INTRODUCTION

Fournier’s gangrene (FG) is a rare necrotizing fasciitis of the scrotum and perineum. FG was first described by Jean-Alfred Fournier in 1883.1 FG predominantly affects men, with an incidence of 1.6 per 100,000 in the United States.2 Risk factors associated with FG include diabetes, chronic alcoholism, immunodeficiency, chronic steroid abuse, oncologic conditions, cytotoxic drugs, malnutrition, and low socioeconomic status.3,4

Treatment of FG entails rapid diagnosis, antibiotic therapy, and debridement. Once the patient is stabilized, reconstructive options to restore the remaining defects are then prioritized. It is estimated that up to 67% of patients will need some degree of reconstruction afterward.5

Existing literature on FG is available; however, few studies evaluated the disease process and spectrum of patient care from presentation to reconstruction. We aimed to offer a comprehensive review on practical clinical management and reconstructive options used for these patients.

METHODS

The PubMed database was queried on September 8, 2021 by using the following key search: “[Fournier’s gangrene] AND [reconstruction] OR [Fournier’s gangrene] AND [repair] OR (management)].” Inclusion criteria consisted of English language literature, which described management, reconstructive methods, complications, and/or outcomes of five or more FG patients. Unavailable studies, nonEnglish studies, and studies with less than five patients were not included in this review. After all inclusion and exclusion criteria were applied, 103 studies remained, and five studies were added from other sources. A total of 108 articles met the inclusion criteria. Level of evidence was assigned based on the methodological quality of the studies’ design.

RESULTS

Our review includes a total patient pool of 11,069 (Table 1). Most of the studies (n = 104) were retrospective.
with level III (n = 22) and IV (n = 83) evidence. Only four studies were prospective, corresponding to level II evidence.

**Comorbidities and Origin**

Based on our review, the most frequent comorbidities related to FG are diabetes mellitus (31.7%), hypertension (26.1%), and obesity (12.1%) (Table 2). The role of comorbid conditions in the prognosis of FG is conflicting. Chalva et al. found significant higher mortality in patients with diabetes ($P = 0.001$), whereas Ioannidis et al. found no statistical significance. Interestingly, several studies have found that renal failure is associated with higher mortality. Chronic renal failure was present in 0.9% of patients included in this review.

Sources of infection include cutaneous, genitourinary, gastrointestinal, traumatic, and other causes. Skin sources were responsible for FG in 24.3% of cases, urologic in 16.8%, gastrointestinal in 11.9%, trauma in 5.1%, mixed anorectal and urogenital sources in 1.7%, unknown in 32.4%, and other sources of infection in 3.6% of cases (Table 3).

**Pathophysiology**

FG is often caused by a polymicrobial infection that progresses to obliterator endarteritis with microthromboses along fascial planes. It begins in the genitalia or perineum and further spreads along Buck’s fascia, Collé’s fascia, and, in some cases, Scarpa’s fascia. The edema and compromised blood supply result in progressive exponential

**Takeaways**

**Question:** Which is the current evidenced-based management for Fournier’s gangrene?

**Findings:** In the acute phase, aggressive fluid resuscitation, broad-spectrum antibiotics, and immediate radical surgical debridement are required. Secondarily, patients will need definitive reconstruction. Skin grafts and flaps are recommended for reconstruction depending on the situation.

**Meaning:** Fournier’s gangrene requires rapid diagnosis and individualized management strategies for reconstruction.
| Author            | No. Cases | Study Type     | Level of Evidence | Reconstruction (No. Cases)                                      | Reconstruction of Complications (No. Cases) |
|-------------------|-----------|----------------|-------------------|----------------------------------------------------------------|--------------------------------------------|
| Parkash et al     | 43        | Retrospective  | IV                | Scrotal advancement flap = 40; skin graft = 3                  | Minor scrotal wound dehiscence = 4         |
| Morris et al      | 18        | Retrospective  | IV                | Skin graft = 6; skin flap = 12; tissue adhesive = 18          | Flap wound breakdown = 1                  |
| Ferreira et al    | 43        | Retrospective  | IV                | Skin graft = 22; scrotal musculocutaneous flap = 17; local advancement flap = 9; superomedial thigh flap = 28 | Superomedial thigh flap partial suture dehiscence = 1 |
| Hsu et al         | 8         | Retrospective  | IV                | Gracilis myofasciocutaneous advancement flap = 8              | Hematoma = 1; donor site abscess = 1       |
| Carvalho et al    | 67        | Retrospective  | IV                | Healing by secondary intention = 11; scrotal advancement flap = 16; skin graft = 20; skin flap = 21 | Skin graft infection = 5; flap infection = 2; flap loss = 2 |
| Bhatnagar et al   | 110       | Retrospective  | IV                | Skin graft = 20; thigh pouch = 26; fasciocutaneous thigh flap = 12; orchiectomy = 4 | Scrotal advancement flap partial loss = 1; scrotal advancement flap wound necrosis = 2; pedicled anterolateral thigh flap hematoma = 1; skin graft partial loss = 1 |
| Chen et al        | 31        | Retrospective  | IV                | Scrotal advancement flap = 11; skin graft = 9; pedicled anterolateral thigh flap = 3; gracilis flap = 5 | Skin graft infection = 1; skin graft scarring = 1; skin graft adhesions = 5; skin graft bilobed appearance = 1; medial thigh flap shallow scrotal sac = 1; thigh pouch scrotal sac absent = 1 |
| Tan et al         | 27        | Retrospective  | IV                | Skin graft = 24; thigh pouch = 1; VRAM flap = 1; medial thigh flap = 1 | None                                        |
| Coskunfirat et al | 7         | Retrospective  | IV                | Medial circumflex femoral artery perforator flap = 7          | Flap suture dehiscence = 2               |
| Lee et al         | 7         | Retrospective  | IV                | Skin graft = 4; gracilis muscle flap = 7; internal pudendal artery perforator flap = 7 | Flap wound dehiscence = 1; partial flap necrosis = 1 |
| Siviroğlu et al   | 15        | Retrospective  | IV                | Skin graft = 15                                               | None                                       |
| Akilov et al      | 28        | Retrospective  | IV                | Skin graft = 8; loose wound approximation = 6; secondary intention = 14 | Orchiectomy due to late epididymo-orchitis = 3; orchiectomy due to chronic scrotal pain after STSG = 1; Flap hematoma = 1; flap marginal necrosis = 1 |
| Ünerdi and Kemaloğlu | 13  | Retrospective  | IV                | Internal pudendal artery perforator flap = 13       | None                                       |
| Eswara and McDougal | 32  | Retrospective  | IV                | Skin graft = 17; Flap = 2; healing by secondary intention = 5; primary closure = 2 | None                                       |
| Wolach et al      | 10        | Retrospective  | IV                | Thigh pouches = 6; skin graft = 4; bilateral orchiectomy = 1 | None                                       |
| El-Khatib         | 13        | Retrospective  | IV                | Pudendal thigh flap = 8; skin graft = 3                      | None                                       |
| Jejase et al      | 38        | Retrospective  | IV                | Skin graft = 6; delayed primary closure = 31; orchiectomy = 8 | None                                       |
| Louro et al       | 15        | Retrospective  | IV                | Skin graft = 6; internal pudendal pedicled flap = 2; contralateral rotational flap = 1; internal thigh bilateral fasciocutaneous transposition flap = 1; McGregor propeller flap = 1; local sliding flap = 1; medial femoral circumflex fasciocutaneous flap = 1; internal thigh flaps = 2 | Partial skin graft loss = 3; skin flap partial dehiscence = 2; skin flap partial necrosis = 1 |
| Chen et al        | 41        | Retrospective  | IV                | Skin graft = 6; scrotal advancement flap = 9; gracilis muscle flap = 1; pudendal thigh fasciocutaneous flap = 4 | Skin graft partial loss = 1; scrotal advancement flap partial loss = 1 |
| Zhang et al       | 12        | Retrospective  | IV                | Skin graft = 6; advancement flap = 1; pudendal thigh flap = 1 | None                                       |
| Koukouras et al   | 45        | Retrospective  | IV                | NA                                                            | NA                                         |
| Perry et al       | 17        | Retrospective  | IV                | NA                                                            | NA                                         |
| Saffle et al      | 30        | Retrospective  | IV                | NA                                                            | NA                                         |
| Gürdal et al      | 28        | Retrospective  | IV                | Skin graft = 14                                               | NA                                         |
| Wang et al        | 24        | Retrospective  | IV                | Skin graft = 15                                               | None                                       |
| Omsiango et al    | 11        | Retrospective  | IV                | NA                                                            | NA                                         |
| Khanal et al      | 14        | Retrospective  | IV                | Bilateral pudendal flaps = 14                                 | Flap necrosis = 1                                         |
| Dadaci et al      | 29        | Retrospective  | IV                | Limberg thigh flaps = 29                                      | Dehiscence and seroma = 4                  |
| Boughammli et al  | 18        | Retrospective  | IV                | N/A                                                           | N/A                                         |
| Agwi et al        | 47        | Retrospective  | IV                | Scrotal advancement flap = 2; secondary intention = 10; primary closure = 16 | N/A                                         |
| Garg et al        | 72        | Retrospective  | IV                | Skin graft = 16                                               | N/A                                         |
| Lin et al         | 70        | Retrospective  | IV                | Skin graft = 45; primary closure = 15                         | N/A                                         |
| Sockalingam et al | 34        | Prospective    | II                | Skin graft = 2; prepubial skin flap = 2; primary closure = 15 | N/A                                         |
| Lin et al         | 103       | Retrospective  | IV                | N/A                                                           | N/A                                         |
| Arora et al       | 50        | Prospective    | II                | N/A                                                           | N/A                                         |
| Hahn et al        | 41        | Retrospective  | IV                | Skin graft = 8; skin flap = 5; primary closure = 10; orchiectomy = 4 | N/A                                         |
| Kranz et al       | 154       | Retrospective  | IV                | Orchiectomy = 22                                             | N/A                                         |
| Kuzaka et al      | 13        | Retrospective  | IV                | Thigh pouch = 1; orchiectomy = 2                             | N/A                                         |
| Author                  | No. Cases | Study Type | Level of Evidence | Reconstruction (No. Cases)                                                                 | Reconstruction of Complications (No. Cases) |
|-------------------------|-----------|------------|-------------------|------------------------------------------------------------------------------------------|-------------------------------------------|
| Ioannidis et al**       | 24        | Retrospective | IV                | Secondary intention = 14; skin graft = 5                                                   | N/A                                       |
| Lauer et al**           | 198       | Retrospective | IV                | Secondary intention = 101; primary closure = 67                                           | N/A                                       |
| Morais et al**          | 19        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Obun et al**            | 165       | Retrospective | IV                | Skin graft = 34; orchiectomy = 12                                                          | N/A                                       |
| El-Shazy et al**        | 28        | Prospective  | II                | Skin graft = 12                                                                           | N/A                                       |
| Tarchouli et al**       | 72        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Chalya et al**          | 28        | Prospective  | II                | Skin graft = 12                                                                           | N/A                                       |
| Lauerman et al**        | 168       | Retrospective | IV                | Secondary intention = 101; primary closure = 67                                           | N/A                                       |
| Morais et al**          | 19        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Osbun et al**           | 165       | Retrospective | IV                | Skin graft = 54; orchiectomy = 12                                                          | N/A                                       |
| El-Shazy et al**        | 28        | Prospective  | II                | Skin graft = 12                                                                           | N/A                                       |
| Tarchouli et al**       | 72        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Chalya et al**          | 28        | Prospective  | II                | Skin graft = 12                                                                           | N/A                                       |
| Oguz et al**            | 43        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Aliyu et al**           | 38        | Retrospective | IV                | Skin graft = 4; skin flap = 20; secondary intention = 14                                     | N/A                                       |
| Avakoudjo et al**       | 72        | Retrospective | IV                | Orchiectomy = 5                                                                           | N/A                                       |
| Benjelloun et al**      | 50        | Retrospective | IV                | Orchiectomy = 1                                                                           | N/A                                       |
| Katib et al**           | 20        | Retrospective | IV                | Orchiectomy = 6; penile amputation = 3                                                     | N/A                                       |
| Amr et al**             | 71        | Retrospective | IV                | Complex intention = 7; orchiectomy = 11                                                    | N/A                                       |
| Altar et al**           | 114       | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Djedovic et al**        | 10        | Retrospective | IV                | Skin graft = 2; medial thigh lift flap = 10                                               | Wound infection = 2; hematoma and partial flap necrosis = 1; hematoma and wound dehiscence = 1 |
| Chia and Crum-Gianflone | 59        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Yanar et al**           | 35        | Retrospective | IV                | Orchietomy = 6                                                                           | N/A                                       |
| Iacovelli et al**       | 92        | Retrospective | III               | Orchiectomy = 26                                                                          | N/A                                       |
| Ferres et al**          | 197       | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Beecroft et al**        | 143       | Retrospective | IV                | Primary local flaps and split thickness skin graft = 6; gracilis myocutaneous flaps, fasciocutaneous flaps, local flaps, xenografts and split thickness sk | N/A                                       |
| Ovelowo et al**         | 31        | Retrospective | III               | Secondary wound closure = 21, skin grafting = 10                                          | N/A                                       |
| Michalczyk et al**      | 35        | Retrospective | III               | N/A                                                                                      | N/A                                       |
| Cipriani et al**        | 81        | Retrospective | III               | N/A                                                                                      | N/A                                       |
| Lauer et al**           | 168       | Retrospective | IV                | Complete primary wound closure = 67; orchiectomy = 9                                       | N/A                                       |
| Chang et al**           | 13        | Retrospective | IV                | Local flap = 6; direct suture = 7                                                          | N/A                                       |
| Yucel et al**           | 25        | Retrospective | IV                | Primary closure or skin graft                                                             | N/A                                       |
| Hong et al**            | 29        | Retrospective | IV                | Skin flap = 4                                                                             | N/A                                       |
| Furt et al**            | 9249      | Retrospective | IV                | Complete wound closure = 816, orchiectomy = 153                                           | N/A                                       |
| Yanaral et al**         | 54        | Retrospective | IV                | Tertiary closure = 50; skin graft = 20                                                      | N/A                                       |
| Ozkan et al**           | 12        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Rosen et al**           | 35        | Retrospective | III               | Skin graft or myocutaneous flap coverage = 22                                              | N/A                                       |
| Zhang et al**           | 36        | Retrospective | IV                | Skin grafting = 36                                                                       | N/A                                       |
| Eray et al**            | 48        | Retrospective | IV                | Skin grafting or primary wound closure                                                      | N/A                                       |
| Milanese et al**        | 6         | Retrospective | IV                | Two fasciocutaneous flaps = 1                                                              | N/A                                       |
| Li et al**              | 28        | Retrospective | III               | Scrotal skin grafting = 15                                                                 | N/A                                       |
| Li et al**              | 51        | Retrospective | III               | Skin grafting = 16                                                                        | N/A                                       |
| Haidari et al**         | 17        | Cross sectional | III               | Testicular thigh pouches; orchiectomy = 2                                                  | N/A                                       |
| Ugwumba et al**         | 28        | Retrospective | IV                | Scrotal skin apposition = 22; scrotal skin apposition and split-skin grafting = 8           | N/A                                       |
| Altunoluk et al**       | 14        | Retrospective | III               | Scrotal reconstruction = 14                                                                | N/A                                       |
| Ozturk et al**          | 44        | Retrospective | III               | Skin grafting = 11                                                                        | N/A                                       |
| Malik et al**           | 73        | Prospective  | II                | Skin grafting = 7                                                                         | N/A                                       |
| Mehl et al**            | 40        | Retrospective | IV                | Skin grafting = 10                                                                        | N/A                                       |
| Canmek et al**          | 35        | Retrospective | III               | Meshed grafts or flaps                                                                    | N/A                                       |
| Ozturk et al**          | 10        | Retrospective | III               | Tertiary closure = 6; split thickness skin grafting = 4                                    | N/A                                       |
| Al-Meshaan et al**      | 11        | Retrospective | III               | N/A                                                                                      | N/A                                       |
| Karaçal et al**         | 8         | Retrospective | IV                | Neurovascular pedicled pudendal thigh flaps = 5                                            | N/A                                       |
| Talman et al**          | 33        | Retrospective | IV                | Secondary closure = 8; delayed closure = 15; skin grafting = 6                             | N/A                                       |
| Singh et al**           | 9         | Retrospective | IV                | Split skin grafting = 2; secondary suturing = 2; delayed closure = 5                       | N/A                                       |
| Tayib et al**           | 9         | Retrospective | IV                | Skin grafting = 6; orchiectomy = 1                                                         | N/A                                       |
| Zeropotamos et al**     | 11        | Retrospective | IV                | Secondary closure = 8; healing by second intention = 3                                     | N/A                                       |
| Norton et al**          | 33        | Retrospective | IV                | N/A                                                                                      | N/A                                       |
| Villanueva-Saenz et al**| 28        | Retrospective | IV                | Reconstruction of scrotum = 2                                                              | N/A                                       |
| Filo et al**            | 8         | Retrospective | IV                | Reconstruction = 2; orchiectomy = 1                                                         | N/A                                       |
| Corman et al**          | 23        | Retrospective | IV                | Skin muscle flaps = 2                                                                     | N/A                                       |
| Frezza and Atlas**      | 9         | Retrospective | IV                | Skin muscle flaps = 2                                                                     | N/A                                       |
| Asci et al**            | 34        | Retrospective | IV                | Split-thickness skin graft = 19; delayed closure = 12; subcutaneous thigh pouches = 11; skin flaps = 5; orchiectomy = 11 | N/A                                       |

(Continued )
perifascial dissection with overlying skin and subcutaneous tissue necrosis,\textsuperscript{115} which occurs at rates of 2–3 cm per hour, necessitating rapid diagnosis and treatment.\textsuperscript{114}

**Microbiology of FG**

From 1227 patients with polymicrobial or monomicrobial infections reported in culture, polymicrobial infections accounted for 58.4% of the cases, whereas monomicrobial infections accounted for 30.1% of the cases (Table 4). A total of 2521 bacterial isolates were identified. Due to small microbiologic isolates, \textit{Staphylococcus aureus} was the most common causative organisms. Interestingly, sterile cultures were reported in 18.7% of cases. Culture status was unknown in 3.7% of cases (Table 4). It is important to recognize that drug resistance has been observed in patients with FG. For instance, Chia and Crum-Cianflone\textsuperscript{26} identified 12 cases of FG being caused by multidrug-resistant organisms (MDROs). The majority is caused by Methicillin-resistant \textit{Staphylococcus aureus}. They found MDROs were responsible for 67% of FG cases in their cohort over the final 3 years of the 10-year study. MDROs were more strongly associated in patients with immunosuppression and chronic wounds, indicating that these patients might benefit from empiric antibiotic therapy.\textsuperscript{10}

**Clinical Presentation and Diagnosis**

Diagnosis of FG can be difficult due to nonspecific presenting symptoms. Scrotal swelling, fever, pain, necrosis, and erythema and edema changes were the most common presenting symptoms (Table 5). Fatigue is a rare symptom that has been reported in severe cases.\textsuperscript{117,118} Early diagnosis and treatment are critical to decreasing mortality. Ultrasound and CT scan imaging can help exclude other diagnoses such as epididymo-orchitis or testicular torsion.\textsuperscript{115,119} However, imaging should not delay operative intervention.

**MANAGEMENT**

**Fluid Resuscitation and Glucose Management**

Fluid resuscitation should be initiated immediately. Patients often present with electrolyte imbalances and elevated blood glucose levels. In fact, the majority of FG patients with uncontrolled diabetes present with diabetic ketoacidosis.\textsuperscript{\textsuperscript{11}} As poor diabetes control correlates with more aggressive FG disease progression,\textsuperscript{44} glucose levels should be immediately corrected.\textsuperscript{11} Managing blood glucose in patients with FG can be challenging when blood glucose levels reach up to 1020 g per dL.\textsuperscript{10} In these cases, insulin pumps seemed to be more suitable to subcutaneous insulin\textsuperscript{115,118}; however, there was no evidence to support this recommendation.

**Antibiotic Therapy**

Broad spectrum antibiotics covering gram positive (including methicillin-resistant \textit{Staphylococcus aureus}), gram negative, and anaerobic organisms are essential in FG due to the increasing prevalence of MDROs and polymicrobial infections.\textsuperscript{15} Aerobic, anaerobic, and fungal blood and urine cultures should be collected, and antibiotic therapy should be initiated immediately after this. Vancomycin or daptomycin can be initiated,\textsuperscript{122} plus a carbapenem (imipenem, meropenem, or ertapenem) or carbapenem (imipenem, meropenem, or ertapenem) or piperacillin-tazobactam.\textsuperscript{122} Chindamycin can be added to this regimen if suspicious of toxin production.\textsuperscript{15,122} Local antibiograms should be reviewed to allow customization of proper coverage depending on local drug resistance at

**Table 1. (Continued)**

| Author             | No. Cases | Study Type | Level of Evidence | Reconstruction (No. Cases) | Reconstruction of Complications (No. Cases) |
|--------------------|-----------|------------|-------------------|---------------------------|----------------------------------------|
| Korhonen et al\textsuperscript{109} | 33        | Retrospective | IV               | Skin grafts, secondary closure, implantation of testicles | N/A |
| Hollabaugh et al\textsuperscript{100} | 26        | Retrospective | IV               | Testicular thigh pouches = 11; split-thickness skin grafts = 11; local advancement flap = 2; combination of skin graft with local advancement flap = 2 | N/A |
| Ayamba and Magoha\textsuperscript{101} | 46        | Retrospective | IV               | Skin grafting = 5; secondary wound closure = 15; primary closure = 1; orchietomy = 1 | N/A |
| Pizzorno et al\textsuperscript{102} | 11        | Retrospective | IV               | Urethroplasty with onlay flap = 1; Sachse’s internal urethrotomy = 1; split-thickness skin graft = 1 | N/A |
| Ong and Ho\textsuperscript{103} | 12        | Retrospective | IV               | Thigh pouches = 2; orchietomy = 1 | N/A |
| Benizzi et al\textsuperscript{104} | 24        | Retrospective | IV               | Skin grafting = 1; orchietomy = 1 | N/A |
| Elem et al\textsuperscript{105} | 41        | Retrospective | III              | Secondary suturing = 19; scrotal reconstruction with medial thigh fasciocutaneous flap = 2 | N/A |
| Salvinho et al\textsuperscript{106} | 10        | Retrospective | IV               | Split-thickness skin graft = 5; testicular thigh pouches = 2 | N/A |
| Attah et al\textsuperscript{107} | 13        | Retrospective | IV               | N/A | N/A |
| Thambi Dorai and Kandasami\textsuperscript{108} | 12        | Retrospective | IV               | Secondary suturing = 3; secondary intention = 2; split thickness skin grafts = 6 | N/A |
| Hirn and Nilnikoski\textsuperscript{109} | 11        | Retrospective | IV               | Orchiectomy = 2 | N/A |
| Scott et al\textsuperscript{110} | 5         | Retrospective | IV               | Secondary intention = 4 | N/A |
| Barkel and Villalba\textsuperscript{111} | 8         | Retrospective | IV               | N/A | N/A |
| Badejo\textsuperscript{112} | 16        | Retrospective | IV               | Subcutaneous thigh pouch, and shift peduncle graft (N/A); orchietomy = 2 | N/A |

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that hospital/community. Once culture results are available, antibiotics can be refocused based on sensitivity.45 Antibiotic treatment duration does not seem to influence mortality, primary closure, surgical site infection, nor rates of *C. difficile* colitis.45 Antibiotics may be stopped after a set course of 14 days or before when surgical control was achieved depending on the case.45

**Surgical Debridement**

Extensive surgical debridement prevents progression of FG while also decreasing mortality (Fig. 2). The timing of debridement is paramount to clinical outcomes. Lin et al developed the simplified Fournier Gangrene Severity Index (sFGSI), a three variable scoring system that can predict mortality and categorize patients as high-risk or low-risk. In sFGSI high-risk patients, timing of intervention dramatically decreased mortality from 68.8% in those with late intervention to 23.8% in those with early intervention. The optimal window for surgery from time of presentation to the emergency department has been determined to be within the first 14.35 hours.48 El-Shazly et al39 found higher rates of patients requiring more aggressive surgical debridement due to disease progression in

| Comorbid Condition* (N = 20,259) | n | % |
|---------------------------------|---|---|
| Diabetes                        | 6264 | 31.7 |
| Hypertension                    | 5163 | 26.1 |
| Obesity                         | 2395 | 12.1 |
| Anemia                          | 1961 | 9.9 |
| Heart failure/CAD/CHF/PVD        | 1156 | 5.8 |
| Alcoholism/liver disease/cirrhosis | 1045 | 5.3 |
| Coagulopathy                    | 666  | 3.4 |
| Smoking                         | 187  | 0.9 |
| CRF/ESRD                        | 179  | 0.9 |
| HLD                             | 126  | 0.6 |
| COPD                            | 117  | 0.6 |
| HIV/AIDS                        | 109  | 0.6 |
| Immunosuppression               | 53   | 0.3 |
| Malignancy                      | 78   | 0.4 |
| Colorectal disease              | 38   | 0.2 |
| Bedridden                       | 37   | 0.2 |
| IV drug use                     | 16   | 0.1 |
| Urologic disease                | 29   | 0.1 |
| Neurological deficit (paraplegia, hemiplegia, quadriplegia) | 19 | 0.1 |
| Immunonutrition/malnutrition    | 16   | 0.1 |
| Pelvic radiotherapy             | 13   | 0.1 |
| Chemotherapy                    | 13   | 0.1 |
| Filariasis                      | 12   | 0.1 |
| Steroid use                     | 11   | 0.1 |
| Uremia                          | 9    | 0.05 |
| Malaria                         | 8    | 0.04 |
| Chronic wound                   | 7    | 0.04 |
| Stroke                          | 7    | 0.04 |
| Psychiatric disease             | 6    | 0.03 |
| Hormonotherapy                  | 6    | 0.03 |
| Hypoproteninemia                | 6    | 0.03 |
| Tuberculosis                    | 3    | 0.02 |
| Neurogenic bladder              | 3    | 0.02 |
| Hidradenitis                    | 3    | 0.02 |
| Extramammary Paget’s disease    | 2    | 0.01 |
| GERD                            | 2    | 0.01 |
| Adrenal insufficiency           | 2    | 0.01 |
| SLE                             | 2    | 0.01 |
| Chicken pox                     | 1    | 0.01 |
| Dermatitis                      | 1    | 0.01 |
| Gout                            | 1    | 0.01 |
| MGUS                            | 1    | 0.01 |
| Omphalitis                      | 1    | 0.01 |
| Pemphigus vulgaris              | 1    | 0.01 |
| Sickle cell disease             | 1    | 0.01 |
| Spondylarthrosis                | 1    | 0.01 |
| Ulcereative colitis             | 1    | 0.01 |
| Psoriasis                       | 1    | 0.01 |
| Dementia                        | 1    | 0.01 |
| Wegener’s granulomatosis        | 1    | 0.01 |

**Table 3. Sources of Infection Leading to FG**

| Cause* (N = 1638) | n | % |
|-------------------|---|---|
| Skin              | 398 | 24.3 |
| Perianal abscess/infection | 166 | 10.1 |
| Perianal abscess  | 53  | 3.2 |
| Ischiorectal      | 32  | 2.0 |
| Perirectal abscess| 27  | 1.6 |
| Scrotal abscess/infection | 18  | 1.1 |
| Fistula           | 15  | 0.9 |
| Pressure ulcer    | 9   | 0.5 |
| Chronic perineal itching | 8   | 0.5 |
| Penile abscess    | 4   | 0.2 |
| Bartholin gland cyst | 4   | 0.2 |
| Scrotal furuncle  | 3   | 0.2 |
| Fissure           | 1   | 0.06 |
| Perianal wound    | 1   | 0.06 |
| Thigh abscess     | 1   | 0.06 |
| Inginal abscess   | 1   | 0.06 |
| Infected sebaceous cyst | 1   | 0.06 |
| Burns             | 1   | 0.06 |
| Folliculitis      | 1   | 0.06 |
| Dermatologic unspecified | 52 | 3.2 |
| Urologic sources  | 343 | 16.8 |
| UTI               | 96  | 5.9 |
| Urethral stricture| 50  | 3.1 |
| Urethral rupture  | 46  | 2.8 |
| Urethral catheterization | 29 | 1.8 |
| Acute epididymo-orchitis | 20 | 1.2 |
| Urethral fistula  | 4   | 0.2 |
| Urinary extravasation | 3  | 0.2 |
| Prostatic abscess | 2   | 0.1 |
| Penile pain at coitus | 1  | 0.06 |
| Erosion of catheter| 1   | 0.06 |
| Blocked catheter  | 1   | 0.06 |
| Acute prostatitis | 1   | 0.06 |
| Genitourinary unspecified | 67 | 4.1 |
| Gastrointestinal sources | 195 | 11.9 |
| Rectal cancer      | 15  | 0.9 |
| Hemorrhoidectomy   | 9   | 0.5 |
| Inguinal hernia    | 9   | 0.5 |
| Thrombosed hemorrhoid | 8   | 0.5 |
| Intestinal obstruction/perforation | 3  | 0.2 |
| Anal fistula       | 3   | 0.2 |
| Diverticulitis     | 1   | 0.06 |
| Anal cancer        | 1   | 0.06 |
| Anorectal/colorectal unspecified | 146 | 8.9 |
| Mixed anorectal and urogenital | 28  | 1.7 |
| Trauma             | 84  | 5.1 |
| Other sources      | 59  | 3.6 |
| Recent surgery     | 37  | 2.3 |
| Instrumentation    | 7   | 0.4 |
| Paraplegia         | 3   | 0.2 |
| Injection          | 3   | 0.2 |
| Filariasis         | 2   | 0.1 |
| Radiotherapy       | 2   | 0.1 |
| Steroid enema treatment for ulcerative colitis | 1 | 0.06 |
| Lumbar puncture    | 1   | 0.06 |
| Nursery manipulation | 1  | 0.06 |
| Carcinoma of bladder | 1  | 0.1 |
| Unknown            | 531 | 32.4 |

*A total of 57/108 studies (N = 1638 cases) 44,48,49,50,52,54–56,60,68,69,71,72,77,79,81–84,87,89,90,93,94,96,98,100–110

* A total of 92/111 Studies (N = 20,259 cases) 1,3,4,5,6,11–15,17,18,20,22,23,25,26,29–31,34,37,38,40,41,44,46,49,50,52,54–56,60,68,69,71,72,77,79,81–84,87,89,90,93,94,96,98,100–110
those who had longer delays in getting to the operating room (76.5% versus 27.2%, respectively). The authors also reported that patients with conservative management had significantly greater body surface area affected, required more serial debridement, and longer hospital stays than their counterparts who underwent urgent exploration. 48

Zhang et al 25 reported that debridement should continue until reaching normal-appearing fascia. Surgeons should have a low threshold to return to the operating room and perform further debridement if there is evidence of continued progression. Attempting to salvage tissue with the incentive of making later reconstruction easier should be avoided, as this increases the risk of fulminant disease.

Interestingly, Osbun et al 47 compared management of FG at high-volume and low-volume FG health centers. They found that low-volume centers had higher rates of orchiectomy when compared with high-volume centers. On the contrary, high-volume centers had higher rates of reconstruction in FG patients. There was no difference in mortality between these groups; however, delayed transfer from a low-volume to a high-volume center was associated with mortality in four patients. 47 Although referrals should be a thoughtful clinical decision based on the capabilities to stabilize and treat these patients, it is preferable for FG patients to be transferred to high volume centers, when possible.

Orchiectomy

The consensus is that orchiectomy should be avoided whenever possible and should never be done prophylactically. Testicular involvement in FG is rare—credited to the separate blood supply of the testicles by the gonadal
arteries. Although incidence is not widely reported, we found that 290 (2.6%) of 11,069 patients underwent orchiectomy. \cite{Michalczyk64,Altunoluk81,Yanar60} found that when orchiectomy was performed, using surgeon judgment, 100% of final histologic analysis showed normal testicular tissue with no signs of FG—supporting the principle that orchiectomy is often not necessary. There are no guidelines about the best timing to perform orchiectomy when needed.

### OTHER MEDICAL TREATMENT

#### Hyperbaric Oxygen

Adjunctive hyperbaric oxygen therapy (HBOT) increases tissue oxygen levels, enhancing collagen synthesis, angiogenesis, epithelialization, and resistance to bacteria that may be beneficial for FG cases. \cite{Feres61} HBOT has been reported to reduce morbidity and mortality for patients with FG. \cite{Michalczyk64,Altunoluk81,Michalczyk66} Feres et al.\cite{Feres61} studied 79 patients who underwent adjunctive HBOT for FG and compared their mortality rates with a control group of 118 patients who underwent traditional treatment, including debridement, antibiotic therapy, and intensive care. They found a significantly lower mortality rate in patients who were treated with HBOT (5.7%) compared with the control group (28.8%, \( P < 0.001 \)). \cite{Feres61} Similarly, Li et al.\cite{Li77} evaluated 28 cases with FG retrospectively, and found a statistically significant lower mortality and lower number of surgical debridements, indwelling drainage tube time, and curative time for patients who had HBOT (\( P < 0.05 \)). However, they did not find any difference in the length of stay (LOS) between groups. \cite{Li77} An absolute contraindication for HBOT is the untreated pneumothorax. Relative contraindications include upper respiratory infections, low threshold for seizures, emphysema with \( \text{CO}_2 \) retention, high fever, and congenital spherocytosis. \cite{Michalczyk64} Disadvantages to this treatment include barotrauma, claustrophobia, and availability of hyperbaric chambers. \cite{Michalczyk64}

#### Dressings or Ointments

Conventional wet-to-dry dressings are commonly used once the debridement is accomplished, but frequent changes to keep the wound clean are needed. \cite{Michalczyk62} Conventional dressings that contain multiple active agents such as saline, povidone-iodine, potassium permanganate, Dakin’s solution, enzymatic agents, or polyhexanide have been used to promote wound healing after surgical debridement in FG cases. \cite{Michalczyk67} Only a few studies evaluated the use of dressings to promote wound healing in these patients. Altunoluk et al.\cite{Altunoluk81} compared the use of daily anti-septic dressings with povidone-iodine (\( n = 6 \)) and dressings with Dakin’s solution (sodium hypochlorite 0.025%) (\( n = 8 \)). They found a statistically significant shorter length of hospital stay in those receiving dressings with Dakin’s solution. \cite{Altunoluk81} Plates and strips of calcium alginate followed by hydrogel and polyurethane dressings have also shown promising outcomes in a few cases. \cite{Michalczyk67} Still, the hyperbaric oxygen sessions that these patients also received might have influenced these outcomes. Dermal matrix has also been beneficial for patients with FG. \cite{Zhang74} Zhang et al.\cite{Zhang74} evaluated the use of porcine acellular dermal matrix for wound healing in patients with FG. They found statistically significant shorter preparation wound time (until granulation tissue was suitable for skin grafting or wound was repaired) and hospitalization period in patients who had porcine acellular dermal matrix compared with those whose wounds were cleaned with hydrogen peroxide and sodium hypochlorite solution. In addition, moist exposed burn ointment, an herbal formulation containing \( \beta \)-sitosterol, baicalin, and berberine, has been reported to be beneficial by inducing keratinocyte migration and interaction with growth factors. \cite{Michalczyk68} Finally, the use of enzymatic debridements with topical lyophilized collagenase applied twice a day in 11 patients whose active infection was arrested, demonstrated to reduce the number of surgical debridements and duration of hospitalization compared with 23 patients who did not have it as part of their treatment. \cite{Michalczyk68} In general, further studies with higher sample size are needed to determine the type of dressing that produces the best wound healing. However, this is hard to assess given the differences in the extent of the disease and each patient’s individual treatment.

#### Negative Pressure Wound Therapy

Vacuum-assisted closure therapy (VAC) has been implemented in the treatment of FG by some institutions with positive results. \cite{Michalczyk66,Michalczyk67,Michalczyk68,Michalczyk69} A lower pressure between 50 and 125 mm Hg, with 5 minutes of suction followed by 2 minutes of rest, is recommended. \cite{Michalczyk62,Michalczyk67} VAC can only be applicable after proper debridement of FG. Before debridement, this therapy is contraindicated because it can hide the disease’s progression. VAC dressing changes should be done every 48–72 hours, and in case of progressive necrosis, surgical debridement needs to be repeated. \cite{Michalczyk67,Michalczyk68} Iacomelli et al.\cite{Iacomelli71} performed a multi-institutional cohort study evaluating the use of VAC therapy for patients with FG. They observed higher rates of survival at 90 days and higher rates of wound closure at 10 weeks after surgery in patients with disseminated FG compared with those who were not treated with VAC. \cite{Michalczyk67} Yanaral et al.\cite{Yanar67} compared the use of conventional antiseptic dressings with VAC after debridement of FG in 54 patients, retrospectively. They found that VAC statistically significantly decreased pain, number of daily dressing changes, number of daily analgesics and narcotics, and increased mobilization per day compared with conventional dressings. Similarly, Ozturk et al.\cite{Ozturk68} compared five patients who received conventional wet-to-dry dressings with saline and five patients who underwent VAC therapy. The authors observed less pain and use of analgesics in those patients treated with VAC therapy. \cite{Ozturk68} These two prior studies reported a similar LOS for both groups. \cite{Michalczyk62} 

Michalczyk et al.\cite{Michalczyk62} performed a retrospective study evaluating the use of HBOT in combination with VAC for wound healing after debridement in patients with FG. The authors did not find any statistical difference in hospitalization time compared with patients who had an open standard wound care, but showed a correlation with the extent of resection. These findings suggest that the use of
combined therapy might be beneficial for patients with large wound defects.64

The current evidence on VAC therapy for FG consists only of retrospective and observational studies with a low number of subjects. Further studies are needed to determine its real benefit and potential treatment algorithm.

Honey

The use of topical unprocessed honey to promote granulation after wound debridement in FG cases has been investigated. Even though some studies suggested that honey accelerated wound healing29,108 and showed less hospitalization time29 in patients with FG, there is still not enough evidence that honey can be directly associated with improved wound healing. Further studies are needed with control of confounding factors and greater sample size.

Fecal Management System

Urinary or fecal diversion is required in those patients with necrosis involving the periurethral and perianal area to protect the wound from urinary and fecal discharge. Fecal management systems appeared as an alternative to colostomy. Flexi-Seal Fecal Management System is a short-term fecal diversion consisting of a rectal tube that allows diversion of feces from the rectum to a collector bag.72 It has been suggested to be a promising method in the treatment of FG when used along with VAC.72 However, studies are needed to determine its efficacy and specific indications.

RECONSTRUCTION

No studies, with high-level evidence, were identified to discuss superiority of reconstructive options or approaches. The majority of studies discussing reconstruction methods were level of evidence IV.

Healing by Secondary Intention

Eighteen studies included 179 patients who underwent healing by secondary intention/secondary closure.10-17,21,26,27,31,35,41,45,50,52,56,60,63,66,92,108,110 Zhang et al25 left healing by secondary intention for defects occupying less than 50% of the scrotum. This was feasible due to increased elasticity of the scrotum, and adequate cosmetic results were achieved. Similarly, Eswara et al19 found healing by secondary intention ideal for small or dehisced wounds, especially those located near the anus or inguinal folds. It has been reported that 18% of FG wounds that underwent attempted healing by secondary intention remained open at 6 months.27 Even though no correlation was identified between surface area and time to closure,66 when leaving defects to close by secondary intention, it should be expected to observe prolonged time of healing, contractions, and as a consequence, poorer patient satisfaction.

Skin Grafts

Skin grafts were used in 521 patients. Although minimally complex, they can be used to successfully reconstruct scrotal skin, which has unique properties (Fig. 3). Graft take occurred in most of the cases; a single patient’s graft became infected, resulting in scarring, and five patients developed scarring with adhesions. It has been reported that neoscrotal contraction can occur in 3–6 months following skin grafting.13 However, with daily massaging using emollients, contraction can be reduced to minimum.13 Neoscrotal rugosity and cremasteric activity may also be observed after 6 months of reconstruction.13 Ferreira et al8 also found utility
in using skin grafts in patients with penile involvement. Thick split-thickness skin grafts were preferred to minimize contractures.9 Full-thickness skin grafts were used in four patients for tubed urethroplasty.9 Importantly, when skin grafting is needed to cover defects in the testicles, the tunica vaginalis needs to be intact; in its absence, skin grafting will not be successful13 (Fig. 4). This procedure is considered a good option to keep morbidity low when specialized care is not available. Downsides to split-thickness skin graft include high rates of skin contracture, poor take in areas with abnormal contours such as the perineum, and less protection for future injury.24 In addition, cosmesis and patient satisfaction have been reported to be poor.11 In summary, skin grafting is a good option for reconstruction, especially in areas with poor resources where a plastic surgeon may not be available.

**Subcutaneous Thigh Pouches**

Twelve studies (63 patients) underwent reconstruction with subcutaneous thigh pouches.11,13,17,20,22,38,43,98,100,103,106 Subcutaneous thigh pouches offer low surgical complexity but should be avoided due to poor aesthetics, poor patient satisfaction, chronic testicular pain, and disruption of spermatogenesis caused by elevated testicular temperatures.8

**Loose Wound Approximation**

Akilov et al17 recommended loose wound approximation for FG defects that affect less than 50% of the scrotum. Their study compared loose wound approximation using a U-stitch (six patients) to healing via secondary intention (14 patients), finding a shorter LOS in the U-stitch group. The benefits include loose wound approximation immediately after debridement, testicular coverage, the ability to place a drain that theoretically will allow drainage of residual infection and reduction of contracture, technical ease, and shorter LOS.17 Further studies with a larger sample size are necessary to determine the efficacy of this method.

**Tissue Adhesive**

Morris et al7 found that diluted fibrin sealant resulted to be successful when flaps and grafts were used for reconstruction. All patients who required split-thickness skin graft (n = 6) had 100% graft take, and 11 of 12 patients who required flap reconstruction had excellent flap adherence. Almost all patients had no complications and satisfactory results. A single patient developed flap breakdown in the setting of reconstruction immediately following a large debridement.7 Sivrioglu et al16 used 2-octyl-cyanoacrylate glue in FG patients needing skin grafts and found 100% success in all patients with a mean length of hospital stay of 9 days (range: 7–12). Its application allowed meticulous graft positioning and decreased the need for quilting sutures, showing possible antimicrobial properties.16 Although requiring further investigation, tissue adhesive appears to be beneficial at fixing the abnormal contours of the perineum.7,16

**Flap Reconstruction**

Flap reconstruction is helpful in some defects (Figs. 5 and 6). A total of 33 articles reported on the use of some sort of flap with a total pool of 373 (31.7%) patients6–15,18,19,21,23–25,28,32,33,35,36,41,50,52,58,66,76,78,87,88,97,98,100,105 (Table 6).
Table 6. Reconstructive Methods in FG

| Method                              | Studies | Patients (%) |
|-------------------------------------|---------|--------------|
| Healing by secondary intention      | 179     | 15.2         |
| Skin grafts                         | 521     | 44.3         |
| Subcutaneous thigh pouches          | 63      | 5.4          |
| Loose wound approximation           | 6       | 0.5          |
| Tissue adhesive                     | 33      | 2.8          |
| Flaps (total)                       | 373     | 31.7         |
| Scrotal advancement flap            | 86      | 7.3          |
| Gracilis muscle flap                | 24      | 2.0          |
| Gracilis myofasciocutaneous advancement flap | 14 | 1.2 |
| Pudendal thigh flap                 | 63      | 5.4          |
| Peduncular anterolateral thigh flap | 18      | 1.5          |
| Peduncular fasciocutaneous flap     | 23      | 2.0          |
| Internal pudendal artery perforator flap | 20   | 1.7          |
| Internal pudendal pedicle flap      | 2       | 0.2          |
| Medial or lateral thigh fasciocutaneous flaps | 59  | 5.0          |
| Superomedial thigh flap             | 28      | 2.4          |
| Medial lift                         | 10      | 0.9          |
| Fasciocutaneous thigh flap          | 12      | 1.0          |
| Pedicled anterolateral thigh flap   | 3       | 0.3          |
| Medial thigh flap                   | 3       | 0.3          |
| Internal thigh bifurcated fasciocutaneous flap | 1 | 0.1 |
| transposition flaps                 | 1       | 0.1          |
| Internal thigh rotational flap      | 1       | 0.1          |
| Rotational thigh flap               | 1       | 0.1          |
| Medial circumflex femoral flaps     | 8       | 0.7          |
| Medial femoral artery perforator flap | 7      | 0.6          |
| Medial femoral circumflex artery perforator flap | 1  | 0.1 |
| Fasciocutaneous flap                | 73      | 6.2          |
| Limberg thigh flap                  | 29      | 2.5          |
| Scrotal musculocutaneous flap       | 7       | 0.6          |
| Local advancement flap              | 17      | 1.4          |
| Prepubial skin flap                 | 2       | 0.2          |
| VRAM flap                           | 1       | 0.1          |
| Lattissimus flap                    | 1       | 0.1          |
| Contralateral rotational flap       | 1       | 0.1          |
| McGregor rotational flap            | 1       | 0.1          |
| Local sliding flap                  | 1       | 0.1          |

* A total of 67/108 studies (N = 1175 patients).

Scrotal Advancement Flaps

A total of 88 patients (5.6%) underwent scrotal advancement flaps. Scrotal advancement flaps offer a good aesthetic result and fulfill the “replace like by like” principle. This flap is recommended for small-to-medium defects of the scrotum, smaller than 50% of the total scrotal surface area. The largest reported defect repaired with this flap was 96 cm². In addition, they can be used when neither secondary intention nor primary closure have resulted in wound closure. It is not recommended for larger defects, as they require a tension-free closure, without which flap loss and wound edge necrosis are more likely. Benefits of this method include durable and good skin quality, elasticity (presence of dartos muscle), and robust blood supply that allows adequate healing.

Gracilis Flaps

Five studies used variations of gracilis muscle flaps. Chen et al. reported using gracilis muscle to fill deep perineal defects when harvested as a muscle or myocutaneous flap. The advantages of using this flap include the proximity to the affected area, the single-stage procedure, the ability to fill larger/deeper defects, and the robust vascular supply that allows better penetration of antibiotics to the affected tissue. The gracilis flap has a long pedicle that allows a good arc of rotation and great blood supply, in addition to the well-nourished sensitive skin.

Complications related to gracilis flap included hemotoma, donor site abscess, wound dehiscence, and partial flap necrosis. Disadvantages include the time-consuming dissection, its relative bulk when compared with native tissue, the risk of split-thickness skin graft contracture, and the need for patient compliance with multiple dressing changes per day to avoid humidity and infections.

Pudendal Thigh Flaps

Nine studies used pudendal thigh flaps in 63 patients. Chen et al. reported using a pudendal thigh fasciocutaneous flap for a scrotal defect affecting less than 50% of total surface area, or in combined defects involving the scrotum and perineum, reporting no complications. The benefits of a pudendal thigh flap are numerous and include the preservation of sensation in the flap, the presence of a reliable blood supply, less bulk than other options, minimal donor site morbidity, and the avoidance of using a functional muscle. Interestingly, several patients expressed concern regarding fertility. However, semen analyses were performed 3 months postoperatively, showing normal results in these patients.

Medial or Lateral Thigh Fasciocutaneous Flaps

Eight studies used a variation of a medial thigh fasciocutaneous flap in 59 patients. Ferreira et al. used superomedial thigh flaps in 26 patients. In patients with large defects, bilateral flaps were needed to increase the transverse dimension and cover the defect. Bhattacharjee et al. used fasciocutaneous medial thigh flaps in 12 patients, reporting an 83.3% success rate. Chen et al. performed pedicled anterolateral thigh flaps in patients who had defects involving more than 50% of the scrotum and combined defects involving the scrotum. Benefits include being a single-stage procedure that provides sensate coverage with adequate cosmesis and patient satisfaction; however, specialized surgical skills are often required. Reported complications consisted of dehiscence, hemotoma, shallow scrotal sac, higher morbidity, and longer hospital stay.

Medial Circumflex Femoral

Two studies used the medial circumflex femoral artery perforator flaps in eight patients with good results. Coskunfirat et al. used these flaps in seven patients. Five patients had a propeller flap variation to cover both testes, whereas two patients had a VY advancement flap when only one testicle needed to be covered. All patients were immobilized for 3–5 days, and only two minor dehiscences were reported, with one repaired by secondary suture and the other by secondary intention.

Other Types of Flaps

Dadaci et al. reported using Limberg thigh flaps for reconstruction in 29 patients with defects occupying 50% or more of the scrotum. Benefits included no need for specialized microsurgical skills, the ability to close the primary donor site, adequate cosmesis, and easy harvesting while...
providing a tension-free repair. Tan et al. used a vertical rectus abdominis myocutaneous (VRAM) flap in a single patient, which offered good coverage but had an unsatisfactory aesthetic result with an abnormal appearing scrotum. VRAM flaps, like gracilis flaps, are useful especially for testicles where tunica vaginalis is no longer present. The benefit of using a VRAM flap relies upon a constant blood supply that makes it ideal in conditions of a contaminated recipient bed such as the perineum, and the wide flat shape that makes it easy to inset. Other possible flaps included scrotal musculocutaneous flaps, local advancement or sliding flaps (not necessarily scrotal), latissimus free flap, contralateral rotational flap, and McGregor propeller flap. Ferreira et al. reported using scrotal musculocutaneous flaps in 10 patients with small- and medium-sized defects.

**DISCUSSION**

Management of FG relies on four pillars: fluid resuscitation, broad-spectrum antibiotics, rapid/aggressive debridement, and reconstruction, if indicated (Fig. 7). Early management of FG should be warranted. Many options to reconstruct FG defects with flaps exist; however, deciding which type of flap depends on the size of the defect, location, surgeon skill, patient age, and desires. Surgeons should be aware of the potential complications of using flaps for FG reconstruction, including the possibility of total flap loss. Scrotal advancement flaps or secondary intention closure are used for defects of less than 50% of the scrotum that cannot close by primary intention. In contrast, skin grafts or flaps ± skin grafts are better suited for defects of greater than 50% of the scrotum or extending beyond the scrotum.

**LIMITATIONS**

Our study is not without limitations. No randomized control trials or level I evidence was identified or included in this study. Furthermore the majority of studies in this review fall below level II evidence.

**CONCLUSIONS**

FG is a life-threatening condition. The most frequent comorbidities associated with FG included diabetes, alcoholism/liver cirrhosis, and hypertension. A polymicrobial infection often causes FG, but *E. coli* was the most evidence-based FG treatment flowchart.
common causative organism involved. Treatment should be initiated as soon as possible with fluid resuscitation, broad-spectrum antibiotics, aggressive surgical debridement, and reconstruction. Skin grafts and a variety of flaps are commonly used for reconstruction. The best option for reconstruction should rely on the surgeon’s expertise, patient preference, and available resources.

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REFERENCES

1. Fournier JA. Jean-Alfred Fournier 1832–1914. Gangrène foudroyante de la verge (overwhelming gangrene). Sem Med 1883. Dis Colon Rectum. 1988;31:984–988.
2. Sorensen MD, Krieger JN, Rivara FP, et al. Fournier’s gangrene: population based epidemiology and outcomes. J Urol. 2009;181:3210–3216.
3. Chennamsetty A, Khourdaji I, Burks F, Killinger KA. Contemporary diagnosis and management of Fournier’s gangrene. Ther Adv Urol. 2015;7:203–215.
4. Iacovelli V, Gipriani C, Sandri M, et al. The role of vacuum-assisted closure (VAC) therapy in the management of Fournier’s gangrene: a retrospective multi-institutional cohort study. World J Urol. 2021;39:121–128.
5. Silva J, Gomes J, Vendeira P, Diniz P, Cruz F, Reis M. Fournier’s gangrene: ten year experience at a single institution. Eur Urol Suppl. 2002;2:1178.
6. Parkash S, Gajendran V. Surgical reconstruction of the sequlae of penile and scrotal gangrene: a plea for simplicity. Br J Plast Surg. 1984;37:354–357.
7. Morris MS, Morey AF, Stackhouse DA, et al. Fibrin sealant as tissue glue: preliminary experience in complex genital reconstructive surgery. Urology. 2006;67:499; discussion 691.
8. Ferreira PC, Reis JC, Amarante JM, et al. Fournier’s gangrene: a review of 43 reconstructive cases. Plast Reconstr Surg. 2007;119:175–184.
9. Hsu H, Lin CM, Sun TB, et al. Unilateral gracilis myofasciocutaneous advancement flap for single stage reconstruction of scrotal and perineal defects. J Plast Reconstr Aesthet Surg. 2007;60:1055–1059.
10. Carvalho JP, Hazan A, Cavalcanti AG, et al. Relation between the area affected by Fournier’s gangrene and the type of reconstructive surgery used: a study with 80 patients. International Braz J Urol. 2007;33:510–514.
11. Bhatnagar AM, Mohite PN, Suthar M. Fournier’s gangrene: a review of 110 cases for aetiology, predisposing conditions, microorganisms, and modalities for coverage of necrosed scrotum with bare testes. NZ Med J. 2008;121:46–56.
12. Chen SY, Fu JP, Wang CH, et al. Fournier gangrene: a review of 41 patients and strategies for reconstruction. Ann Plast Surg. 2010;64:766–769.
13. Tan BK, Rasheed MZ, Wu WT. Scrotal reconstruction by testicular apposition and wraparound skin grafting. J Plast Reconstr Aesthet Surg. 2011;64:944–948.
14. Cooksirat OK, Udo A, Cingolat A, et al. Superiority of medial circumflex femoral artery perforator flap in scrotal reconstruction. Ann Plast Surg. 2011;67:526–530.
15. Lee SH, Rah DK, Lee WJ. Penoscutral reconstruction with gracilis muscle flap and internal pudendal artery perforator flap transposition. Urology. 2012;79:1390–1394.
16. Sivrioglu N, Ikroen S, Ceylan E, et al. 2-octyl-cyanoacrylate glue for fixation of STSG in genitourinary tissue defects due to Fournier gangrene: a preliminary trial. Uroloji. 2013;19:215–218.
17. Akkaw O, Pompeo A, Sehrt D, et al. Early scrotal approximation after hemiscrotectomy in patients with Fournier’s gangrene prevents scrotal reconstruction with skin graft. Can Urol Assoc J. 2013;7:E481–E485.
18. Ünderveri OY. Kemaloglu CA. A reliable technique in the reconstruction of large penoscrotal defects: internal pudendal artery perforator flap. Urology. 2019;128:102–106.
19. Eswara JR, McDougall WS. Long-term outcomes of surgical management for nonmalignant perineal disease. J Urol. 2013;190:2139–2143.
20. Wolach MD, MacDermott JP, Stone AR, et al. Treatment and complications of Fournier’s gangrene. Br J Urol. 1989;64:310–314.
21. El-Khatib HA. VV fasciocutaneous pudendal thigh flap for repair of perineum and genital region after necrotizing fasciitis: modification and new indication. Ann Plast Surg. 2002;48:370–375.
22. Hejase MJ, Simonin JE, Bührle R, et al. Genital Fournier’s gangrene: experience with 38 patients. Urology. 1996;47:734–739.
23. Louro JM, Alhano M, Baltazar J, et al. Fournier’s gangrene: 10 year experience of a plastic surgery and burns department at a tertiary hospital. Acta Med Port. 2019;32:368–374.
24. Chen SY, Fu JP, Chen TM, et al. Reconstruction of scrotal and perineal defects in Fournier’s gangrene. J Plast Reconstr Aesthet Surg 2011;64:528–534.
25. Zhang N, Yu X, Zhang K, et al. A retrospective case series of Fournier’s gangrene: necrotizing fasciitis in perineum and perianal region. BMC Surg. 2020;20:259.
26. Koukouras D, Kallidounis P, Panagopoulos C, et al. Fournier’s gangrene, a urologic and surgical emergency: presentation of a multi-institutional experience with 45 cases. Urol Int. 2011;86:167–172.
27. Perry TL, Kranke LM, Mobley EE, et al. Outcomes in Fournier’s gangrene using skin and soft tissue sparing flap preservation surgery for wound closure: an alternative approach to wide radical debridement. Wounds. 2018;30:290–299.
28. Saffle JR, Morris SE, Edelman L. Fournier’s gangrene: management at a regional burn center. J Burn Care Res. 2008;29:196–203.
29. Gündüz M, Yücebas E, Tekin A, et al. Predisposing factors and treatment outcome in Fournier’s gangrene. Anal Plast Surg. 2019;32:368–374.
30. Wang L, Han X, Liu M, et al. Experience in management of Fournier’s gangrene: a report of 24 cases. J Huazhong Univ Sci Technol Med Sci. 2012;32:719–723.
31. Omisanjo OA, Bioku MJ, Ikuerowo SO, et al. Clinical characteristics and outcome of management of Fournier’s gangrene at the Lagos State University Teaching Hospital, Ikeja, Lagos, Nigeria. Afr J Med Med Sci. 2014;13:174–178.
32. Khanal B, Agrawal S, Gurung R, et al. Pudendal flap—a good option for creating neo-scrotum after Fournier’s gangrene: a case series. J Surg Case Rep. 2020;2020:rjaa414.
33. Dadaci M, Yildirim MEC, Yarar S, et al. Assessment of outcomes after Limberg flap reconstruction for scrotal defects in patients with Fournier’s gangrene. Can Urol Assoc J. 2021;38:65–69.
34. Fournier gangrene: ten year experience of a plastic surgery and burns department at a regional burn center. J Burn Care Res. 2008;29:196–203.
35. Agwu NP, Muhammad AS, Abdullahi AA, et al. Pattern and outcome of management of Fournier’s gangrene at a tertiary hospital. J Plast Reconstr Aesthet Surg. 2019;32:368–374.
36. Saffle JR, Morris SE, Edelman L. Fournier’s gangrene: management at a regional burn center. J Burn Care Res. 2008;29:196–203.
37. Chen SY, Fu JP, Chen TM, et al. Outcomes in Fournier’s gangrene using skin and soft tissue sparing flap preservation surgery for wound closure: an alternative approach to wide radical debridement. Wounds. 2018;30:290–299.
38. Saffle JR, Morris SE, Edelman L. Fournier’s gangrene: management at a regional burn center. J Burn Care Res. 2008;29:196–203.
39. Gündüz M, Yücebas E, Tekin A, et al. Predisposing factors and treatment outcome in Fournier’s gangrene. Anal Plast Surg. 2019;32:368–374.
40. Wang L, Han X, Liu M, et al. Experience in management of Fournier’s gangrene: a report of 24 cases. J Huazhong Univ Sci Technol Med Sci. 2012;32:719–723.
41. Omisanjo OA, Bioku MJ, Ikuerowo SO, et al. Clinical characteristics and outcome of management of Fournier’s gangrene at the Lagos State University Teaching Hospital, Ikeja, Lagos, Nigeria. Afr J Med Med Sci. 2014;13:174–178.
42. Khanal B, Agrawal S, Gurung R, et al. Pudendal flap—a good option for creating neo-scrotum after Fournier’s gangrene: a case series. J Surg Case Rep. 2020;2020:rjaa414.
with a particular focus on those without perineal involvement. *Gastrointest Rep (Oxf).* 2019;7:212–217.

38. Sockalingam VS, Subburayan E, Velu E, et al. Fournier’s gangrene: prospective study of 34 patients in South Indian population and treatment strategies. *Pon Afr Med J.* 2018;31:110.

39. Lin TY, Cheng IH, Ou CH, et al. Incorporating simplified Fournier’s gangrene severity index with early surgical intervention can maximize survival in high-risk Fournier’s gangrene patients. *Int J Urol.* 2019;26:737–743.

40. Arora A, Rege S, Surpam S, et al. Predicting mortality in Fournier gangrene and validating the fournier gangrene severity index: our experience with 50 patients in a tertiary care center in India. *Urol Int.* 2019;102:311–318.

41. Hahn HM, Jeong KS, Park DH, et al. Analysis of prognostic factors affecting poor outcomes in 41 cases of Fournier’s gangrene. *Ann Surg Treat Res.* 2018;95:324–332.

42. Kranz J, Schlager D, Anheuser P, et al. Desperate need for better management of Fournier’s gangrene. *Cent European J Urol.* 2018;71:360–365.

43. Kuzaka B, Wróblewska MM, Borkowski T, et al. Fournier’s gangrene: clinical presentation of 13 cases. *Med Sci Monit.* 2018;24:548–555.

44. Ioannidis O, Kitiskota L, Tatis D, et al. Fournier’s gangrene: lessons learned from multimodal and multidisciplinary management of perineal necrotizing fasciitis. *Front Surg.* 2017;4:36.

45. Lauerman MH, Kolesnik O, Sethuraman K, et al. Less is more? Antibiotic duration and outcomes in Fournier’s gangrene. *J Trauma Acute Care Surg.* 2017;83:443–448.

46. Morais H, Neves J, Ribeiro HM, et al. Case series of Fournier’s gangrene: Affected body surface area—the underestimated prognostic factor. *Ann Med Surg (Lond).* 2017;16:19–22.

47. Osbun N, Hampson LA, Holt SK, et al. Low-volume vs high-volume centers and management of Fournier’s gangrene in Washington State. *J Am Coll Surg.* 2017;224:270–275.e271.

48. El-Shazly M, Aziz M, Aboulaleb H, et al. Management of perineal necrotizing fasciitis. *Arch Ital Urol Androl.* 2016;89:208–211.

49. Tarchouli M, Bounaim A, Essarghini M, et al. Analysis of prognostic factors affecting mortality in Fournier’s gangrene: a study of 72 cases. *Can Urol Assoc J.* 2015;9:E800–E804.

50. Chiala PI, Igegne JZ, Mabula JB, et al. Fournier’s gangrene at a tertiary health facility in northwestern Tanzania: a single centre experiences with 84 patients. *BMC Research Notes.* 2015;8:1–7.

51. Oguz A, Gümüş M, Türkoglu A, et al. Fournier’s gangrene: a summary of 10 years of clinical experience. *Urol Int.* 2016;90:934–941.

52. Aliyu S, Ibrahim AG, Ali N, et al. Fournier’s gangrene as seen in University of Maiduguri Teaching Hospital. *JSR Med.* 2015;6:37121.

53. Avakoudjo D, Natchagandé G, Hounnasso P, et al. Fournier’s gangrene in Cotonou, Benin Republic. *J West Afr Coll Surg.* 2015;3:75–87.

54. Bengelloun el B, Souki T, Yakla N, et al. Fournier’s gangrene: our experience with 50 patients and analysis of factors affecting mortality. *World J Emerg Surg.* 2013;8:13.

55. Katib A, Al-Adawi M, Dakkak B, et al. A three-year review of the management of Fournier’s gangrene presented in a single Saudi Arabian institute. *Cent European J Urol.* 2013;66:331–334.

56. Azizoglu IA, Isol V, Abat D, et al. Epidemiological characteristics of Fournier’s gangrene: a report of 71 patients. *Urol Int.* 2012;89:457–461.

57. Altarac S, Kutsiun D, Crnica S, et al. Fournier’s gangrene: etiology and outcome analysis of 41 patients. *Urol Int.* 2012;88:289–293.

58. Djedovic G, Del Frari B, Matiaske J, et al. The versatility of the medial thigh lift for defect coverage in the genito-perineal region. *Int Wound J.* 2017;14:496–500.

59. Chia L, Crum-Cianflone NF. Emergence of multi-drug resistant organisms (MDROs) causing Fournier’s gangrene. *J Infect.* 2018;76:38–43.

60. Yasar H, Taviloglu K, Ertégün C, et al. Fournier’s gangrene: risk factors and strategies for management. *World J Surg.* 2006;30:1750–1754.

61. Feres O, Feitosa MR, Ribeiro da Rocha JJ, et al. Hyperbaric oxygen therapy decreases mortality due to Fournier’s gangrene: a retrospective comparative study. *Med Gas Res.* 2021;11:18–25.

62. Beecroft NJ, Jaeger CD, Rose JR, et al. Fournier’s gangrene in females: presentation and management at a tertiary center. *Urology.* 2021;151:113–117.

63. Oyelowo N, Ahmed M, Lawal AT, et al. Fournier’s gangrene: presentation and predictors of mortality in Zaria, Nigeria. *Ann Afr Med.* 2021;20:105–110.

64. Michalczyk L, Grahińska A, Banaczyk B, et al. Efficiency of hyperbaric oxygen therapy combined with negative-pressure wound therapy in the treatment strategy of Fournier’s gangrene—A retrospective study [Published online ahead of print Aug 16, 2021]. *Urol J.* 2021.

65. Caprini A, Iacovelli V, Sandri M, et al. The microbiological profile of patients with Fournier’s gangrene: a retrospective multi-institutional cohort study. *Urologia.* [Ahead of print May 22, 2021].

66. Lauerman M, Kolesnik O, Park H, et al. Definitive wound closure techniques in Fournier’s gangrene. *Am Surg.* 2018;84:86–92.

67. Chang FS, Chou C, Hu CY, et al. Suture technique to prevent air leakage during negative-pressure wound therapy in Fournier gangrene. *Plast Reconstr Surg Glob Open.* 2018;6:e1650.

68. Yücel M, Özpek A, Başak F, et al. Fournier’s gangrene: a retrospective analysis of 25 patients. *Ulus Travma Acil Cerrahi Derg.* 2017;23:400–404.

69. Hong KS, Yi HJ, Lee RA, et al. Prognostic factors and treatment outcomes for patients with Fournier’s gangrene: a retrospective study. *Int Wound J.* 2017;14:1352–1358.

70. Furr J, Watts T, Street R, et al. Contemporary trends in the inpatient management of Fournier’s gangrene: predictors of length of stay and mortality based on population-based sample. *Urology.* 2017;102:79–84.

71. Yanardal F, Balci C, Ozgor F, et al. Comparison of conventional dressings and vacuum-assisted closure in the wound therapy of Fournier’s gangrene. *Arch Ital Urol Androl.* 2017;89:208–211.

72. Ozkan OF, Kosal N, Altinli E, et al. Fournier’s gangrene current presentation and predictors of mortality in Zaria, Nigeria. *Ann Afr Med.* 2016;5:206:175–181.

73. Zhang Z, Lv L, Mamat M, et al. Xenogenic (porcine) acellular dermal matrix promotes growth of granulation tissues in the wound healing of Fournier gangrene. *Am Surg.* 2015;81:92–95.

74. Eray IC, Alabaz O, Akcam AT, et al. Comparison of diverting colostomy and bowel management catheter applications in fournier gangrene cases requiring fecal diversion. *Indian J Surg.* 2015;77(Suppl 2):438–441.

75. Milanese G, Quaresima L, Dellabella M, et al. A conservative approach to perineal Fournier’s gangrene. *Arch Ital Urol Androl.* 2015;87:28–32.

76. Li C, Zhou X, Liu LF, et al. Hyperbaric oxygen therapy as an adjuvant therapy for comprehensive treatment of Fournier’s gangrene. *Med Gas Res.* 2015;5:43–48.

77. Li YD, Zhu WF, Qiao JF, et al. Enterostomy can decrease the mortality of patients with Fournier gangrene. *World J Gastrointest.* 2014;6:7950–7954.

78. Haidari M, Nazer MR, Ahmadinejad M, et al. Honey in the treatment of Fournier’s gangrene as an adjuvant: a cross sectional study. *J Pak Med Assoc.* 2014;64:571–573.
102. Pizzorno R, Bonini F, Donelli A, et al. Hyperbaric oxygen therapy in the treatment of Fournier’s disease in 11 male patients. J Urol. 1997;158(3 Pt 1):837–840.

103. Ong HS, Ho YH. Genitoperineal gangrene: experience in Singapore. Aust N Z J Surg. 1996;66:291–293.

104. Benizri E, Fabiani P, Migliori G, et al. Gangrene of the perineum. Urology. 1996;47:935–939.

105. Efem SE. Recent advances in the management of Fournier’s gangrene: preliminary observations. Surgery. 1993;113:200–204.

106. Salvino C, Harford EJ, Dobrin PB. Necrotizing infections of the perineum. South Med J. 1993;86:908–911.

107. Attah GA. New approach to the management of Fournier’s gangrene. Br J Urol. 1992;70:78–80.

108. Thambi Doral CR, Kasanam P. Fournier’s gangrene: its aetiology and management. Aust N Z J Surg. 1991;61:370–372.

109. Hirn M, Niinikoski J. Management of perineal necrotizing fasciitis (Fournier’s gangrene). Ann Chir Gynaecol. 1989;78:277–281.

110. Scott SD, Dawes RF, Tate JJ, et al. The practical management of Fournier’s gangrene. Ann R Coll Surg Engl. 1988;70:16–20.

111. Barkel DC, Villaiba MR. A reappraisal of surgical management in necrotizing perineal infections. Am Surg. 1986;52:395–397.

112. Badejo OA. Management of scrotal gangrene. Trop Geogr Med. 1985;37(4):387–392.

113. Chennamsetty A, Khourdaji I, Burks F, et al. Contempory diagnosis and management of Fournier’s gangrene. Ther Adv Urol. 2015;7:203–215.

114. Gangrene PRSA. Fournier’s gangrene. Urologic Clinics of North America. 1992;19:149–162.

115. Mallikarjuna MN, Vijayakumar A, Patil VS, et al. Fournier’s gangrene: current practices. ISRN Surg. 2012:2012:942437.

116. Eke N. Fournier’s gangrene: a review of 1726 cases. Br J Surg. 2000;87:718–728.

117. Takano N, Yatabe MS, Yatabe J, et al. Fatal Fournier’s gangrene caused by Clostridium ramous in a patient with central diabetes insipidus and insulin-dependent diabetes mellitus: a case report. BMC Infect Dis. 2018;18:363.

118. Yoshino Y, Funahashi K, Okada R, et al. Severe Fournier’s gangrene in a patient with rectal cancer: case report and literature review. World J Surg Oncol. 2016;14:234.

119. Bartolotta TV, Midiri M, Caruso G, et al. [Necrotizing fasciitis of the scrotum (Fournier’s gangrene): ultrasound findings]. Redol Med. 2000;100:510–512.

120. Singh A, Ahmed K, Adivin A, et al. Fournier’s gangrene. A clinical review. Arch Ital Urol Androl. 2016;88:157–164.

121. Rybak MJ, Le J, Lodise TP, et al. Therapeutic monitoring of vancomycin for serious methicillin-resistant Staphylococcus aureus infections: a revised consensus guideline and review by the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Pediatric Infectious Diseases Society, and the Society of Infectious Diseases Pharmacists. Am J Health Syst Pharm. 2020;77:835–864.

122. Anaya DA, Dellinger EP. Necrotizing soft-tissue infection: diagnosis and management. Clin Infect Dis. 2007;44:705–710.

123. Gupta A, Dalela D, Sankhwar SN, et al. Bilateral testicular gangrene: does it occur in Fournier’s gangrene? Int Urol Nephrol. 2007;39:913–915.

124. Ramos RR, Andrews JM, Ferreira LM. A gracilis myocutaneous flap for scrotal reconstruction. J Plast Reconstr Aesthet Surg. 2016;69:e195–e196.

125. Young WA, Wright JK. Scrotal reconstruction with a rectus myocutaneous flap. Br J Plast Surg. 1988;41:190–193.

126. Karian LS, Chung SY, Lee ES. Reconstruction of defects after Fournier gangrene: a systematic review. Eplasty. 2015;15:e18.