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FEMALE UROLOGY (L COX, SECTION EDITOR)

# The Use of Tissue Flaps in the Management of Urinary Tract Fistulas

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**Abstract**
Urinary tract fistulas represent a complex group of pathologies that present significant management challenges. While most such fistulas ultimately require definitive surgical management, compromised local tissue quality or other factors often render straightforward simple one layered closure challenging with a substantial risk of failure. Interpositional tissue flaps have become a mainstay of treatment in these circumstances, enabling the delivery of healthy tissue from other locations to the site of pathology. Herein, we present an overview of the assessment and management of complex urinary tract fistulas involving the reproductive and gastrointestinal organs, and the decision to utilize flaps. We review the underlying principles of tissue flaps and classify different types of flaps. We conclude with a discussion of the indications, advantages, disadvantages, and harvesting techniques for the most commonly utilized flaps in urinary tract fistula repair.

**Keywords** Urinary tract fistulas · Female urology · Tissue flaps · Surgical management

## Introduction

Urinary tract fistulas are extra-anatomic communications formed most commonly with the reproductive tract and the GI tract. Depending on the type of lesion and its severity, the medical impact can range from minimal to life-threatening infections. In cases where urinary or fecal continence is compromised, the psychological impact and effects on quality of life can be debilitating. Primary surgical closure of a fistula may be feasible when the surrounding tissues are well vascularized, healthy, and mobile. Increased fistula complexity or compromised tissue quality may, however, preclude a reliable primary closure. This often occurs in the setting of prior radiation, tissue ischemia, poor nutrition, inflammation/infection, or prior failed repairs. In these cases, tissue flaps provide an invaluable resource. Flaps allow for the delivery of healthy robust tissue to the site of pathology. By interposing between adjacent suture lines, augmenting local metabolic and immune function, and in some situations replacing destroyed epithelial tissue, tissue flaps can facilitate healing in even the most inhospitable environments. In this review, we will discuss common forms of urinary tract fistulas and the factors that may prompt utilization of a flap. We will discuss the underlying theory of tissue flaps and classification of different types of flaps. Finally, we will identify the most commonly utilized flaps, reviewing relevant anatomy, tissue selection, and surgical technique.

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## Urinary Tract Fistulas

### Diagnosis and Evaluation

Acquired fistulas may occur between the lower urinary tract and any of the surrounding pelvic structures including gynecologic viscera, small and large bowel, and rarely, the skin or pelvic blood vessels. Clinical presentation of lower urinary tract fistula is dependent on the anatomic structures involved (see Table 1: Common types and presentations of acquired lower urinary tract fistula). Due to the proximity of elements of the urinary, reproductive, and gastrointestinal systems within the pelvis, this is a common site of fistula pathology. A detailed discussion of non-urogynecologic and uroenteric fistulas lies outside the scope of this review.

**Table 1** Common types and presentations of acquired lower urinary tract fistula

| Fistula | Type | Presentation |
|---|---|---|
| Urogynecologic | Vesicovaginal | Continuous urinary incontinence following pelvic surgery |
| | Urethrovaginal | Urinary incontinence if located in the proximal or middle third of the urethra, or, may be asymptomatic if located in the distal thirds of the urethra |
| | Vesicouterine | Continuous incontinence following a low segment Caesarean section |
| Uroenteric | Enterovesical | Suprapubic pain, frequency, urgency, dysuria, tenesmus (Gouverneur's syndrome), recurrent UTI's, fecaluria, pneumaturia in the setting of bowel disease |
| | Rectourethal | Recurrent UTI's, fecaluria, pneumaturia in the post-prostatectomy patient |
| Urovascular | Iliac vessels | Vigorous hematuria in the setting of indwelling catheters, radiation and/or pelvic malignancy |
| Urocutaneous | Urethrocutaneous | Poor urinary stream, "watering pot perineum" in the setting of urethral stricture disease, genitourinary tuberculosis, or prior urethral surgery (i.e., hypospadias repair) |

In the industrialized world, most urogynecologic fistulas are iatrogenic, a devastating complication from gynecologic or urologic surgery, radiation therapy, or other energy-based ablative techniques [1–3]. In the developing world, they are most commonly a result of prolonged obstructed labor, which can cause pelvic floor ischemia and at times substantial tissue loss [4]. Obstetric fistulas can be extraordinarily complex, and may at times involve the GI tract as well. Uroenteric fistulas most often occur in the setting of inflammatory bowel diseases, diverticulitis, or colorectal carcinoma [5, 6]. In men, surgical and energy-based prostate cancer treatment is also a recognized cause of rectourethral fistulas (RUF) [7, 8]. Less commonly, urinary tract fistulas may be congenital, or result from severe infections or non-surgical and non-obstetric trauma.

The presenting signs and symptoms urinary tract fistulas will depend on the organs involved, as well as the size and specific location of the lesion (see Table 1). Vesicovaginal fistula (VVF) is the most common urogynecologic fistula and will most often present with continuous urinary drainage from the vagina. Depending on the size of the lesion, the leakage may be imperceptible or it may functionally debilitating and cause painful skin damage. Ureterovaginal fistula may present with constant leakage and cyclical bladder filling which continues due to the intact contralateral ureter. Urethrovaginal fistulas may present identically to a VVF if located proximal to the urinary sphincter. When located beyond the continence mechanism, however, they may present only with a splayed stream, or may be entirely asymptomatic. Colovesical and enterovesical fistulas most often present with pneumaturia and may also cause fecaluria or persistent or recurrent urinary tract infections refractory to antibiotics. Rectourethral fistulas most often manifest as watery diarrhea, or less commonly with pneumaturia or infections.

Diagnosis and evaluation in cases of suspected urinary tract fistulas are almost always multimodal, including imaging, endoscopy, and physical examination. The goal is to identify the size and location of the lesion, its anatomic relationship to other structures such as ureters and sphincters, and the availability and viability of surrounding tissues. It is also essential to identify relevant comorbid conditions, such as additional fistulas, urethral strictures, urinary or fecal sphincter incompetence, and vaginal atrophy or prolapse in women. A thorough physical exam is mandatory, particularly in the case of urogynecologic fistulas, where a bimanual and speculum exam can yield invaluable information about relevant vaginal anatomy and tissue quality. Endoscopic evaluation via cystoscopy and vaginoscopy or proctoscopy/sigmoidoscopy is performed to assess fistula location and complexity as well as local tissue quality. Endoscopic biopsy of the fistula tract is essential in the setting of prior pelvic malignancy or any clinical suspicion of malignant etiology. The presence of urologic, gynecologic, colorectal, or other cancer should be established early, as it will radically alter fistula management. Finally, various forms of imaging are typically utilized. Fluoroscopic voiding cystourethrogram, retrograde urethrogram, or fistulogram can enable definitive diagnosis if in question, and can provide more details regarding anatomic location and fistula size. Upper tract evaluation, most often via CT urography, should be performed in cases of postsurgical VVF, as there is a 12% coincidence of ureteral injury or ureterovaginal fistula [9].

## Treatment

A small subset of urogynecologic and uroenteric fistulas may resolve spontaneously with urinary and/or fecal diversion, as the circumstances dictate. There may also be a role for endoscopic interventions such as fistula tract cauterization or fibrin sealant plugging. Nonetheless, the vast majority of patients who are surgical candidates will ultimately require surgical repair. The ideal timing of surgery varies based on several

factors and historically has been a somewhat contentious issue. Contemporary sensibilities and data tend to favor immediate repair of uncomplicated urogynecologic fistula [10]. In cases of ongoing infection, obstetric etiology, or radiation, however, a waiting period of anywhere from 1 to 12 months may be necessary to allow demarcation of inflamed or devascularized tissues. Uroenteric fistulas are often repaired in a delayed and staged fashion, as complicating factors such as fecal soilage are commonly encountered [11].

Innumerable techniques for repair of urinary tract fistulas have been described. Urogynecologic fistulas may be repaired transabdominally or transvaginally. Uroenteric fistulas can be repaired transabdominally, transperineally, or transrectally. At times patient and fistula factors mandate a specific approach, though often, it is a matter of surgeon experience. Whatever their differences, the various techniques all share an adherence to a series of well-established technical principles guiding the surgical repair of fistulas (see Table 2: Principles of urinary fistula repair). Among these principles are (1) adequate exposure of the site of pathology, (2) mobilization of well-vascularized tissue flaps, (3) careful dissection to maintain separation of involved organ cavities, and (4) separate watertight closure of the walls of the two organ cavities with non-overlapping suture lines. When such a closure can be achieved with healthy well-vascularized tissue, then success rates are high. If local tissues lack mobility to stagger the suture lines and there is no healthy intervening local tissue to close between them, there will be significant risk of breakdown and fistula recurrence. In such a situation, an interpositional tissue flap should be employed when feasible.

Although flap interposition is principally utilized as a technique to prevent fistula recurrence, it bares mention that flaps may be similarly applied proactively as a preventative measure in other pelvic surgeries where tissue quality is potentially compromised and the risk of fistula formulation is increased. Examples of this include complex urethral diverticulectomy, mesh excision in the setting of urinary tract erosion, bladder neck closure, and pelvic exenteration.

**Table 2** Principles of urinary fistula repair

| |
|---|
| 1. Adequate exposure of the fistula tract |
| 2. Watertight closure of each layer |
| 3. Well-vascularized, healthy tissue for repair |
| 4. Good hemostasis and minimal use of electrocautery |
| 5. Multiple layer closure |
| 6. Tension-free, non-overlapping suture lines |
| 7. Adequate urinary drainage after repair |
| 8. Prevention of infection (use of pre-, post-, and intraoperative antibiotics |
| 9. Beware of malignant etiology of fistula (biopsy fistula tract if known history of malignancy) |
| 10. Nutritional optimization |

The principal benefit of interposition is the separation of potentially overlapping suture lines. Delivery of an interpositional tissue flap separates the two surgical closure lines, filling the intervening space with healthy well-vascularized tissue. It is notable that the use of muscular flaps in particular brings and provides additional benefits. Such measures may enhance local immune response and help prevent infection [12]. They can also serve as a recipient bed for buccal mucosal graft augmentation when primary mucosal/urothelial closure is not possible [13]. In cases of severe radiation-induced fistulas with adjacent radionecrotic cavities, muscle bulk can fill the dead space that could otherwise precipitate abscess formation and fistula recurrence [14]. In circumstances of substantial tissue loss resulting in significant vaginal or perineal epithelial defects (more commonly seen in oncologic cases), the overlying skin can be included in a musculocutaneous flap and used to replace the acquired defects [14].

## Indications for Interpositional Flaps

There are no well-defined criteria for the use of flap interposition, and ultimately, it is a matter of preoperative and intraoperative assessment of tissue quality (ischemia, radiation effects, etc.) and other factors such as nutritional status, local inflammation/infection, and risk of fistula recurrence. Flaps are most commonly used in the setting of radiated tissues, large fistulas, or multiple coexisting fistulas, or where there are multiple risk factors for failure of primary repair. Obstetric fistulas often benefit from flaps due to their predilection for substantial associated ischemic tissue beyond that which is clinically evident on initial inspection. Conventional wisdom tends to favor flap interposition in the setting of a prior failed fistula, though there is debate over whether this is always necessary [15].

Preoperative assessment of the potential need for flap interposition is important because the selection of a particular surgical approach will determine the tissues available for flapping. During transabdominal repairs of urogynecologic and uroenteric fistulas, omentum is often readily available, and when necessary, rectus muscle can be harvested. A transvaginal approach to urogynecologic fistulas facilitates the interposition of a Martius labial fat flap for urethrovaginal or distal vesicovaginal lesions, and a peritoneal flap for more proximal VVFs. In cases of large or complicated VVFs, the gracilis muscle from the medial thigh can be harvested during abdominal, vaginal, or combined repairs. Transperineal approaches to rectourethral fistulas quite commonly utilize the gracilis flaps, while transanal and transsphincteric approaches do not easily allow for the use of any of these interpositional flaps.

Finally, there are several other mitigating preoperative factors when considering use of a flap. Patient positioning (e.g.,

supine, lithotomy), location of drapes, and even the extent of surgical preparation area (antisepsis) may affect the choice of available flaps. Furthermore, certain incisions or paths of dissection may compromise the vascular supply of some types of potential flaps.

## Flaps

Proper selection and utilization of flaps are aided greatly by an understanding of the underlying principles of tissue transfer and of the classification of different categories of flaps, as well as a thorough knowledge of the vascular anatomy, as well as the advantages and shortcomings of particular flaps.

The two pillars of tissue transfer are grafts and flaps. Use of a graft involves complete transfer of tissue away from its native blood supply to a remote recipient site where survival is initially dependent on local factors such as imbibition. Flaps, on the other hand, involve transfer of tissue with its native blood supply either completely intact or surgically reestablished at the recipient site. By providing its own blood supply, a well-selected and well-harvested flap can deliver robust, healthy, and reliable tissue into otherwise inhospitable locations. The principle limitation of flapping, of course, is delivering this tissue to the area of need with its blood supply intact or successfully re-establishing this via microvascular anastomotic techniques ("free flap"). This challenge has inspired the advent of a remarkably diverse array of flaps, utilizing virtually all types of tissue, reliant on an assortment of vascular arrangements. Most commonly flaps are classified based on three factors: blood supply (random vs axial), tissue being transferred (skin, fascia, muscle, bone, visceral, composite), and donor site (local vs distant, pedicled vs free) (Table 3). An intimate understanding of these aspects of the transferred tissue, of the needs at the donor site, and of all the relevant anatomy are essential to the successful use of flaps in reconstructive surgery.

## Flap Classification

### Blood Supply

By definition, tissue flaps bring along with them a blood supply that continues to sustain them at the target site. This blood supply can take two forms: random and axial. Random flaps represent the most primordial form of the technique, with recorded uses in the form of skin flaps dating back to 600 B.C. [16] Random flaps are supported by a subepithelial plexus, as opposed to a recognized artery. Vascularity is maintained through these delicate pedicles by adherence to length and width ratios (3:1) [17]. Axial flaps, based on an anatomically defined vascular territory for a specific artery, represent an additional level of complexity. Greater knowledge of vascular anatomy allowed for identification of consistent, reliable, and reproducible pedicles that could support flaps of greater complexity and versatility. Axial flaps can be rotated or even transferred to distant locations based on the predictable blood supply that typically forms their basis.

### Tissue Type

Flaps can involve virtually any tissue type contained within the body, and at times multiple types simultaneously. Random flaps are often composed of epithelial tissues such as skin or peritoneum. Axial flaps are extraordinarily diverse and may be composed of visceral tissue such as omentum, fibrofatty tissue such as the labia majora, or muscular tissues such as the rectus, gluteus, or gracilis. Muscular flaps represent the most robust flaps and may also be transferred as composite flaps with adjacent tissues such as fascia, skin, and even bone.

### Location of Donor Site

Local flaps involve tissue transfer directly from an adjacent defect, and are often based on a random blood supply. Local flaps can be rotated, advanced, or transposed. Alternatively, tissues transferred from nonadjacent sites are known as distant flaps. Distant flaps may be pedicled or free. Pedicled flaps remain attached their native blood supply and thus are limited by the length of the flap and the arc of rotation. Care must be taken to select pedicle flaps with the capacity to reach the target site without kinking or twisting the vascular pedicle. If no appropriate pedicled flaps are available, then a free flap is indicated. Free flaps involve microvascular transplantation of the flap vascular pedicle to a recipient vessel at the target site. This grants tremendous versatility, though at the expense of substantially greater operative time, technical complexity, and donor site morbidity.

## Commonly Used Flaps in Fistula Repair

Reconstructive urologists have found uses for every type of tissue flap imaginable. Even within the context of urinary tract fistula repair, the literature contains descriptions of a remarkably diverse assortment of flaps. Here, we will identify the most commonly utilized flaps in fistula repair, discussing their uses, advantages, disadvantages, and harvesting techniques.

### Omental Flap

The greater omentum has many properties that make it an excellent adjunct to fistula repair as an axial pedicled flap. It is quite rich in lymphatics and blood vessels. It is the primary source of immune response to intraperitoneal infections. It

**Table 3** Classification of tissue flaps

| Category | Type | Definition | Urologic example |
|---|---|---|---|
| Blood supply | Random | Supplied by vascular plexus contained within connective tissue, no named vessels | Peritoneal flap<br>Vaginal wall flap |
| | Axial | Supplied by predictable reliable pedicles based on named vessels | Martius flap<br>Gracilis/rectus flap |
| Tissue type | Simple | Single-tissue type | Peritoneal flap<br>Gracilis/rectus flap |
| | Compound | Multiple adjacent tissues supported by single vascular supply | Full thickness Martius flap<br>Myocutaneous gracilis/rectus flap |
| Donor site | Local | Transfer from adjacent tissue | Peritoneal flap<br>Vaginal wall flap |
| | Distant | Transfer from a distant site based on mobility of vascular pedicle | Martius flap<br>Gracilis/rectus flap |
| Distant | Pedicle | Movement of tissue to a distant site based on the rotation of intact blood supply | Martius flap<br>Gracilis/rectus flap |
| | Free | Microvascular transplantation of graft blood supply to vessel at target site | Radial forearm phalloplasty |

adheres densely to sites of inflammation and has angiogenic properties that may support adjacent ischemic tissues [18, 19]. The robust and predictable blood supply of the greater omentum is derived from omental branches of the left and right gastroepiploic arteries along the greater curvature of the stomach. Harvesting is fairly straightforward. Division of one gastroepiploic artery as well as the vasa recta along the greater curvature, with mobilization off of the transverse colon typically enables rotation of omentum deep into the pelvis, supported by the remaining gastroepiploic pedicle. The right pedicle is typically chosen to reach the pelvis, owing to larger arterial caliber and a more caudal orientation, however, either can be used. Due to the need for mobilization, omental flaps are typically utilized during transabdominal repairs.

In the case of VVF, following isolation of the fistula tract and separation of the adherent bladder and vaginal walls, the urinary and genital tracts are closed in watertight fashion on both sides. The mobilized omentum is brought down in to the pelvis and secured with absorbable suture interposed between the two structures beyond the site of the repair. This anatomically separates the two suture lines and facilitates a more hospitable environment for healing and may improve the success rate of VVF repair [20–22]. Variations on this technique have been described extensively in open as well as minimally invasive manners. More recent series focus on the feasibility of robotic performance. Typically in these cases, the omentum is mobilized through traditional laparoscopy prior to docking of the robot, though the versatility of newer generation robotic systems may render this unnecessary [23, 24].

Omentum can be used similarly in the repair of enterovesical and colovesical fistulas. After resection of the adherent bowel segment and reconstitution of the GI tract and closure of the bladder, the omentum is secured over the bladder [5, 25]. In cases where the bladder defect is small and cannot be identified intraoperatively, omentum may still be draped over the affected portion of the vesical wall as the bladder heals with catheter drainage [26]. Omentum can also be used to provide interposition during transabdominal rectourethral fistula repair [27]; however, these lesions less often tackled via this approach due to their location deep in the pelvis below the levator muscles.

The disadvantages of an omental flap are mostly related to the increased morbidity associated with transabdominal procedures, when alternative approaches are available.

## Peritoneal Flap

The harvesting and interposition of a local random flap of peritoneum has been extensively reported for both transvaginal and transabdominal approaches to fistula repair. In transabdominal approaches where omentum is not available or cannot be mobilized to the site of fistula repair, either due to anatomical restrictions or scarring from prior procedures, a flap of peritoneum may be rotated to provide interposition [22, 28].

Transvaginal peritoneal interposition is typically utilized in the repair of VVF occurring near the apex. This is most commonly performed in the setting of the repair of post-hysterectomy VVF. Generally, at or just beyond the dorsal or caudal margin of the fistula, anterior to the rectum, the peritoneum is found. This often becomes evident following complete mobilization of the tissues surrounding the VVF either as a discrete shiny tissue layer or as the peritoneal cavity is entered purposefully or inadvertently from the vaginal approach. This tissue can sometimes be challenging to identify due to the surrounding inflammation and edema which may be

associated with the initial fistula formation. In either case, a tongue of peritoneum is mobilized. Following closure of the bladder side of the VVF, the peritoneal tongue is advanced beyond the bladder closure and secured in position to the perivesical fascia with absorbable suture. The vaginal flaps are then closed with care to avoid overlapping suture lines at the level of the distal extent of the peritoneal flap. This creates a three-layer closure (bladder, peritoneal flap, vaginal wall) without overlapping suture lines. Reported VVF cure rates are >90% with transvaginal peritoneal flaps, and the morbidity associated with the flap is minimal [3, 29, 30]. Anatomical restrictions preclude the use of peritoneal flaps for urethrovaginal fistula, where Martius (labial fat pad) flaps are preferred. In cases where the peritoneal reflection is not identifiable due to extensive scarring at the cuff, a Martius flap may be mobilized to reach the apex [31].

Peritoneal flaps utilized during transabdominal fistula repairs more closely conform to the previously described definition of a random flap. A strip of peritoneum and underlying fat is harvested from a site adjacent to the repair, typically along the posterior abdominal and pelvic wall. Ideally, this flap should be wider at the base to preserve blood supply to the apex. The flap is then rotated and secured over the site of fistula repair. This use has been described for the repair of vesicovaginal, colovesical, enterovesical, and rectourethral fistulas [27, 28, 32, 33]. In general, omentum is considered the preferred tissue for interposition when available, with peritoneal flaps serving as a secondary option.

## Martius (Labial Fat Pad) Flap

The Martius flap is commonly utilized for tissue interposition in the repair of complex urethrovaginal fistulas, or VVF located in the distal vagina involving the bladder neck or trigone. Originally conceived by its namesake as a bulbocavernosus muscle flap, [34] the modern incarnation of the procedure instead utilizes the adjacent fibrofatty tissue of the labia majora (Fig. 1). The fat pad has a dual blood supply, derived from the internal pudendal artery inferiorly (via the posterior labial vessels) and from the external pudendal artery superiorly. This arrangement affords the surgeon freedom to create an axial flap based on either a superior or an inferior pedicle, as dictated by the location of the lesion.

After completion of a two-layer fistula closure, a 4–5 cm vertical incision is made over the labia majora usually in a fold between the labia minora and majora (labiocrural fold) until fatty tissue is identified. Blunt dissection begins laterally, developing the avascular plane between the lateral skin and the underlying fat pad and is continued cephalad. Medial dissection is performed separating the fatty tissue from the adjacent vaginal wall. Circumferential control can typically be achieved bluntly, with dissection and judicious cautery utilized as needed. The borders of the dissection include the bulbocavernosus muscle medially, and Colles fascia posteriorly [35]. Depending on the location of the fistula, an inferior or superior pedicle is chosen and the other end is ligated and transected. A subepithelial tunnel is then made from the labial incision along the vaginal wall to the site of fistula repair, through which the flap is

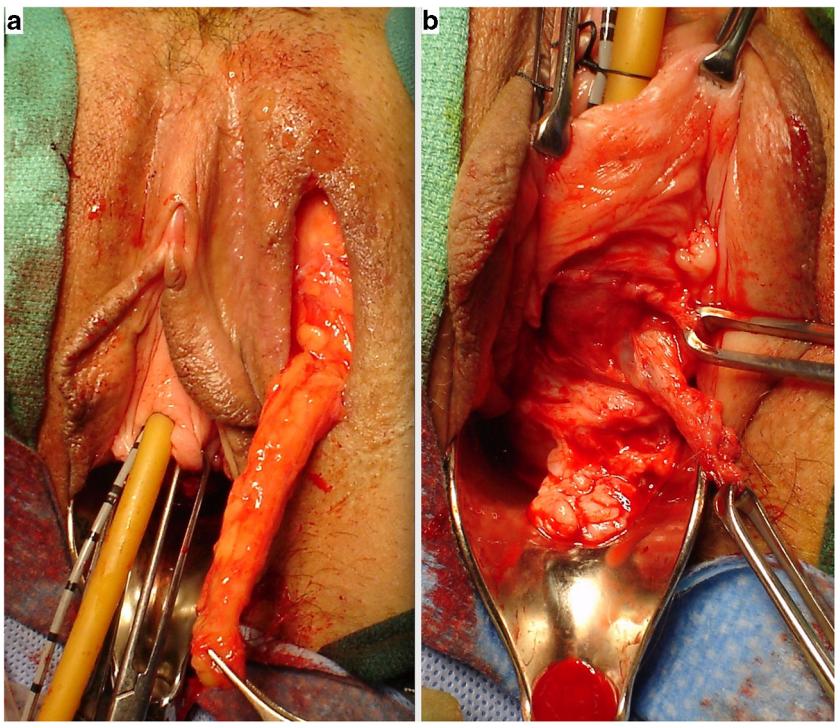


**Fig. 1** **a** A martius flap harvested based on an inferior pedicle. **b** The flap is tunneled behind the lateral vaginal wall and emerges at the site of a fistula repair where it can provide tissue interposition

delivered in an interpositional location. The flap is secured in place beyond the fistula closure using absorbable suture. The vaginal wall and labial skin are then closed.

Reported success rates for fistula closure using labial fat pad interposition are high, typically greater than 90% [3, 21, 36, 37•]. Short-term and long-term complications are infrequent and include pain, bleeding, and permanent asymmetry of the labia majora. Despite this, high rates of cosmetic satisfaction are noted with Martius flap utilization [38, 39].

For apically located posthysterectomy fistulas, peritoneal flaps are preferred. Extensive mobilization of the labial fat pad to allow tunneling to an apical lesion is possible; however, this may compromise the blood supply to the flap [35]. In the repair of larger defects, bilateral labial fat pad flaps have been used [40]; however, in such situations, strong consideration can be given to a more robust muscular flap such as the gracilis muscle. In cases where substantial tissue destruction leaves inadequate epithelium for vaginal wall closure, the use of a full thickness Martius flap including an overlying skin island has been described. This can cause significant external genital distortion. Variations utilizing skin from the medial thigh [41] or the medial edge of the labium [42] may improve the cosmetic outcome in some cases.

## Gracilis Flaps

Gracilis muscle flaps are used extensively in pelvic and perineal reconstruction. The muscle is much wider and more robust than the labial fat pad, making it an excellent choice for interposition in the repair of large and complex VVF where a Martius flap is inadequate. It is also used in commonly in the transperineal repair of uroenteric fistulas, particularly in the setting of post-radiation or post-ablation rectourethral fistulas.

Nearly everything about the gracilis muscle makes it an excellent axial pedicle flap in pelvic reconstruction. It sits in close proximity to the perineum, passing through the medial thigh from its origin in the ischiopubic ramus to its insertion in the medial tibial condyle of the knee. It is long and thin and tapers as it approaches its distal extent. It has a dominant pedicle, the medial circumflex femoral artery, which inserts approximately 10 cm distal to the base. There may be a distal minor pedicle that can be divided without any compromise of the muscle. The flap can be harvested with relative ease through a rather inconspicuous incision. While it functions in knee flexion and thigh adduction, it can be transposed without any significant detriment to limb function (Table 4).

Harvest of the gracilis flap is typically performed in a lithotomy position. An 8-cm longitudinal incision is made on the posterior aspect of the medial thigh starting at the estimated location of the vascular pedicle. The pedicle can be identified (often with the help of Doppler) on the anterior boarder of the muscle. A small counter incision is made distally over the site of insertion of the muscle into the knee. The muscle is lifted off the belly of the underlying adductor magnus with cautery and blunt dissection. Alternative techniques include an additional mid-thigh incision [43] or one long continuous incision [44] along the length of the muscle to aid in identification and mobilization. The distal tendinous insertion is transected and the muscle is pulled through the proximal incision. At this point, a tunnel is made between the thigh and the perineal or vaginal incision. The muscle is rotated 180° and passed through the tunnel where it is secured in place between the two suture lines of the fistula repair [45].

**Table 4** Advantages of gracilis flap in pelvic reconstruction

| |
|---|
| Close proximity to pelvis |
| Dominant pedicle close to pubic origin |
| Secondary distal pedicles expendable |
| Long and tapered |
| Relative ease of harvest |
| Inconspicuous incision in on medial thigh |
| Minimal function impact on lower extremity |

Success rates for rectourethral fistula repair utilizing gracilis flap are reported as high as 83–95% [8, 43, 46]. Gracilis flap usage is less widely reported in the repair of uncomplicated VVF, and is typically reserved for very complex obstetric or radiation induced fistulas, with good results [47]. When the size of the urinary tract defect precludes primary closure, or there is a concomitant bulbomembranous urethral stricture, a buccal mucosa graft repair can be performed, with the interpositional gracilis flap as the recipient site. The healthy well-vascularized muscle supports graft takes quite well [13, 48]. In cases of massive vaginal wall loss, as may be seen in very complex fistulas or oncologic pelvic exenteration, a composite myocutaneous gracilis flap which includes the overlying thigh skin can be used to perform partial or even complete vaginal reconstruction [14].

Reported donor site complications are uncommon, including medial thigh numbness and infrequent seroma formation or wound dehiscence [43, 44]. There is typically little to no alteration of lower extremity motor function.

## Other Flaps

Many other flaps have been described for use in urinary tract fistula repair. Rectus abdominis muscle axial flaps based on an inferior epigastric pedicle can be utilized in abdominal repair of vesicovaginal fistulas with good results [49]. As with the gracilis muscle, a rectus myocutaneous flap can be utilized when substantial vaginal wall reconstruction is required [50]. Rotational bladder flaps for closure of large VVF have been performed, with or without the support of a concomitant gracilis flap [51]. For large uroenteric fistulas where the gracilis muscle is too narrow or unable to reach, gluteus maximus flaps may be used [52].

## Conclusion

Urinary tract fistulas are nearly always unexpected occurrences that can have a significant medical, functional, and psychological impact on patients. These lesions nearly always require surgical intervention; however, poor local tissue quality often creates major challenges to successful repairs. While meticulous preoperative evaluation and planning are essential, equally important is the intraoperative flexibility provided by a familiarity with a wide range of management strategies. Tissue flaps represent a diverse and versatile collection of techniques that allow for the delivery of supportive healthy tissue to potentially inhospitable environments thus optimizing operative success. Armed with an understanding the underlying principles of flap use, an ingrained familiarity with local and regional anatomy, and quite a bit of creativity, reconstructive urologists have proven the utility of tissue flaps in the management of even the most complex urinary tract fistulas.

### Compliance with Ethical Standards

**Conflict of Interest** Andrew C. Margules and Eric S. Rovner each declare no potential conflicts of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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