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Review

Robotic management of urinary fistula

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Abstract *Objectives:* To highlight critical preoperative and intraoperative considerations in approaching fistula repair robotically.
Methods: A search of the literature was conducted to identify relevant articles pertaining to robotic management of urinary fistulae.
Results: Fistulae of the genitourinary tract can be a challenging dilemma for urologists, as definitive management may require surgical intervention. Pathogenesis of both enteric and non-enteric fistulae are multifactorial, and successful repair hinges on the meticulous perioperative evaluation, planning, and execution. Traditional open techniques can subject patients to increased morbidity and prolonged hospitalizations. Since its introduction, the robotic surgical platform has continued to expand its indications. Its three-dimensional visualization and tremor free wristed instrument movements have made the robotic platform an attractive option for genitourinary fistula reconstruction.
Conclusion: Robotic management of complex urinary fistulae is feasible in expert hands; more studies are needed to define its role in the treatment algorithm of this devastating conditions.

1. Introduction

A fistula is an abnormal communication between two hollow organs or a hollow organ and the body surface [1]. Fistula formation can be driven by several factors such as diabetes, malnutrition, infections, chronic inflammation, malignancies, surgeries, trauma, radiation, and/or energy treatments [2].

Urological fistulae have a low incidence, with 30 000–130 000 annual cases expected worldwide, and

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more than 95% occur in developing countries [3]. Urological fistulae in these regions are typically urogynecological, while in developed countries, most common causes are iatrogenic [4].

There are urinary fistula classifications in the literature; for the purpose of this review, we will divide them into two main groups: non-enteric urologic fistulae and uroenteric fistulae.

1.1. Non-enteric urologic fistula

These abnormal communications between the urinary tract and adjacent structures outside the gastrointestinal tract can arise due to various etiologies, including iatrogenic injuries, inflammatory processes, or malignancies [5]. This group is comprised of vesicouterine fistula, vesicovaginal fistula (VVF), ureterovaginal fistula (UVF), and urinary-pubic symphysis (urosymphyseal) fistula. For the purpose of this review, we will elaborate more on the ones that we managed by means of robotic surgical repairs.

1.1.1. VVF

The worldwide incidence is estimated to be 0.3%—2% [6,7]. Of these, 90% are secondary to obstetric complications in regions with limited access to obstetrical services [6—9]. During prolonged labors, the pressure caused by the fetal head in the birth canal can lead to tissue necrosis of the vesicovaginal septum, resulting in VVF formation. Conversely, in places with readily available obstetric care, the most common cause of VVF is iatrogenic injury or the urinary tract during pelvic surgery, of which 75%—80% occur during hysterectomies [6,7,10].

1.1.2. UVF

UVF incidence is very low (0.16%), often presenting iatrogenically after unrecognized ureteral injury during pelvic surgery [11,12].

1.1.3. Urinary-pubic symphysis (urosymphyseal) fistula

It is a rare but extremely debilitating complication that may occur as a result of radiotherapy or energy ablation used in the treatment of prostate cancer [13]. Chronic pelvic pain that persists after surgery or radiotherapy for prostate cancer is often misdiagnosed as other conditions, such as osteitis pubis, osteonecrosis, or osteomyelitis [14,15]. If osteomyelitis is resistant to treatment and progresses to severe pain, urinary blockage, and urosepsis, it may be suspected that a urinary-pubic symphysis fistula has developed [13,16].

1.2. Uroenteric fistula

Uroenteric fistulae present a complex subset of urological disorders characterized by abnormal connections between the urinary tract and the gastrointestinal tract. These intricate conditions can arise from various causes, including inflammatory bowel disease, radiation therapy, diverticular disease, or malignancies [17—19]. Within this group, we have the following fistulae: colovesical, ureterocolonic, rectovesical, rectourethral, and pyeloenteric. Herein, we will delve further into some of them.

1.2.1. Colovesical fistula (CVF)

CVF accounts for 95% of all enterovesical fistulae; its incidence hangs around $<$0.01% [20]. It is more common in males than females (3:1 ratio) due to the presence of the uterus between the bladder and the sigmoid [18]. The most common etiology is diverticulitis, which accounts for around 66% of cases. Other causes include pelvic malignancies, Crohn's disease, iatrogenic injuries, and radiation therapy [17—19].

1.2.2. Rectovesical fistula (RVF)

RVF has been reported as a rare surgical complication with an incidence of around 0.53% after radical prostatectomy [21]. There is some association with inflammatory bowel disease, colon cancer, and intraoperative rectal injuries during prostatic procedures that involve the bladder [22,23]. In cases where the RVF arises after radical prostatectomy, which happens in 1% of patients who undergo this procedure [24], physicians may sometimes misidentify them as rectourethral fistulae (RUFs). However, in most instances, these fistulae originate in the bladder neck, specifically at the vesicourethral anastomosis (VUA), rather than in the actual urethra as is the case with RUF. An RVF is classified as such when the fistulous tract is located proximal to the bladder neck, while an RUF occurs when the tract is located distal to the bladder neck [25,26].

1.2.3. RUF

It seems that in more recent years, with the implementation of new focal treatments for prostate cancer and the use of neoadjuvant chemoradiation for rectal cancer, the incidence of RUF has been increasing, with reported incidences of 1% after external beam radiotherapy [27,28], 2% after high-intensity focused ultrasound and cryotherapy [28], and 3% after brachytherapy [29].

2. Methods

A search of the literature was conducted to identify relevant articles pertaining to robotic management of urinary fistulae. The search was carried out in English-language databases, including PubMed, Scopus, and Web of Science.

3. Clinical presentation and diagnosis

3.1. Clinical presentation

Vesicovaginal and UVFs classically present as continuous leakage of urine per the vagina, vaginal pruritus, dysuria, suprapubic pain, and recurrent urinary tract infections (UTIs) [5]. Around 10%—15% of VVF cases present with a concomitant UVF [5,30].

Depending on the event that causes the fistula, the timing of clinical presentation can vary. If it is secondary to an iatrogenic injury during pelvic surgery, symptoms could appear as early as 7—12 days postoperatively. In contrast, if the fistula is caused by radiation therapy, the symptoms can develop after months or years [5,30,31].

Physical exam may not identify the fistulous opening in acute cases; nevertheless, mucosal changes like erythema and edema can be observed (Fig. 1) [30]. Clinical diagnosis and differentiation of these fistulae can also be performed with the dual-dye tampon test [5,30].

Fistulae between the urinary tract and the pubic bone can promote the inflammation of the symphysis pubis and surrounding tissue, osteomyelitis presenting as pubic or suprapubic pain, as well as refractory UTIs and urinary incontinence [32,33].

Uroenteric fistulae are linked with recurrent UTIs leading to suprapubic pain, tenesmus, frequency, and dysuria, which are known as the Gouverneur syndrome and have been described as the hallmark presentation of enterovesical fistulae [31]. Nevertheless, recurrent UTIs, pneumaturia, and fecaluria are more specific findings associated with enterovesical fistulae, and they are present in 46.6%, 50.1%, and 40.9% of cases, respectively [17,32,33]. The passage of urine into the rectum is a rare symptom seen in RVF and RUF in around 15% of patients [18].

3.2. Diagnosis

3.2.1. Imaging

Urinary fistulae diagnosis requires a multimodal and multidisciplinary approach, combining the results obtained from a thorough clinical evaluation and appropriate diagnostic studies.

Voiding cystourethrography is an imaging technique classically used to diagnose lower urinary tract fistulae; however, CT cystography has been gaining popularity as it allows for three-dimensional reconstruction [34].

The presence of contrast or air in the vagina can be indicative of a vesicovaginal or vesicouterine fistula [30]. Likewise, indirect signs of enterovesical fistula can also be observed with CT imaging, encompassing intravesical or intramural air, adherence of the intestine to the bladder, and localized bladder wall thickening [5,34]. CT with rectal contrast has also been described to have an accuracy of 90% for the diagnosis of CVF [31].

Intravenous pyelogram, retrograde pyelography, and CT urogram are imaging studies that provide visualization of the upper urinary tract and are essential in the diagnostic workup when ureteral involvement is suspected.

Fistulography has been described as the study of choice for cutaneous fistulae when the fistulous orifice is identifiable [34].

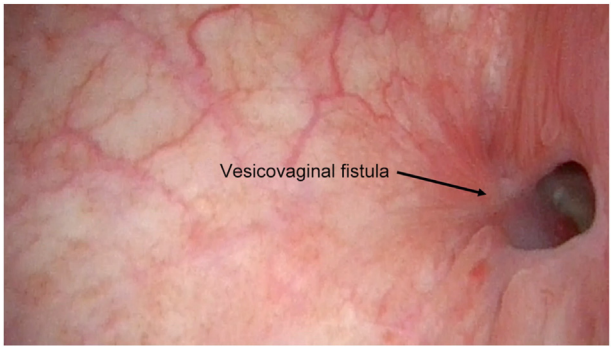

Figure 1 Cystoscopic view of a vesicovaginal fistula tract.

MRI arguably represents the best imaging modality to evaluate pelvic and perineal structures. It has a higher soft-tissue contrast than CT, making it an excellent alternative for diagnosing urovaginal and enterovaginal fistulae [35,36].

3.2.2. Endoscopic study

Cystoscopy has a low sensitivity for the diagnosis of enterovesical fistula, being able to correctly identify it in 35%–46% of cases [17,31]. Likewise, colonoscopy can accurately diagnose CVF in up to 55% of patients; regardless, it is an integral step in the diagnostic workup as it may be able to determine the underlying pathology that causes the fistula, as most CVFs are secondary to diverticular disease, malignancy or inflammatory bowel disease [17].

When a urinary fistula is identified, its relationship between the urinary sphincter, bladder neck, and ureteral orifices should be established to determine their involvement for preoperative planning and counseling patients on postoperative expectations [5].

Cystoscopy or vaginoscopy are especially useful in VVF to better characterize the location, size, complexity, and number of fistulous openings in both the urinary tract and vaginal canal; this is a procedure that is easily performed and well tolerated by most patients. Additionally, it allows for the biopsy of fistulous borders or suspicious tissue in patients with previous or suspected malignancy and fistulae secondary to radiation [30,37].

4. Management

4.1. Conservative management

The goal of conservative management is minimization of transit through the fistulous tract, allowing spontaneously closure [26]. Diversion away from the fistulous tract initially begins with the placement of a urethral foley catheter, while more complex fistulae involving the digestive tract may require colostomy diversion. The optimal trial for conservative management should last about 6–12 weeks [38].

The conservative management for uroenteric fistula has poor outcomes, with $\geq$80% failure rate, but at least 68% of enterovesical fistula patients get a colostomy as the initial form of treatment [26,39].

4.2. Surgical management

One of the main challenges in managing urinary fistulae is that every case has its own peculiarities, which has limited comparative studies. Despite these differences, key principles should be followed for every case for successful reconstruction [40].

- The two organs should be properly dissected apart from each other with adequate exposure of the fistulous tract.
- Suture lines should be perpendicular to each other to avoid re-fistulization.
- Tissue interposition should be used to avoid the recurrences.

- Edges of the fistulous tract are resected to viable tissue with adequate blood supply.
- Organ closures have to be watertight with no overlapping suture lines.
- Any concerns for malignancy should be confirmed with intraoperative frozen sections.
- Surgical repair should not be performed in the setting of active inflammatory processes or malignancy, poor nutritional status, or obstruction of the urinary or gastrointestinal tract distal to the repair.

Proper counseling on the added difficulties of these cases should be discussed extensively with the patient and the surgical team. Urinary fistulae secondary to prior abdominal surgeries, energy treatments, urinomas, inflammatory conditions, or malignancies are often accompanied with significant bowel adhesions and fibrotic changes. The incidence of major complications during salvage prostatectomies for prostate cancer hangs between 0% and 33%, with rectal injury contributing up to 9% of the cases [41]. In patients undergoing robotic fistula repair for RUF and RVF, complications are reported in 12%—60% of the patients with a readmission rate of up to 13% [38,40]. These complications are primarily low-grade (*i.e.*, UTI and ileus). The most common complication is UTI, and its incidence is between 8% and 33% [38,40,42]. Lastly, we recommend preoperative mechanical bowel preparation in our practice to all patients with uroenteric fistulae to decrease complications associated with stool spillage in the surgical field.

Patient-related situations that could discourage robotic repair include a history of extensive intra-abdominal interventions and comorbidities that decrease a patient's fitness for prolonged pneumoperitoneum or Trendelenburg. The location of the fistula is another determinant (*i.e.*, fistulae involving the perineum or anterior urethra are not candidates for robotic surgery). Likewise, this approach requires a multidisciplinary team that has all been trained in robotic surgery including urologists along with colorectal surgeons and gynecologists, according to each case [8,43]. Finally, there are no randomized data showing the superiority of robotics over open repairs; hence, the selection of the surgical approach is based on the surgeon's preference.

Endoscopic management, such as fibrin glue or transanal approach, can be considered in patients who are poor surgical candidates [43].

4.2.1. Port placement

Access to the abdomen is achieved using an open approach (Hasson's technique). If the concern for abdominal adhesions is high, we recommend obtaining access at Palmer's spot or location away from previous abdominal incisions.

In most cases, we use a six-port transperitoneal configuration with the camera port at the level of the umbilicus, two 8-mm ports at the level of the pararectal lines, one more 8-mm port at the level of the right iliac crest, and a 5-mm assistant port at the level of the left iliac crest (Fig. 2). The da Vinci Xi surgical system (Intuitive Surgical, Sunnyvale, CA, USA) should be docked from the patient's side, given the possibility of performing an intraoperative cystoscopy or a digital rectal exam (Fig. 3). In patients with prior colostomies, the port configuration should be shifted away from it to avoid injuries to the colostomy.

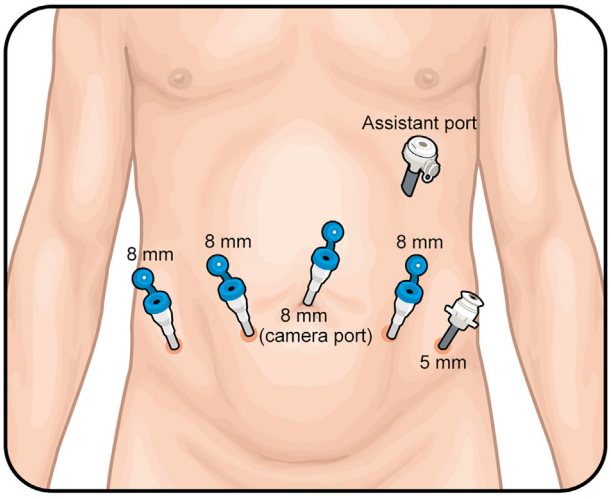

Figure 2 Port placement configuration.

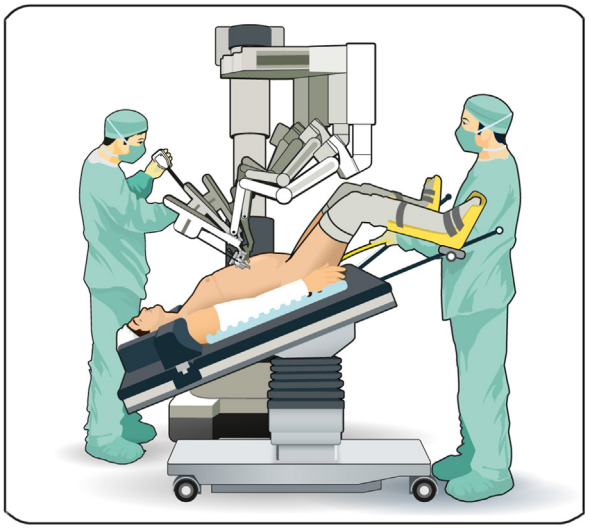

Figure 3 Illustration showing the robotic system docked with the patient in Trendelenburg's position and another surgeon performing a cystoscopy for cases in which cannulation of the ureters or the fistulous tract is needed.

4.2.2. Genitourinary fistula

For all genitourinary fistula repair procedures, the fistulous tract should be cannulated with a 5-Fr open-ended catheter for intraoperative tract identification and access for potential instillation of irrigation or indocyanine green (Akorn, Lake Forest, IL, USA) (Fig. 4).

For VVF, different approaches to dissect the fistulous tract have been described. A retrovesical approach entails the dissection of the space between the bladder and the vagina (vesicouterine pouch) [57]. A handheld vaginal retractor manipulated by the bedside assistant as transillumination of the bladder with a cystoscope can aid in fistula identification and guide the dissection [29]. In contrast, the retrovesical approach may be accompanied with fibrotic changes which carry increased risk of rectal and cervical injuries (Fig. 5A). Lastly, a transvesical

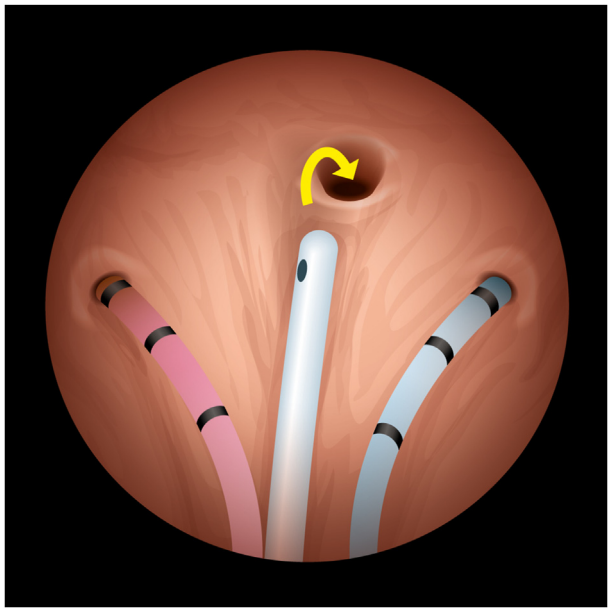

Figure 4 Cannulation of the fistulous tract and both ureters in preparation for a robotic surgical repair to aid with the intraoperative identification of these structures.

approach involves performing a modified O'Connor incision in the bladder (Fig. 5B). Once the longitudinal incision is made, the dissection towards the fistulous tract is easier as it is done under direct vision of the tract and the ureteral orifices while avoiding injuries to nearby structures. Finally, it is worth noting that robotic VVF repair has been suggested to result in minimal voiding dysfunction and a significant improvement in overall quality of life [44].

UVF evaluation should focus on identifying the location and iatrogenic injury (*i.e.*, ureteral ligation *vs.* transection). Once identified, successful fistula repair entails reinforcing the vaginal closure and a ureteric reimplant using an end-to-end anastomosis if there is good tissue quality versus a Boari flap or a psoas hitch. Indocyanine green can be utilized to ensure proper vascularity of the ureter, which has shown to decrease stricture rates.

Omentum is our preferred choice for interposition, but peritoneum or vaginal flaps can also be used. Omentum is maybe harvested laparoscopically prior to docking the robot or robotically. Finally, both structures, the bladder and vagina, are closed separately with barbed absorbable sutures in a running fashion after which the omentum is fixed in place between suture lines.

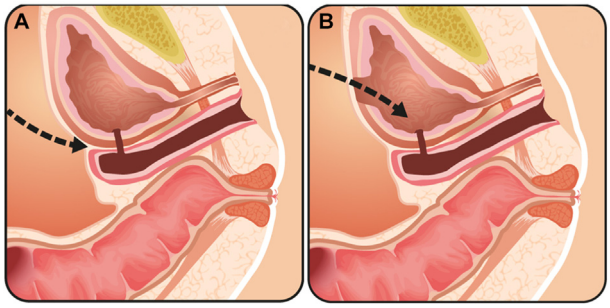

Figure 5 Retrovesical and transvesical approaches for vesicovaginal fistula repairs. (A) Retrovesical approach (between bladder and vagina); (B) Transvesical approach (cystotomy).

4.2.3. Enterourinary fistula

The surgical management of a CVF normally entails a partial cystectomy with posterior closure of the bladder with V-Loc sutures (Covidien, Dublin, Ireland) in a running fashion, followed by a partial colectomy or hemicolectomy by the colorectal surgery team.

Surgical management for RUF involving the prostatic urethra is often prostatectomy [55]. A posterior approach is performed, starting with dissection of the posterior plane of the prostate until the proximal edge of the fistulous tract is visualized. Then, the Retzius space is dissected distally towards the prostate's apex. Following this, the urethra is incised and the distal border of the fistulous tract is found (that is RUF), completing the prostatectomy. Once the specimen is removed, the rectum is closed transversely to preserve its diameter with V-Loc sutures. Finally, the omentum is interposed, and a VUA is performed.

For RVF, our approach is based on the presence of the prostate. In cases when the prostate is absent, repair involves a vertical cystotomy towards the fistulous defect, excision of the fistulous tract, interposition of omentum between the two organs, and closure of the bladder and rectum with V-Loc sutures in a single layer running fashion. If there is a concomitant bladder neck contracture, the bladder neck is dissected circumferentially until healthy tissue and patent urethra are identified. Finally, a VUA anastomosis is done in our standard fashion.

In patients with a prostate in place who suffer from an RVF, the approach includes a prostatectomy mirroring the RUF approach, removing the prostate aids with the bladder neck mobilization, allowing adequate organ separation, and allowing for easier interposition of tissue.

At times, the urethra needs to be resected until a healthy urethral margin is seen; this can hamper the surgeon's ability to achieve a tension-free anastomosis. Several maneuvers have been described when this situation is encountered.

- The lateral edges of the bladder neck are released to facilitate approximation of the bladder distally.
- A posterior reconstruction of the bladder neck is performed. This maneuver reduces the space between the bladder neck and the urethra.
- The bladder neck closure can be closed, and a cystotomy is done at the most dependent aspect of the bladder; then a neo-urethral anastomosis can be performed.
- A transperineal urethral mobilization can be done as a last resource. A second surgeon at the bedside performs a perineal dissection of the urethra circumferentially until the level of the bulbospongiosus muscle, and it is advanced proximally towards the pelvis so it can be anastomosed to the bladder (Fig. 6).

If performing a VUA is not possible, urinary drainage options are the continent catheterizable conduit, suprapubic tube or a simple cystectomy with an ileal conduit.

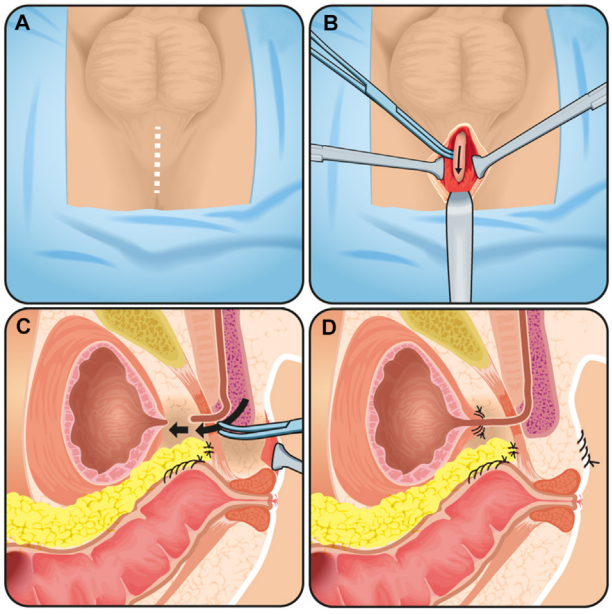

Figure 6 Transperineal urethral mobilization. (A) Perineal midline incision; (B) Urethral dissection and exposure; (C) Retrograde advancement of the urethra; (D) Vesicourethral anastomosis.

In our experience, we have managed one urethropubic fistula complicated by osteomyelitis. The only feasible option was an ileal conduit given the severe tissue reaction found and one urethroperineal fistula that healed after conservative management.

5. Consultation

Urinary fistulae may involve other organs outside the genitourinary system. Therefore, multidisciplinary management is often required.

5.1. Pubovesical fistula (PVF) and orthopedic surgery

Because pubic symphysis osteomyelitis is a frequent complication of the PVF, treatment options such as local or systemic antibiotics, surgical debridement, dead-space management, or pubectomy should all be considered [45].

Most cases will benefit from pubic bone debridement while considering placement of topical antibiotic beads. Arguably, the biggest downside of inserting antibiotic beads is the need to remove them in a second surgery [46]. However, for some cases, bone debridement may not be sufficient, and pubectomy is indicated when the infection has extended throughout the pubic bone [47]. On the other hand, although non-surgical or conservative management of pubic osteomyelitis with intravenous and oral antibiotics has been described, this approach is usually reserved for patients with contraindications to surgery, as bone debridement has shown to be superior [48].

Shu et al. [49] retrospectively described six patients with PVF that underwent bone debridement and antibiotic bead placement. Similarly, Ambrosini et al. [46] reported four patients, of which one refused surgery. This case was treated with bilateral nephrostomy and a prolonged antibiotic course for 12 weeks, achieving complete resolution at 6 months. Notably, all participants who underwent bone debridement received antibiotics for less than 4 weeks.

Consequential to its rarity, PVF lack clear management guidelines; hence, the importance of a multidisciplinary decision-making process between urology and orthopedic surgery that allows a tailored approach for each patient is primordial.

5.2. RUF and colorectal surgery

Colorectal surgery is normally consulted when an RUF is encountered to consider a fecal diversion and whether to preform it either prior to or during the fistula repair itself. Although alike outcomes have been described when comparing patients with RUF who did and did not underwent fecal diversion, this procedure was done in most cases because it likely decreases fistula and/or pelvic infection risk, inflammation, rectal wall tension, and therefore, failure of the fistula repair [40]. Moreover, a fecal diversion yields symptom relieve regarding fecaluria, pneumaturia, and urinary leakage through the rectum until the fistula repair is completed, which is usually recommended at least 6 weeks from presentation [40,50,51].

A substantial argument behind performing a fecal diversion first is based on a potential spontaneous resolution of the fistula that avoids surgical intervention of the urinary tract [5,52]. Despite still being an option, the conservative approach remains controversial since success rates greatly vary from 7% to up to 100% [5,40]. For example, cases with an important infection and larger fistulae, almost always require surgical closure, so performing both procedures at the same operative time will prevent a second surgery and delayed fistula repair [50]. In these cases, a transabdominal approach is optimal for creating a simultaneous fecal and urinary diversion, along with the fistula repair and omentum interposition [40].

Once the fistula has been successfully managed, most patients undergo stoma closure and restitution of the lower intestinal tract. Notably, a Hartmann's reversal procedure constitutes itself a risk factor for future developing CVF in up to 4.08% of the cases [53,54]. Regardless, 22% of the patients end up with permanent diversion [52], suggesting that certain cases may benefit from planning this procedure as the primary treatment, especially among those with risk factors for permanent diversion such as previous radiation and/or energy-ablation treatments [55].

From the colorectal standpoint, another surgical option for the management of RUF is an anorectal pull-through [40,51]. This technique has been mostly described for the management of fistulae associated with anorectal malformations in children [56]. After the repair of the fistula through an endorectal approach, the proximal colonic stump is anastomosed with the anal canal. This is a relatively straightforward technique that can be done in a minimally invasive fashion [56,57].

6. Postoperative management

General measures should be done to prevent postoperative complications, including deep venous thrombosis prophylaxis, and continued antibiotic therapy according to each case. The Foley catheter aids in the permanent drainage of the bladder, which is fundamental in the postoperative period. Trial of void can be considered 10—14 days after a cystogram, which confirms the closure of the fistula with no contrast leakage from the anastomosis [40,51]. Each case may vary, and some patients could require prolonged catheterization of up to 1 month. Moreover, pericatheter removal antibiotics are given and urine cultures should be collected at that time and 2 weeks later [5,40]. Most cases will also require a Jackson Pratt drain placement, which should be monitored and removed once the output is under 50 mL per day.

To increase the likelihood of a successful surgery outcome, one needs to optimize the local tissue and environment. Hyperbaric oxygen (HO) has long been used for conditions like radiation cystitis, burns, and wound healing, but its application for urinary fistulae is less common [58—60]. HO stimulates the immune system to kill microbes, promotes cell growth and tissue repair, and improves blood supply to damaged areas, which is particularly beneficial for radiated tissue [61]. Its potential in preoperative and postoperative settings shows promise for flaps, grafts, and poorly healing radiated tissue after surgery [62—64]. By significantly increasing tissue oxygen levels, HO can make ischemic radiated tissue more suitable for split-thickness skin grafts after 20—30 treatments. In irradiated patients, it is recommended to undergo 30 treatments before surgery and 10 treatments afterward to achieve optimal outcomes. While robust scientific evidence is still lacking, HO holds great promise and should be considered to aid urinary fistula repair in radiated tissue when multiple procedures have failed or when postoperative flaps or grafts are compromised.

All patients should be encouraged to resume daily activities as tolerated. As for PVF, patients should begin to bear weight as early as possible, as tolerated [49].

Finally, adequate follow-up must be ensured during months 1, 3, and 6 up to 12 months [49], although some recurrences and complications could present in 2 years [65].

7. Conclusion

The surgical management of complicated urinary fistulae using minimally invasive approaches is feasible in centers of expertise and typically requires a multidisciplinary effort. Nonetheless, more studies are needed to define the role of this approaches in the treatment algorithm of this condition. Ultimately, surgeons should opt for the approach with which they are most comfortable.

Author contributions

Study concept and design: Luis G. Medina, Randall A. Lee, Rene Sotelo.
Data acquisition: Luis G. Medina, Randall A. Lee, Rene Sotelo, Valeria Celis, Veronica Rodriguez, Jaime Poncel, Aref S. Sayegh.
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Drafting of manuscript: Luis G. Medina, Randall A. Lee, Rene Sotelo, Valeria Celis, Veronica Rodriguez, Jaime Poncel, Aref S. Sayegh.
Critical revision of the manuscript: Luis G. Medina, Randall A. Lee, Rene Sotelo.

Conflicts of interest

The authors declare no conflict of interest.

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