul style="list-style-type: none"> 2 (18.2) partial flap loss/necrosis 1 (9.1) distal skin graft loss/necrosis 	<ul style="list-style-type: none"> None reported
Fibula flap ⁷	<ul style="list-style-type: none"> 5 (8.2) wound healing problems 2 (3.3) infection 1 (1.6) with difficulty with intromission because of penile girth 	<ul style="list-style-type: none"> 9 (5.4) fistula 15 (24.6) stricture/stenosis 	<ul style="list-style-type: none"> 3 (4.9) total flap loss/necrosis 4 (6.6) partial flap loss/necrosis 6 (9.8) anastomotic revisions/exploration 	<ul style="list-style-type: none"> None reported

(Continued)

Table 2. (Continued)

Flap Type	General Complications (%)	Urethral Complications (%)	Flap Complications (%)	Donor-Site Complications (%)
Radial forearm flap ⁸	<ul style="list-style-type: none"> • 7 (0.62) infection • 83 (7.38) wound healing problems • 1 (0.09) groin cellulitis • 3 (0.27) abscess • 6 (0.53) pulmonary embolisms • 4 (0.36) nerve compression in lower leg caused by positioning • 2 (0.18) muscular and nerve injuries of the lower legs • 1 (0.09) rib extrusion • 1 (0.09) hemorrhage • 11 (0.98) other unspecified complications 	<ul style="list-style-type: none"> • 299 (26.60) fistula • 138 (12.28) stenosis/stenosis • 106 (9.43) fistulas/strictures requiring urethroplasty • 2 (0.18) urinary obstruction following gradual stream diminishing • 1 (0.09) chronic moderate hydronephrosis • 1 (0.09) acute urinary retention • 1 (0.09) urinary leakage at anastomosis 	<ul style="list-style-type: none"> • 1 (0.09) hematoma • 19 (1.69) total flap loss/necrosis • 61 (5.43) partial flap loss/necrosis • 4 (0.36) distal skin loss/necrosis • 88 (7.83) anastomotic revisions/exploration • 2 (0.18) anastomotic thrombosis • 1 (0.09) wound dehiscence of neourethra • 2 (0.18) vesicle formation around distal urethral flap • 1 (0.09) immediate postoperative thrombus • 1 (0.09) urethral skin tube revision • 2 (0.18) partial abdominal flap necrosis • 6 (0.53) with some bone resorption • 1 (0.09) rib extrusion • 1 (0.09) late fracture of bone segment 	<ul style="list-style-type: none"> • 16 (1.42) regrafting of the arm defect • 10 (0.89) infection at donor site • 7 (0.62) prolonged swelling of arm • 6 (0.53) incomplete graft take • 3 (0.27) poor donor-site scarring • 1 (0.09) partial graft loss at donor site • 1 (0.09) hematoma under skin graft • 1 (0.09) burn on grafted forearm because of temperature insensitivity • 11 (0.98) unspecified donor-site morbidity (e.g., radius fracture, decrease grip/pinch power, cold intolerance)

UTI, urinary tract infection; TE, tissue expander.

¹Total of 508 metoidioplasty patients from articles that reported complications.

²Total of 202 abdominal flap reconstruction patients from articles that reported complications.

³Total of 53 latissimus dorsi flap reconstruction patients from articles that reported complications.

⁴Total of 165 groin flap reconstruction patients from articles that reported complications.

⁵Total of 45 anterolateral thigh flap reconstruction patients from articles that reported complications.

⁶Total of 11 gracilis flap reconstruction patients from articles that reported complications.

⁷Total of 61 fibula flap reconstruction patients from articles that reported complications.

⁸Total of 1124 radial forearm flap reconstruction patients from articles that reported complications.

Table 3. Patient-Reported Satisfaction by Main Flap Types Reported

Flap Type	No. of Articles Reporting Satisfaction	No. of Patients Reporting Satisfaction	Satisfaction Results, No. (%)
Metoidioplasty	4	320	<ul style="list-style-type: none"> • 298 (93.1) satisfied overall • 2 (0.6) satisfied somewhat • 20 (6.3) satisfied with sex life • 14 (1.3) reported length of the neophallus inadequate for full penetration
Abdominal flap	7	168	<ul style="list-style-type: none"> • 96 (57.1) satisfied overall • 23 (13.7) satisfied with appearance • 19 (11.3) satisfied with penile length • 17 (10.1) satisfied with penile circumference • 33 (19.6) satisfied with intercourse • 20 (11.9) satisfied with the frequency of their sexual activities • 17 (10.1) satisfied with their current sexual life • 13 (7.7) satisfied with the frequency of orgasm
Latissimus dorsi flap	4	48	<ul style="list-style-type: none"> • 45 (93.8) satisfied overall • 3 (6.3) dissatisfied overall
Groin flap	6	29	<ul style="list-style-type: none"> • 29 (100) satisfied overall
Anterolateral thigh flap	5	5	<ul style="list-style-type: none"> • 5 (100) satisfied overall
Gracilis	3	10	<ul style="list-style-type: none"> • 10 (100) satisfied overall
Fibula flap	3	27	<ul style="list-style-type: none"> • 27 (100) satisfied overall
Radial forearm flap	28	634	<ul style="list-style-type: none"> • 495 (78.1) satisfied overall • 3 (0.5) dissatisfied overall • 2 (0.3) uncertain about satisfaction • 85 (13.4) satisfied with appearance • 15 (2.4) satisfied with size • 13 (2.1) satisfied with sex lives • 3 (0.5) satisfied with erogenous sensation • 12 (1.9) no regrets about pursuing gender reassignment • 51 (8.0) reported physical appearance now in accord with feeling of masculinity

sexual intercourse.^{13,30} Suprapubic phalloplasty is the most commonly used abdominally based flap currently. This is generally a two-step procedure where the abdominal skin is tubularized and later released on one side (generally the portion more proximal to the trunk). A neourethra is concomitantly created from skin or vaginal epithelium. In the transsexual population, the denuded clitoris can be placed under the neophallus to allow for some erogenous sensation; however, prostheses are generally required to achieve penetrative intercourse.^{31,32}

Studies have shown that the average dimensions of the phallus after abdominal flaps are 3.7 to 16 cm in length and 9.5 to 12 cm in diameter. Some patients (37.3 percent) experienced adequate urinary function in standing position, and 19.6 percent were able to engage in penetrative sexual intercourse (Table 1). The most common complications were related to urethral

reconstruction, including fistula formation (21.8 percent) and stricture/stenosis (26.7 percent), but other postoperative complications including wound infection (9.9 percent), shearing sutures (8.9 percent), and need for regraft (7.4 percent) were also reported (Table 2). Prostheses were used in 19 of 192 patients (10 percent), with over 20 percent having complications (see Table, **Supplemental Digital Content 7**, <http://links.lww.com/PRS/B801>). Most patients (57 percent) reported being overall satisfied with the results (Table 3).^{4,32-52}

Latissimus Dorsi Flap

More recently, free reinnervated or functional pedicled latissimus dorsi musculocutaneous flaps have been used in phalloplasty. In the free reinnervated flap, the neophallus is transferred to the pubic region, where the neurovascular thoracodorsal bundle is anastomosed to the recipient groin

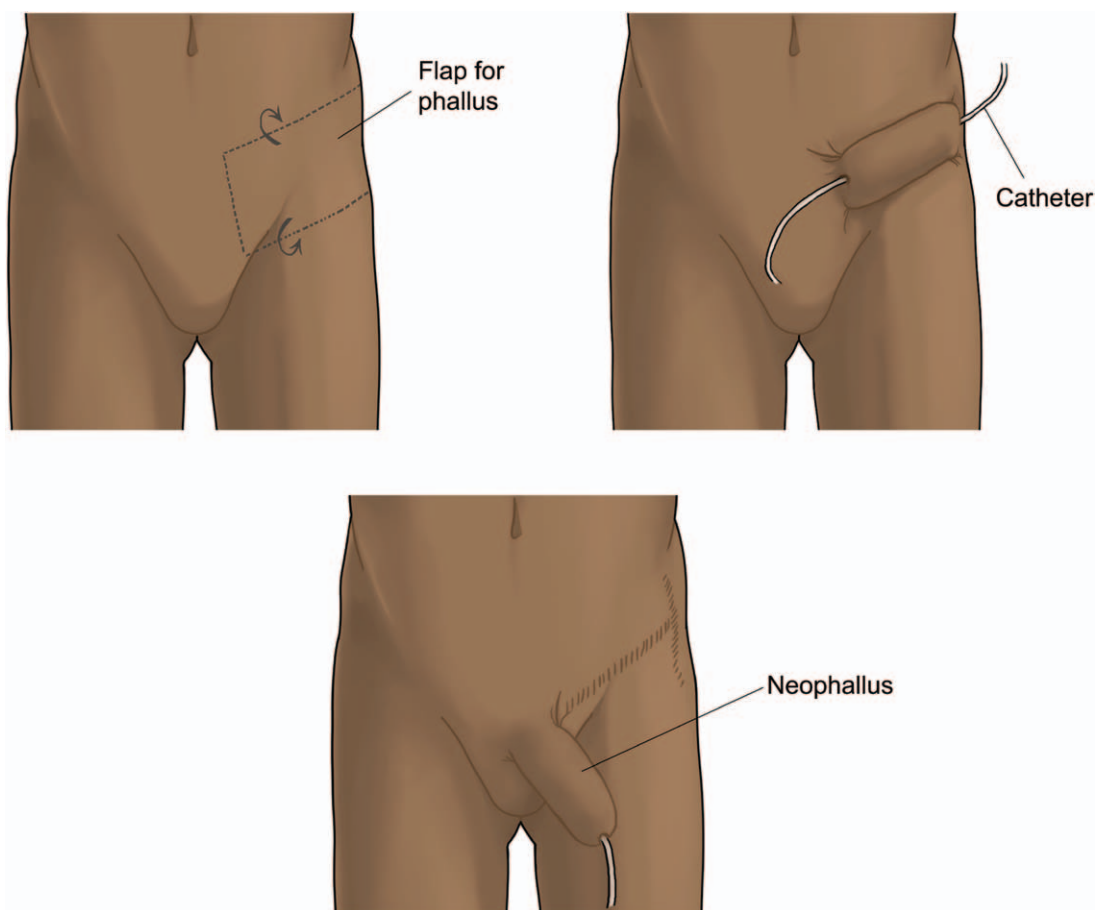


Fig. 2. Illustration of groin flap. The groin flap with or without the iliac bone can be performed in either one or two stages. The two-stage procedure is based on the superficial circumflex iliac artery and the deep circumflex iliac artery. The lateral and medial skin edges of the flap are sutured together, constructing a tube still attached to the body. After some time, the flap is raised on its pedicle. The neourethra is reconstructed using a full-thickness skin graft from the contralateral groin.

vessels and nerves. In the functional transfer, the resulting neophallus allows for patient-controlled contraction and erection formation, but there is lack of long-term follow-up. Moreover, tonic contraction of the phallus is not practical during sexual intercourse. Ranno et al. reported that, in 22 patients who underwent free latissimus dorsi flap transfer, the onset of muscle movement was achieved postoperatively at a mean of 4.25 months (range, 3 to 13 months). Patients were able to lift an average of 1129 g (range, 100 to 2750 g) with the reinnervated muscle. Eighteen of 22 patients (82 percent) were able to contract the muscle, with an average length reduction of 3.08 cm and a circumference enlargement of 4 cm.⁵³

Studies have shown that the average dimensions of the phallus after latissimus dorsi transfer are 7 to 17 cm in length, 10 to 20 cm in circumference, and 3.5 cm in diameter. All patients (100 percent) experienced adequate urinary function in standing position, and 14.8 percent were able to engage in penetrative sexual intercourse (Table 1). The most common complications included fistula formation (13.2 percent) and hematoma (13.2 percent). Other complications included excessive swelling of the neophallus (5.7 percent) and vascular thrombosis (3.8 percent) (Table 2). Prostheses were used in 10 of 74 patients (13.5 percent), with one patient (10 percent) reporting erosion of the implant (see **Table, Supplemental Digital Content 7**, <http://links.lww.com/PRS/B801>). Most patients (93.8 percent) reported being overall satisfied with the results, and 6.3 percent reported dissatisfaction (Table 3).⁵⁴⁻⁶⁰

Groin Flap

Groin flaps are generally based off the iliac vessels and were more common in the premicrosurgery era. Drawbacks are similar to those of the abdominally based flaps, with minimal sensation, atrophy over time, and limited ability to urinate in the standing position or engage in penetrative sexual intercourse.⁶¹⁻⁶³ Use of the iliac crest bone or cartilage as an autologous prosthetic has been trialed with adequate results.^{62,64} Generally, the procedure is performed in two steps, similar to the abdominal flaps, but a prefabricated urethra can be placed early in the tubularization to minimize dissection in the second procedure (Fig. 2).

Studies have shown that the average dimensions of the phallus after groin flaps are 7.5 to 15 cm in length and 4 to 5 cm in diameter. All patients (100 percent) experienced adequate

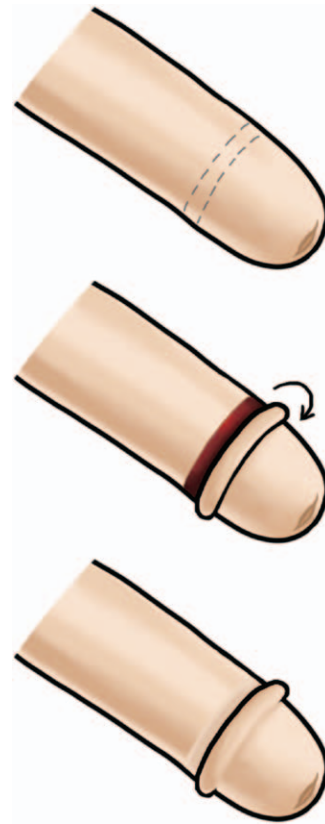


Fig. 3. Illustration of the Norfolk technique. A distal circumferential portion of the neophallus shaft is elevated and rolled to create the corona. A split- or full-thickness skin graft is then placed over the defect on the shaft.

urinary function in standing position, but only nine patients had reported this outcome. All patients (100 percent) were able to engage in penetrative sexual intercourse although, similarly, few patients (five total) reported this outcome measure. The most common complications were related to the flaps themselves, including distal necrosis (15.8 percent) and edema and/or venous congestion (8.5 percent). Other postoperative complications included fistula (5.5 percent), total flap loss (3 percent), and hematoma (2.4 percent) (Table 2). Prostheses were used in 31 of 167 patients (18.6 percent), with no complications reported (see **Table, Supplemental Digital Content 7**, <http://links.lww.com/PRS/B801>). All patients (100 percent) who reported satisfaction reported being overall satisfied (Table 3).⁶¹⁻⁷¹

Anterolateral Thigh Flap (Free and Pedicled)

First described in 1965, the free and pedicled anterolateral thigh flap for phalloplasty has since become a mainstay in phallic

reconstruction.⁷² In general, the pedicled option has become more favored because of microsurgical procedures potentially resulting in increased risk of flap failure and prolonged operative time. Neural coaptation of the lateral femoral cutaneous nerve has allowed for better erogenous sensation.^{73,74} Some have even used chimeric flaps for the creation of a neo-tunica albuginea.⁷⁵ A more anatomical corona can be created with the Norfolk technique or mushroom flap^{9,13,73,76} (Figs. 3 through 6). Advantages

of the anterolateral thigh flap include the color match of the anterolateral thigh compared with that of more distant flaps, and retained bulkiness of the phallus. Disadvantages include the large donor defect that potentially requires a split-thickness skin graft and less-than-ideal sensation to the reconstructed phallus if no neural coaptation is performed. One patient who had penile reconstruction with a pedicled anterolateral thigh flap was recently able to conceive a child.⁷⁷

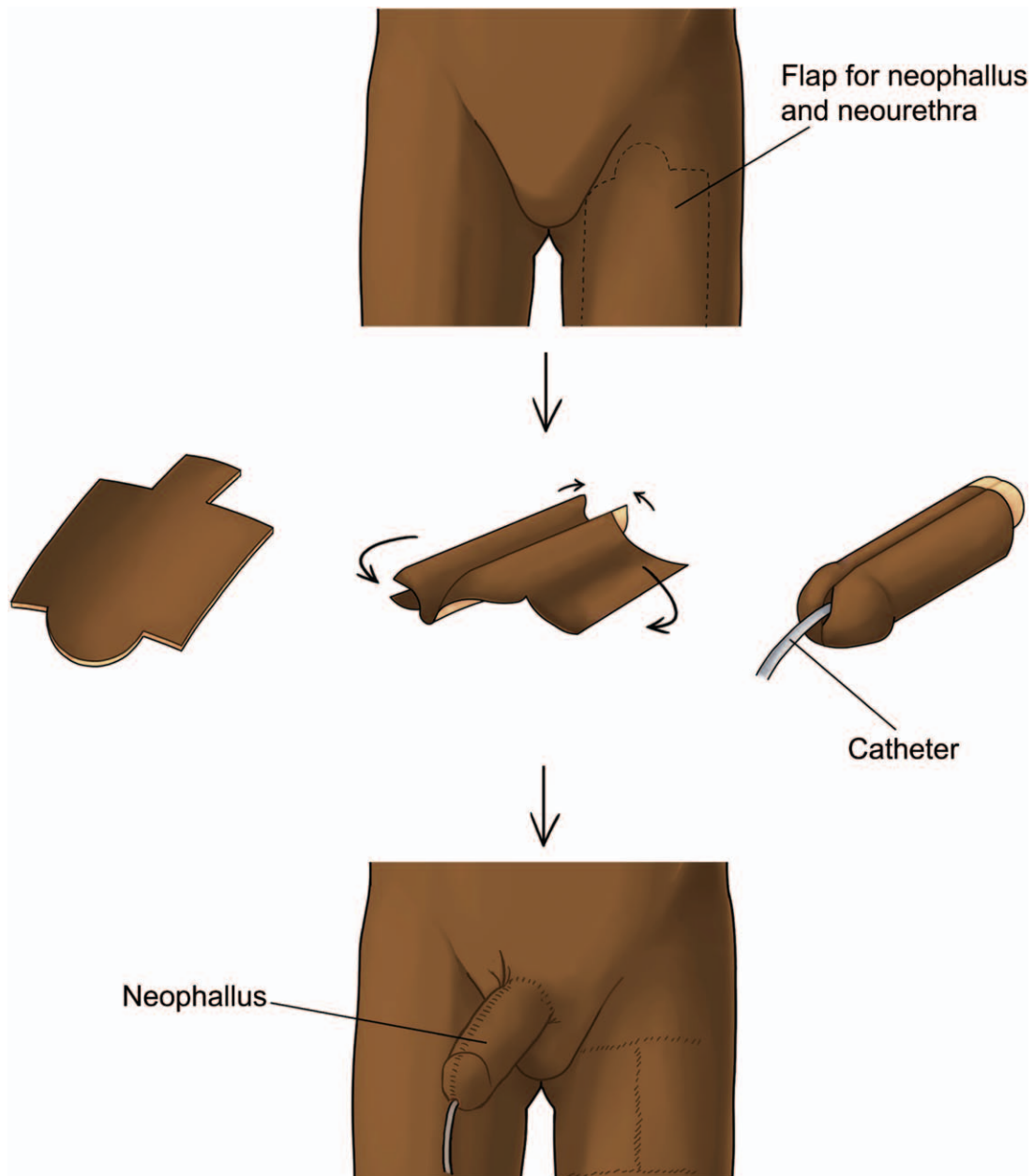


Fig. 4. Illustration of the pedicled anterolateral thigh flap. A tube-within-a-tube design is used. The inner conduit becomes the neourethra, and the outer tubularized tissue represents the neophallus. The semicircular extension at the distal portion of the flap more accurately approximates the circumcised male phallus.

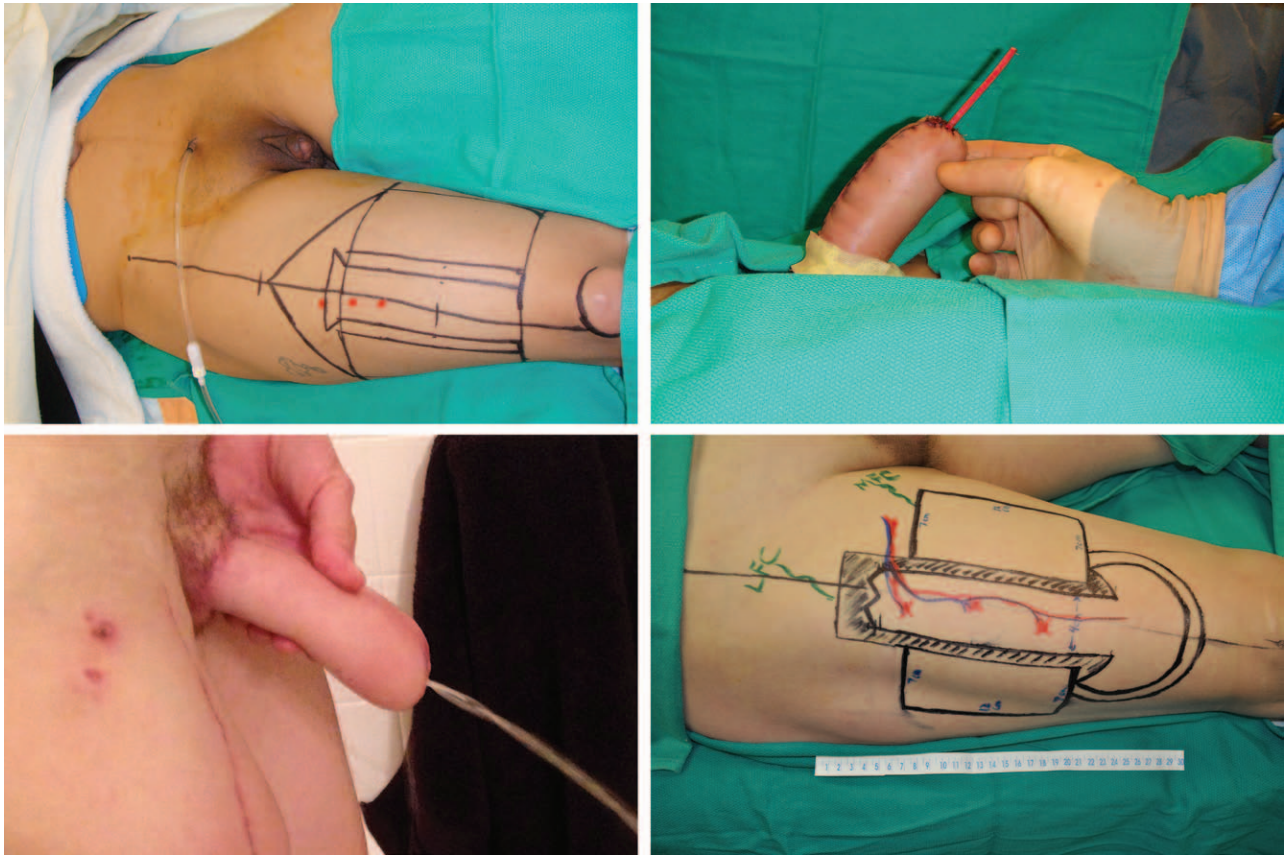


Fig. 5. Patient outcomes with the pedicled anterolateral thigh flap. Photographs obtained (*above, left*) initially preoperatively, showing outline of the anterolateral thigh flap for tube-in-tube phalloplasty; (*above, right*) immediately postoperatively, showing the anterolateral thigh flap; (*below, left*) 1 month postoperatively, showing the patient micturating in standing position; and (*below, right*) showing modification of the tube-in-tube anterolateral thigh flap with distal semicircular extension.



Fig. 6. Photograph obtained immediately postoperatively, showing modified anterolateral thigh flap.

One article reported reconstructive dimensions following anterolateral thigh flap as follows: length, 10 cm; and diameter, 3.5 cm. Most patients (66.7 percent) experienced adequate urinary function in standing position, and 60 percent were able to engage in penetrative sexual intercourse. The most common complications were related to urethral reconstruction, including fistula formation (22.2 percent) and stricture/stenosis (6.7 percent). Prostheses were used in two of 45 patients (4.4 percent), with no reported complications (**see Table, Supplemental Digital Content 7, <http://links.lww.com/PRS/B801>**). All patients (100 percent) reported being overall satisfied with the results, although only five patients reported satisfaction as an outcome (Table 3).^{72-76,78-82}

Gracilis Flap

Orticochea pioneered the use of the gracilis flap for phalloplasty.⁸³ One-stage procedures, using a tube-in-tube concept, were eventually

reported using both muscle and musculocutaneous flaps and anteromedial fasciocutaneous units with gracilis muscles for additional bulk (Fig. 7).⁸⁴⁻⁸⁷ Advantages of gracilis flaps include sufficient nerve length for nerve coaptation, low flap donor-site morbidity, potential for a one-stage phalloplasty, and possible concomitant scrotal reconstruction if needed. Drawbacks include lack of rigidity for sexual intercourse without prostheses and the hair-bearing nature of the area.

Studies have shown that the average dimensions of the phallus after gracilis flaps are 4 to 15 cm in length 6 to 10 cm in diameter (Table 1). All patients (100 percent) experienced adequate urinary function in standing position, although only three patients reported this outcome (Table 1). The most common complication was partial flap necrosis (18.2 percent), followed by wound dehiscence (9.1 percent), distal skin graft loss (9.1 percent), and fistula formation (9.1 percent) (Table 2). A prosthetic implant was used in one of 11 patients (9.1 percent) and resulted in eventual explantation because of distal flap necrosis (see Table, Supplemental Digital Content 7, <http://links.lww.com/PRS/B801>). All patients (100 percent) reported being overall satisfied with the results (Table 3).⁸⁵⁻⁸⁸

Osteocutaneous Free Fibula Flap

First described in 1993, the osteocutaneous free fibula flap offers the rigidity of a penile implant with the use of an autologous bone transfer. The lateral or posterior sural cutaneous nerves along with the peroneal artery are included. The tunica albuginea (when available) is used to anchor the periosteum of the fibula, and the nerves are coapted to the dorsal penile or clitoral nerves (Fig. 8).⁸⁹ Long-term follow-up has shown that bone resorption is minimal, the neourethra is patent with retained phallic sensation, the bone remains viable, and patients have minimal quality-of-life changes because of sustained erection.^{90,91} It has been suggested that the fibula bone is the optimal candidate for rigidity because of its weight-bearing properties, allowing for penetrative sexual intercourse. Previous attempts with costal cartilages, rib bones, radial osteocutaneous flaps, and acrylic resins have led to inadequate functional and aesthetic outcomes.⁹² However, there are significant urethral complications with the prefabricated neourethra.^{89,93}

None of the studies queried reported final dimensions for free fibula flap reconstruction. Most patients (90 percent) experienced adequate urinary function in standing position, and

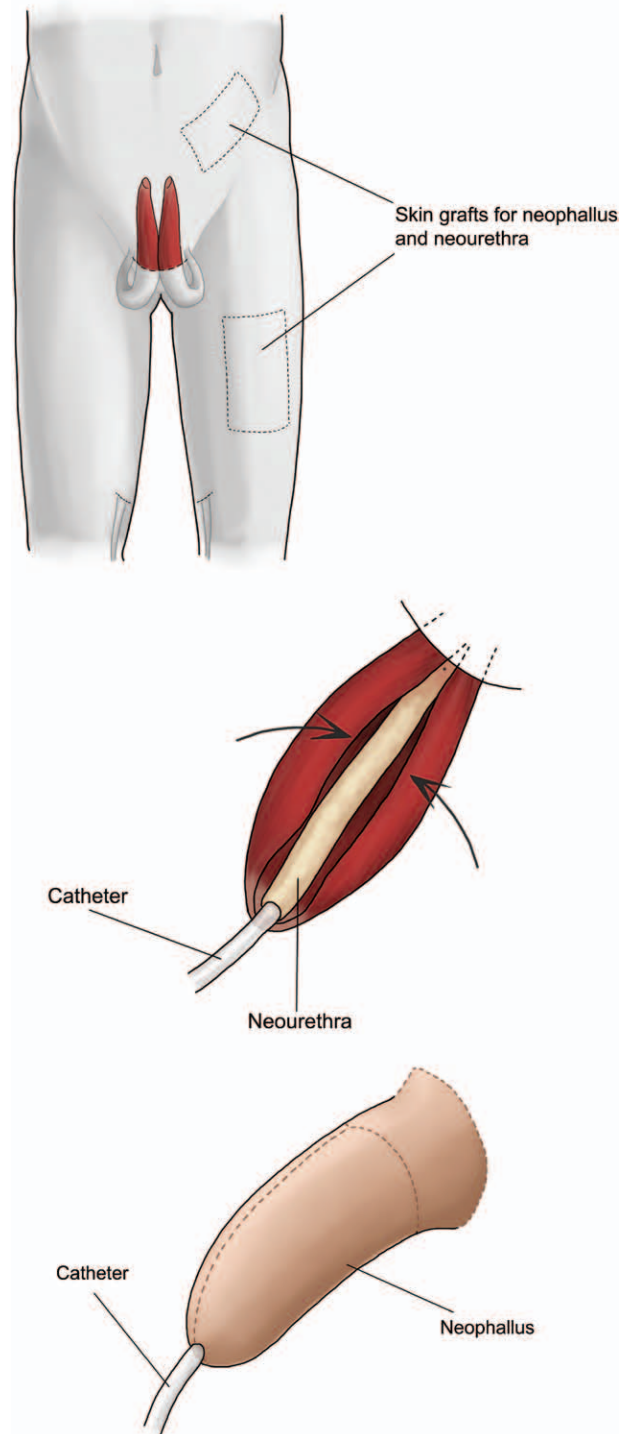


Fig. 7. Illustration of the gracilis flap. A bipediced gracilis muscle flap is harvested and pedicled into the groin. Once joined together around a skin graft used for the neourethra, another skin graft is placed around the muscle.

51.7 percent were able to engage in penetrative sexual intercourse (Table 1). The most common complication was urethral stricture/stenosis (24.6 percent), followed by requirement for

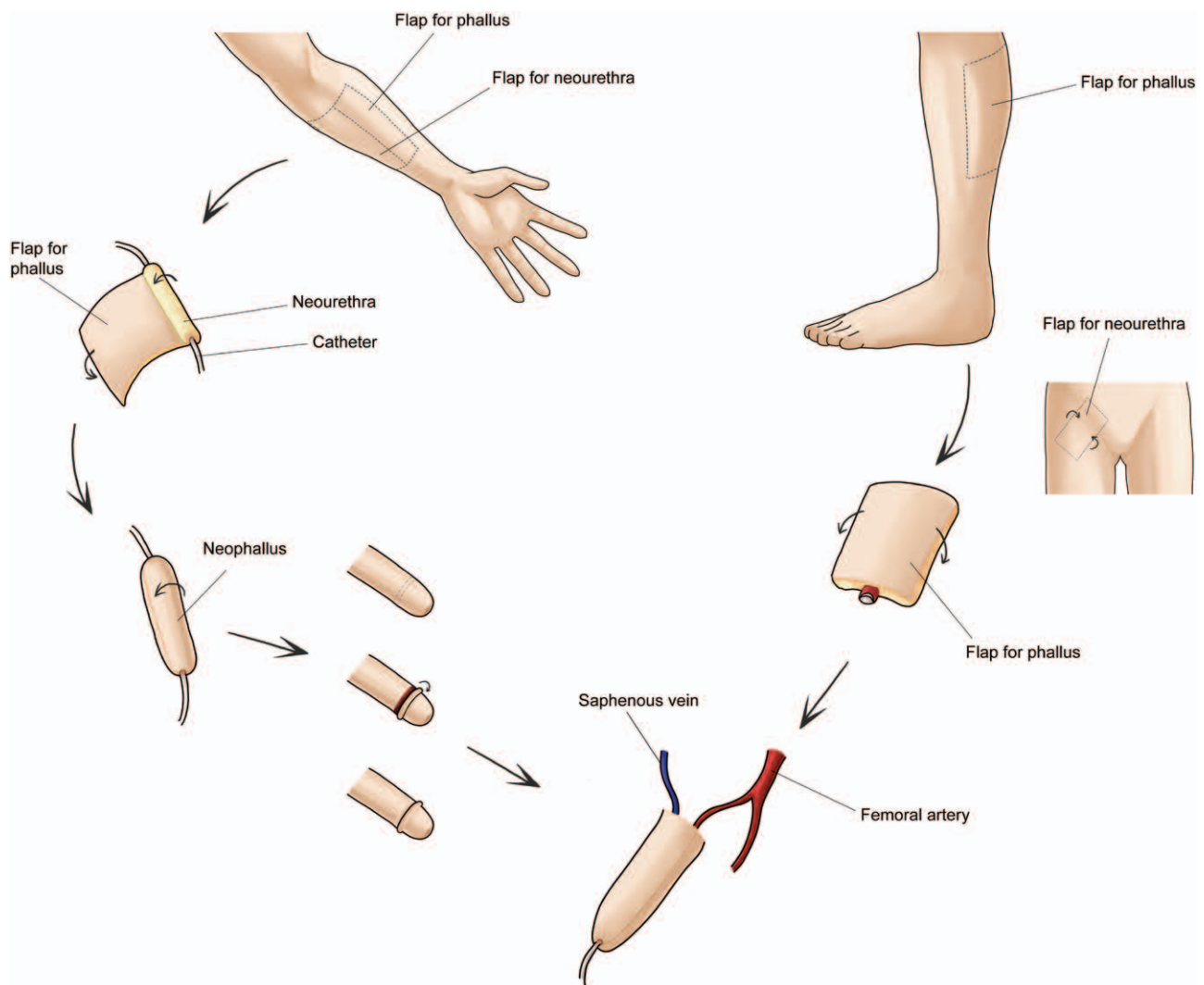


Fig. 8. Illustration of the radial forearm free flap and the fibula osteocutaneous free flap. In the osteocutaneous free fibula flap, the fibula is harvested with a cuff of muscle, the peroneal artery, and either the lateral or posterior sural nerve to create the sensate phallus. The neourethra is created from a groin skin flap. In the radial forearm free flap, the tube-in-tube design is used to create a neophallus and neourethra in a single flap. The radial artery and the antebrachial nerves are harvested to create the sensate phallus. The Norfolk technique is used for the radial forearm free flap to create a glans.

anastomotic revision (9.8 percent) and wound healing problems (8.2 percent) (Table 2). All patients (100 percent) reported being overall satisfied with the results (Table 3).^{89,90,93–96}

Radial Forearm Free Flap

The radial forearm free flap is the most commonly used technique in contemporary phalloplasty. The medial and lateral antebrachial cutaneous nerves are generally preserved and coapted with the ilioinguinal nerve and dorsal nerve of the penis/clitoris or the deep pudendal nerve, thereby allowing for erogenous and tactile sensation.⁹⁷ In cases of gender reassignment surgery, the clitoris is deepithelialized and placed

directly under the neophallus.^{98,99} Rigidity of the neophallus can be obtained with insertion of a prosthesis or part of the radial bone in a radial forearm osteocutaneous free flap.^{13,14,100,101} Finally, a glans penis can be constructed through a Norfolk procedure (Figs. 2 and 7 through 10).^{9,13,91} Erogenous and tactile sensitivity have been maintained in these flaps, with studies reporting enough tactile sensitivity for sexual activity and ability to achieve an orgasm.^{102,103}

Inclusion of part of the radius allowed for rigidity; however, there were numerous problems with fracture of the radius in the neophallus.^{100,104–109} Complications with prosthetics were high, and even higher for female-to-male

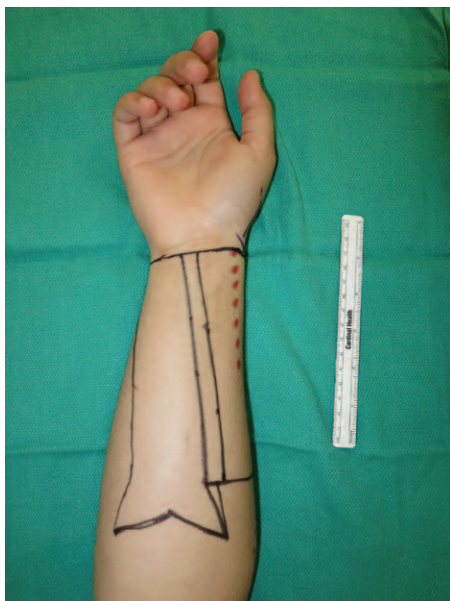


Fig. 9. Patient outcomes with the radial forearm free flap. Initial preoperative outline of the radial forearm free flap that will be used for tube-in-tube construction.

transsexuals because of the lack of tunica albuginea as an insertion site for prostheses.^{14,101} In the longest follow-up study to date, over 40 percent of the cohort suffered urologic complications, but approximately half of the fistulas and strictures could be managed nonoperatively.¹⁴

Donor-site morbidity, requiring full- or split-thickness skin grafts, continues to be a significant drawback of these operations (Fig. 10).¹⁴ Some difficulties of this approach to phalloplasty include atrophy of the neophallus occurring after several months, discoloration between the phallus and surrounding tissue, difficulty obtaining adequate bulk of the neophallus, and requirement for microsurgical techniques and equipment.^{7,73}

Studies have shown that the average length of the phallus after radial forearm free flap surgery is 7.5 to 14 cm (Table 1). Most patients (97.5 percent) experienced adequate urinary function in standing position, and 21.1 percent were able to engage in penetrative sexual intercourse (Table 1). The most common complications were urethral fistula (26.58 percent) and stricture/stenosis (12.27 percent). Other complications included need for anastomotic revision (7.82 percent), wound healing problems (7.38 percent), and partial flap necrosis (5.42 percent). The most common donor-site complication was regrafting of the arm defect (1.42 percent) (Table 2). Prostheses were used in 377 of 1544 patients (24.4 percent), with the most common complications

being requirement for revision surgery (34.7 percent) and inability to perform intercourse (16.3 percent) (see Table, Supplemental Digital Content 7, <http://links.lww.com/PRS/B801>). Most patients (78.1 percent) reported being overall satisfied with the results (Table 3).^{14,97,99,100,104–153}

Other Forms of Reconstruction

Fifty other articles were identified in our literature search that did not use one of the eight types of reconstruction reported above. These have been detailed in the supplemental tables (see Tables, Supplemental Digital Content 2 through 8, <http://links.lww.com/PRS/B796>, <http://links.lww.com/PRS/B797>, <http://links.lww.com/PRS/B798>, <http://links.lww.com/PRS/B799>, <http://links.lww.com/PRS/B800>, <http://links.lww.com/PRS/B801>, <http://links.lww.com/PRS/802>) and have similar outcomes as the flap types reported above.^{15,17,92,154–200}

Penile Replantation

In cases where the penis is severed in trauma, replantation is an option. Penile replantation depends solely on the dorsal arteries and has a high incidence of complications.^{201–203} The studies queried revealed that full sensation was maintained in 53.4 percent, with diminished sensation in 21.9 percent and absent sensation in 24.7 percent. Most patients (97.4 percent) reported adequate urinary function. Among the articles reporting erectile function after replantation, 77.5 percent reported normal erection, 12.5 percent with diminished erection and 10 percent with no erection. The most common complications were skin necrosis (54.8 percent) and edema/venous congestion (20.2 percent). Although most patients had no urethral complications, stricture (11.0 percent) and fistula (6.6 percent) were most often seen. More than half of amputations (52.0 percent) were attributable to self-inflicted causes. Microvascular anastomosis was performed for the majority of penile replantations (69.9 percent). All patients (100 percent) reported overall satisfaction with the results, although most studies did not report outcomes and did not use validated or quantifiable approaches to address satisfaction (see Table, Supplemental Digital Content 9, <http://links.lww.com/PRS/B803>).^{180,201,203–275}

Penile Transplantation

Penile transplantation holds promise for cases where the penis cannot be replanted or is too mangled to be salvaged. Two attempts have yielded one successful fully functioning phallus, with the

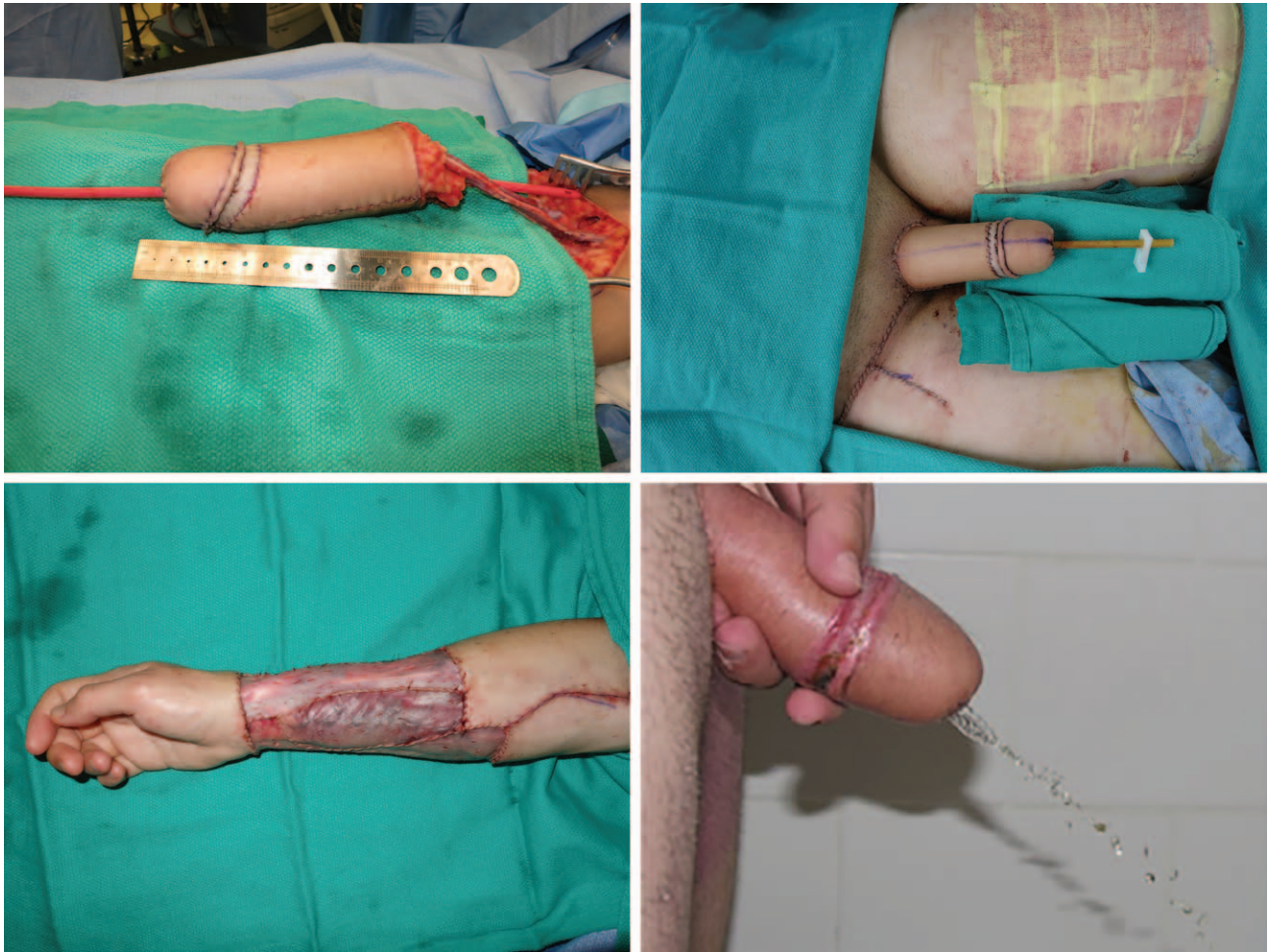


Fig. 10. (Above, left) Tubularized radial forearm flap after the Norfolk procedure still connected to vasculature. (Above, right) Immediate postoperative radial forearm free flap. (Below, left) Donor site immediately postoperatively with split-thickness skin graft. (Below, right) One month postoperatively, with the patient micturating in standing position.

recipient continuing on to conceive a child. The other transplanted phallus was removed for psychiatric reasons.^{276–278} Based on a set of guidelines published by the authors who reported the first transplant, extensive workup, including psychiatric/psychological evaluation and ethical considerations, is needed before penile transplantation.²⁷⁹ No long-term data currently exist because of the paucity of cases.

DISCUSSION

Based on our review, the most commonly used technique for total phallic reconstruction was the radial forearm free flap, with 54 of 171 articles on flap-based reconstruction reporting on this technique. Although the radial forearm free flap is most commonly reported, each technique has its advantages and disadvantages. As such, a detailed discussion with the patient is warranted

to identify the patient's reconstructive goals and willingness to lose aesthetics and function from a donor site. Based on aggregated data on complications (Table 2) (see Table, Supplemental Digital Content 6, <http://links.lww.com/PRS/B800>), the radial forearm free flap seems to have the lowest rate of serious complications. However, as several flap types did not have many publications reporting on their outcomes, overall complication rates for these techniques cannot be reported without large-scale cohort studies.

As this review draws from a large number of publications that lack standardization of outcomes, complications, and satisfaction data reporting, a meta-analysis of the collected data is severely limited. This is an inherent limitation of any review that draws from case reports and case series. Despite this, summarizing the literature and providing a comprehensive review of the techniques of total phalloplasty is valuable and

provides both the physician and the patient with information that can aid in the decision around pursuing gender-confirming surgery or total phallic reconstruction.

CONCLUSIONS

Phallic reconstruction is an evolving field because of the inherent challenge and complexity of restoring the anatomical form and the urologic and sexual function of the penis. Phalloplasty requires a multidisciplinary team approach for optimal outcomes. Various operative techniques have been described, but given the lack of long-term efficacy and the potential morbidity of each technique, no ideal technique exists. Free radial forearm, abdominal, and anterolateral thigh flaps are the most studied and reported in the literature. In all techniques, complication rates are high, especially urethrocutaneous fistulae and stricture, but patient satisfaction and sexual function are high.

Penile replantation and transplantation are options for individuals with traumatic injuries, but only two transplants have been completed to date. Although there is no ideal reconstructive technique because of a lack of replacement for erectile and urethral tissue, currently, phalloplasty using flap-based approaches appears to be the best option for a patient with acquired absence/defect of penis or a desire to undergo gender reassignment surgery. A surgical approach should be individualized depending on the patient's request, surgeon experience, and body habitus, ideally using a multidisciplinary approach.

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