

Contemporary diagnosis and management of Fournier's gangrene

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Abstract: Fournier's gangrene, an obliterative endarteritis of the subcutaneous arteries resulting in gangrene of the overlying skin, is a rare but severe infective necrotizing fasciitis of the external genitalia. Mainly associated with men and those over the age of 50, Fournier's gangrene has been shown to have a predilection for patients with diabetes as well as people who are long-term alcohol misusers. The nidus for the synergistic polymicrobial infection is usually located in the genitourinary tract, lower gastrointestinal tract or skin. Early diagnosis remains imperative as rapid progression of the gangrene can lead to multiorgan failure and death. The diagnosis is often made clinically, although radiography can be helpful when the diagnosis or the extent of the disease is difficult to discern. The Laboratory Risk Indicator for Necrotizing Fasciitis score can be used to stratify patients into low, moderate or high risk and the Fournier's Gangrene Severity Index (FGSI) can also be used to determine the severity and prognosis of Fournier's gangrene. Mainstays of treatment include rapid and aggressive surgical debridement of necrotized tissue, hemodynamic support with urgent resuscitation with fluids, and broad-spectrum parental antibiotics. After initial radical debridement, open wounds are generally managed with sterile dressings and negative-pressure wound therapy. In cases of severe perineal involvement, colostomy has been used for fecal diversion or alternatively, the Flexi-Seal Fecal Management System can be utilized to prevent fecal contamination of the wound. After extensive debridement, many patients sustain significant defects of the skin and soft tissue, creating a need for reconstructive surgery for satisfactory functional and cosmetic results.

Keywords: debridement, Fournier's Gangrene, Fournier's Gangrene Severity Index, necrotizing fasciitis

Introduction

Fournier's gangrene (FG) is a type of necrotizing fasciitis of the perineal, genital and perianal region that has a rapidly progressive and potentially fatal course [Vick and Carson, 1999]. Similar to other necrotizing soft tissue infections, the inflammation and edema from the polymicrobial infection lead to an obliterative endarteritis of the subcutaneous arteries [Korkut *et al.* 2003]. This impaired blood supply furthers perifascial dissection with spread of bacteria and progression to gangrene of the overlying subcutaneous tissue and skin.

Even though FG was first described by Baurienne in 1764 [Nathan, 1998], it is credited to the French venereologist, Jean Alfred Fournier, who provided a detailed description of the disease in

1883 as a fulminant gangrene of the penis and scrotum [Fournier, 1883]. Over the years, experience has shown that FG often has an identifiable cause and it frequently manifests indolently. Many terms have been used to describe the clinical condition including 'idiopathic gangrene of the scrotum', 'periurethral phlegmon', 'streptococcal scrotal gangrene', 'phagedena' and 'synergistic necrotizing cellulitis' [Meleney, 1924; Gray, 1960; Shyam and Rapsang, 2013].

Subjects of both genders and all ages may be affected [Sorensen *et al.* 2009a]; however, FG has a predilection for those over the age of 50 with a male to female ration of 10 to 1 [Alonso *et al.* 2000; Eke, 2000]. Early diagnosis remains imperative, as the rate of fascial necrosis has been noted

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as high as 2–3 cm per hour [Uppot *et al.* 2003; Safioleas *et al.* 2006]. Treatment of FG entails treating sepsis, stabilizing medical parameters and urgent surgical debridement. Despite timely and aggressive management, the condition is life threatening as most studies report mortality rates of between 20% and 40% with a range of 4–88% [Morpurgo and Galandiuk, 2002; Sorensen *et al.* 2009b]. Interestingly, the mortality has been shown to be higher in technologically advanced countries such as the United States, Canada and Europe than in underdeveloped countries [Eke, 2000].

Predisposing factors

Primarily an infective condition, FG has several predisposing factors and theoretically, any condition that decreases the host immunity may predispose a person to the development of FG. The most common predisposing factors are diabetes mellitus and alcohol overindulgence, which are reported to be present in 20–70% and 20–50% of patients, respectively [Clayton *et al.* 1990; Morpurgo and Galandiuk, 2002]. The relatively high incidence of FG in patients with diabetes has been attributed to their small vessel disease, defective phagocytosis, diabetic neuropathy and immunosuppression, all of which can be exacerbated by poor hygiene when present [Vick and Carson, 1999]. Other risk factors include extremes in age, malignancy, chronic steroid use, cytotoxic drugs, lymphoproliferative disease, malnutrition and human immunodeficiency virus (HIV) infection [Mallikarjuna *et al.* 2012]. In certain countries, near epidemic proportions of HIV places a large population at risk for developing FG [Elem and Ranjan, 1995].

Etiology

FG was initially defined as an idiopathic entity, but recent research has shown that less than a quarter of FG cases are now considered idiopathic [Smith *et al.* 1998; Vick and Carson, 1999]. Colorectal sources (30–50% of cases), urogenital sources (20–40% of cases), cutaneous infections (20% of cases) and local trauma are frequently identified as the cause of FG [Eke, 2000]. Colorectal sources include local infection, abscesses (particularly in the perianal, perirectal and ischioanal regions), anal fissures, colonic perforations, diverticulitis, hemorrhoidectomy and rectal carcinoma [Ash and Hale, 2005]. Urologic sources of FG include urethral strictures,

chronic urinary tract infection, neurogenic bladder, epididymitis and recent instrumentation [Amendola *et al.* 1994]. In women, additional sites of origin include Bartholin gland or vulvar abscess, episiotomy, hysterectomy and septic abortion [Morua *et al.* 2009]. Insect bites, burns, trauma and circumcision have also been reported as causes of pediatric FG [Amendola *et al.* 1994].

Pathogenesis and organisms involved

The predisposing and etiologic factors of FG provide a favorable environment for the infection by decreasing the host immunity and allowing a portal of entry for the microorganism into the perineum. The incident leading to the inoculation may be so trivial that the patient or physician may fail to notice. Characteristically, FG exists due to synergism between multiple bacteria that theoretically are not highly aggressive when presented alone. The polymicrobial nature of FG with contributions by both aerobic and anaerobic bacteria is necessary to create the production of various exotoxins and enzymes like collagenase, heparinase, hyaluronidase, streptokinase and streptodornase, which promote rapid multiplication and spread of infection. The aerobic bacteria cause platelet aggregation and induce complement fixation, thereby causing acceleration of coagulation. The anaerobic bacteria promote the formation of clots by producing collagenase and heparinase. Other organisms like *Bacteroides* inhibit the phagocytosis of aerobic bacteria, aiding in further spread of the infection [Morua *et al.* 2009; Shyam and Rapsang, 2013].

The organisms that tend to be found in FG are species that normally exist below the pelvic diaphragm in the perineum and genitalia [Eke, 2000]. The most commonly isolated aerobic microorganisms are *Escherichia coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus*, while the most commonly isolated anaerobic microorganism is *Bacteroides fragilis* [Paty and Smith, 1992]. Other organisms include *Streptococcus*, *Enterococcus*, *Clostridium*, *Pseudomonas* and *Proteus* species. In some series, an average of more than three organisms were cultured from each patient [Addison *et al.* 1984; Thwaini *et al.* 2006]. Group A streptococcal is the most common cause of monomicrobial necrotizing fasciitis [Ekelius *et al.* 2004]. Although rare, necrotizing fasciitis due to *Candida* species as well as *Lactobacillus gasseri* has also been reported [Tleyjeh *et al.* 2004; Jensen *et al.* 2010]. Ultimately, the microorganism's virulence promotes the rapid

spread of the disease from a localized infection near the portal of entry into an obliterative endoarteritis with cutaneous and subcutaneous vascular necrosis, leading to local ischemia and further bacterial proliferation [Mallikarjuna *et al.* 2012].

The infection in FG tends to spread along the fascial planes with initial involvement of the superficial (Colles fascia) and deep fascial planes of the genitalia. Subsequently, there is spread to the overlying skin with sparing of the muscles. Infection of Colles fascia may then spread to the penis and scrotum *via* Buck's and Dartos fascia, or to the anterior abdominal wall *via* Scarpa's fascia, or *vice versa*. The inferior epigastric and deep circumflex iliac arteries supply the lower aspect of the anterior abdominal wall, whereas the external and internal pudendal arteries supply the scrotal wall. With the exception of the internal pudendal artery, each of these vessels travels within Camper's fascia and can therefore become thrombosed in the progression of FG [Katib *et al.* 2013]. The Colles fascia is attached laterally to the pubic rami and fascia lata and posteriorly to the urogenital diaphragm, thus limiting progression in these directions. In contrast, anorectal sources of infection usually start in the perianal area, a clinical variation that can serve as a guide to localizing the foci of infection [Smith *et al.* 1998]. Testicular involvement is limited in FG by the fact that the blood supply is derived from the aorta, independent from the affected region [Gupta *et al.* 2007]. However, involvement of the testis suggests retroperitoneal origin or spread of infection [Eke, 2000; Chawla *et al.* 2003]. Even though thrombosis of the corpus spongiosum and cavernosum has been reported, corpora involvement is rare while the penile skin sloughs off [Campos *et al.* 1990].

Clinical features

The clinical features of FG include sudden pain and swelling in the scrotum, purulence or wound discharge, crepitation, fluctuance, prostration, pallor and fever greater than 38°C (Figure 1) [Yeniyol *et al.* 2004]. Usually the infection starts as a cellulitis adjacent to the portal of entry, commonly in the perineum or perineal region, with an insidious presentation. The affected area is often swollen, dusky and covered by macerated skin and presents with a characteristic feculent odor, which is attributed to the role of anaerobes in the infection [Alonso *et al.* 2000]. Patients also may have pronounced systemic signs, usually out of



Figure 1. Fournier's gangrene in the scrotum. Photo credit D. Rosenstein.

proportion to the local extent of the disease. In those with severe clinical presentation, progression of the gangrenous process to malodorous drainage and sloughing in affected sites results in deterioration of the patient's overall condition. Ferreira and colleagues reviewed 43 cases and found the most common presentations were scrotal swelling, fever and pain [Ferreira *et al.* 2007]. In another review of 70 patients, Ersay and colleagues found the most common presentation was perianal/scrotal pain (79%) followed by tachycardia (61%), purulent discharge from the perineum (60%), crepitus (54%) and fever (41%) [Ersay *et al.* 2007; Mallikarjuna *et al.* 2012]. Crepitus of the inflamed tissues is a common feature due to the presence of gas-forming organisms [Paty and Smith, 1992]. As the subcutaneous inflammation worsens, necrosis and suppuration of subcutaneous tissues progresses to extensive necrosis [Laucks *et al.*, 1994]. Patients can rapidly deteriorate as sepsis and multiorgan failure, the most common cause of death in these cases, develop [Sutherland and Meyer, 1994].

Diagnosis

The diagnosis of FG is primarily based on clinical findings of fluctuance, crepitus, localized tenderness and wounds of the genitalia and perineum. Although diagnosis is straightforward when the lesions are found, failure to examine the genitals, especially in the older or obtunded patient, can result in misdiagnosis. The common laboratory findings are nonspecific and may show anemia, leukocytosis, thrombocytopenia, electrolyte abnormalities, hyperglycemia, elevated serum creatinine level, azotemia and hypoalbuminemia [Shyam and Rapsang, 2013]. The diagnosis of FG

is primarily clinical, and in most cases imaging is neither necessary nor desirable. Under no circumstances should surgery be delayed significantly for imaging of any kind. However, imaging modalities may be useful in cases when the presentation is atypical or when there is concern regarding the true extent of the disease.

Conventional radiography can be used to detect the presence of soft tissue air in the area overlying the scrotum and perineum before clinical crepitus is detected. In addition to demonstrating significant swelling of the scrotal soft tissue, radiographs may also detect subcutaneous emphysema extending from the scrotum and perineum to the inguinal regions, anterior abdominal wall and thighs. However, the absence of subcutaneous air, which is demonstrated in 10% of patients, does not exclude the diagnosis of FG [Sherman *et al.* 1998]. A significant weakness of radiography in the diagnosis and evaluation of FG is the lack of detection of deep fascial gas [Wysoki *et al.* 1997].

Ultrasound (US) findings in FG include a thickened, edematous scrotal wall containing hyperechoic foci that demonstrate reverberation artifacts, causing 'dirty' shadowing which represents gas within the scrotal wall [Levenson *et al.* 2008]. In addition, US can demonstrate paratesticular fluid, which is seen prior to clinical crepitus. This imaging modality is also useful in differentiating FG from inguinoscrotal hernias. Overall, US is considered superior to conventional radiography as soft tissue air is more obvious and scrotal contents along with Doppler blood flow can be examined.

Computed tomography (CT) plays an important role in the diagnosis of FG as well as the evaluation of the extent of the disease to guide appropriate surgical treatment. CT findings include asymmetric fascial thickening, fluid collections, abscess formation, fat stranding around involved structures and subcutaneous emphysema [Rajan and Scharer, 1998; Sherman *et al.* 1998; Levenson *et al.* 2008]. The underlying cause of FG, such as a perianal abscess, a fistulous tract, or an intraabdominal or retroperitoneal infectious process, may also be demonstrated by CT [Rajan and Scharer, 1998]. It can help to evaluate both the superficial and the deep fascia, and to differentiate FG from less aggressive entities such as soft-tissue edema or cellulitis, which may appear similar to FG on physical examination. As a whole, CT has greater specificity for evaluating

disease extent than does radiography, US or even physical examination [Rajan and Scharer, 1998].

Magnetic resonance imaging (MRI) offers an important diagnostic adjunct in the management of FG as it is more useful than conventional radiography and US for specifying range of infection. Some argue that MRI is even more helpful than CT in planning any operative intervention [Sharif *et al.* 1990; Yoneda *et al.* 2010].

Investigations

Despite timely and aggressive treatment, the mortality rate for FG remains high [Morpurgo and Galandiuk, 2002; Sorensen *et al.* 2009b]. Various comorbidities are known to be associated with FG, of which DM is most common. However, its association with increased mortality is debatable [Kabay *et al.* 2008; Unalp *et al.* 2008; Kara *et al.* 2009; Ersoz *et al.* 2012]. Similarly, there is uncertainty about the association of age and mortality in FG [Yeniyol *et al.* 2004; Tuncel *et al.* 2006; Lujan *et al.* 2010]. However, two comorbidities associated with increased mortality in FG are ischemic heart disease and hemodialysis-dependent renal failure [Jeong *et al.* 2005; Altarac *et al.* 2012; Ersoz *et al.* 2012].

The presence of severe sepsis on admission has been significantly associated with mortality [Kara *et al.* 2009; Altarac *et al.* 2012]. Additionally, the volume of necrosis appears to be a prognostic factor as some studies show patients with a gangrenous area less than 3% of the body surface rarely die, whereas patients presenting with a gangrenous area of 5% body surface area or more have a worse prognosis [Dahm *et al.* 2000; Horta *et al.* 2009; Janane *et al.* 2011]. However, the association between larger gangrenous areas and worse prognosis is not universally accepted [Clayton *et al.* 1990; Laor *et al.* 1995].

Abnormal laboratory parameters at admission have also been noted to have a significant impact on mortality. The laboratory values most often predictive of worse prognosis include increased leukocyte counts, creatinine, creatine kinase, urea, lactate dehydrogenase, alkaline phosphatase, and decreased levels of hematocrit, bicarbonate, sodium, potassium, calcium, total protein and albumin [Clayton *et al.* 1990; Laor *et al.* 1995; Chawla *et al.* 2003; Yeniyol *et al.* 2004; Jeong *et al.* 2005; Tuncel *et al.* 2006; Altarac *et al.* 2012; Vyas *et al.* 2013]. Using a weighted point

system of multiple laboratory markers, the Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score is often used to stratify patients into low, moderate or high risk for necrotizing soft tissue infections [Wong *et al.* 2004; Wolf and Wolf, 2010]. A LRINEC score of more than 6 should raise the suspicion of necrotizing fasciitis among patients with severe soft tissue infections, and a score greater than 8 is strongly predictive of FG.

A prognostic index known, as the Fournier's Gangrene Severity Index (FGSI), was created by Laor and colleagues to determine the severity and prognosis of FG in patients [Laor *et al.* 1995]. By quantifying the severity of infection using common vital signs (temperature, heart rate, respiratory rate) and laboratory data (serum sodium, serum potassium, serum creatinine, serum bicarbonate, hematocrit and white blood cell count), the FGSI score helps prognosticate progression and predict the mortality. The degree of deviation from normal is graded from 0 to 4, and individual values are summed to obtain the FGSI score. A score greater than 9 is suggested to have a 75% probability of death, and index score up to 9 is associated with a 78% probability of survival. FGSI has been validated by several studies [Chawla *et al.* 2003; Yenyol *et al.* 2004; Kabay *et al.* 2008; Unalp *et al.* 2008; Kara *et al.* 2009; Altarac *et al.* 2012]. Kabay and colleagues analyzed patients using this index and showed those with FGSI greater than 10.5 had 96% mortality whereas those with a score less than 10.5 had 96% survival [Kabay *et al.* 2008]. Kara and colleagues found that FGSI scores of at least 7 affected mortality rates with statistical significance ($p < 0.05$) and Altarac and colleagues noted that FGSI scores were significantly higher among nonsurvivors (11 *versus* 5, $p < 0.0001$) [Kara *et al.* 2009; Altarac *et al.* 2012]. However, controversy exists regarding the accuracy of FGSI, as Tuncel and colleagues and Janane and colleagues argued the index cannot be relied upon to predict survival [Tuncel *et al.* 2006; Janane *et al.* 2011].

Management of FG

The management of FG is underscored by three main principles: rapid and aggressive surgical debridement of necrotized tissue, hemodynamic support with urgent resuscitation with fluids, and broad-spectrum parental antibiotics [Corman *et al.* 1999; Eke, 2000; Chen *et al.* 2010; Akilov

et al. 2013]. As the rate of fascial necrosis has been noted as high as 2–3 cm per hour, FG is considered a surgical emergency with prompt, pragmatic and individualized therapy being the cornerstone for effective treatment [Eke, 2000; Safioleas *et al.* 2006; Akilov *et al.* 2013].

Broad-spectrum antibiotic coverage

Broad-spectrum parental antibiotic therapy is administered empirically upon diagnosis of FG and then subsequently tailored based on culture results. It is imperative that the antibiotic regimen chosen is effective against staphylococcal, streptococcal and gram-negative bacteria, coliforms, *Pseudomonas*, *Bacteroides* and *Clostridium* [Mallikarjuna *et al.* 2012]. Triple antibiotic therapy consisting of a broad-spectrum penicillin or third-generation cephalosporins, an aminoglycoside (e.g. gentamicin) and metronidazole or clindamycin is typically instituted empirically [Mallikarjuna *et al.* 2012; Benjelloun *et al.* 2013; Wroblewska *et al.* 2014]. Moreover, many have suggested adding penicillin for treatment of streptococci and, in particular, when *Clostridia* is suspected. Alternatively, clindamycin and chloramphenicol can be substituted empirically to facilitate coverage of gram-positive cocci and anaerobes until culture results return [Martinez-Rodriguez *et al.* 2009]. In patients infected with methicillin-resistant *S. aureus*, vancomycin should be utilized. Amphotericin B or caspofungin should be added to the empiric regimen should fungi be detected in tissue cultures [Pais *et al.* 2013; Wroblewska *et al.* 2014].

Radical surgical debridement

In addition to broad-spectrum parental antibiotics, early and aggressive surgical debridement has been shown to improve survival in patients presenting with FG as patients often undergo more than one debridement during their hospitalization [Corman *et al.* 1999; Chawla *et al.* 2003; Sorensen *et al.* 2009b]. In a retrospective study of 219 patients presenting with a diagnosis of FG, Proud and colleagues found that there was no statistically significant difference in mortality between patients who underwent debridement before transfer or within 24 h of presentation to those who had not. The authors attributed this seemingly counterintuitive observation to the range in severity of necrotizing soft tissue infections and to the notion that patients are less likely to succumb to localized infections. Regardless,

the authors still advocate rapid and timely surgical debridement [Proud *et al.* 2014].

Since the treatment of FG often requires highly acute and intensive multidisciplinary care, Sorensen and colleagues examined the difference in case severity and management between teaching and nonteaching hospitals. Overall, the authors analyzed 1641 cases of FG at a total of 593 hospitals. It was found that more FG cases were treated per year at teaching hospitals where more surgical procedures, debridements and supportive care were reported. Interestingly, patients treated at teaching hospitals had longer length of stay, greater hospital charges and a higher case fatality rate secondary to more acutely ill patients. After adjusting for patient and hospital factors, it was found that patients treated at hospitals where more individuals with FG were treated had 42–84% lower mortality than hospitals where only one patient per year was treated. This finding is likely attributable to more aggressive diagnosis and management of FG at experienced hospitals. Overall, the data in the study revealed that hospitals where more patients with FG are treated had lower mortality rates, supporting the need to regionalize care for patients with this disease [Sorensen *et al.* 2009b].

In a retrospective study of 19 patients diagnosed with FG, Chawla and colleagues studied the utilization of the FGSI to determine length of stay and survival. In this study, nonsurvivors had a higher FGSI compared with survivors but length of stay was not predicted by the FGSI. Moreover, it was found that mean number of surgical debridements in survivors was lower compared with that of nonsurvivors. Furthermore, length of stay was not affected by urinary or fecal diversion. Interestingly, it was observed that patient outcomes were similar regardless of management by general surgery or urology services [Chawla *et al.* 2003].

Topical therapy

After initial radical debridement, open wounds are generally managed with sterile dressings or negative-pressure wound therapy. In a retrospective review of 14 patients, Altunoluk and colleagues compared the efficacy of wound management with daily povidone iodine dressing *versus* Dakin's solution (sodium hypochlorite). Dakin's solution has wide antimicrobial efficacy against aerobic and anaerobic organisms. The authors found that

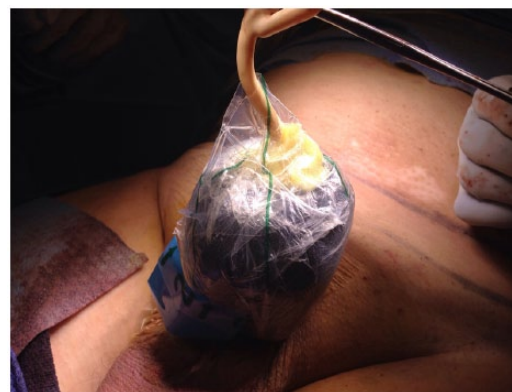


Figure 2. Negative-pressure wound therapy or vacuum-assisted closure therapy in the postoperative management of Fournier's gangrene. Photo credit D. Rosenstein.

the length of hospitalization was significantly shorter in patients managed with Dakin's solution compared with iodine dressing (8.9 days *versus* 13 days) perhaps secondary to the antimicrobial effects of the former [Altunoluk *et al.* 2012]. The use of topical honey has also been described in the management of FG because of its ability to inhibit microbial growth likely related to the osmotic effect of its high sugar content [Tahmaz *et al.* 2006]. Efem described the use of honey in conjunction with oral amoxicillin/clavulanic acid and metronidazole in 20 patients presenting with FG. Despite longer hospitalization compared with those undergoing wound debridement with systemic antibiotics, treatment with topical honey obviated the need for anesthesia and expenses associated with surgical operations. Moreover, response to treatment was found to be expedited in those treated with topical honey [Efem, 1993]. Tahmaz and colleagues found the efficacy of unprocessed honey to be similar in a retrospective review of 33 patients treated with topical honey *versus* radical surgical debridement [Tahmaz *et al.* 2006].

Vacuum-assisted closure therapy

Negative-pressure wound therapy (NPWT) or vacuum-assisted closure (VAC) therapy has been studied in the postoperative management of FG. VAC therapy works by exposing a wound to sub-atmospheric pressure for an extended period to promote debridement and healing (Figure 2) [Mallikarjuna *et al.* 2012]. NPWT can be used in wound management utilizing the lower limit of pressure, which is recommended to be between

50 and 125 mmHg. The negative pressure in NPWT leads to an increased blood supply and thus encourages migration of inflammatory cells into the wound region. Also, this promotes and accelerates the formation of granulation tissue by removing bacterial contamination, end products, exudates and debris compared with traditional dressing [Ozkan *et al.* 2014]. Czymek and colleagues prospectively collected data on 35 patients diagnosed with FG to assess the effectiveness of VAC therapy *versus* daily antiseptic (polyhexadine) dressings. Patients treated with VAC therapy had significantly longer hospitalization and lower mortality. However, significantly more patients required fecal diversion in the group receiving VAC therapy because of the need to reapply the vacuum dressing after each bowel movement. Fecal diversions may have been partially responsible for a higher mean number of surgical procedures in patients treated with VAC therapy compared with those whose wounds were treated with conventional dressings that were more easily changed on the wards. Overall, the authors state that VAC is not superior to conventional dressings in terms of length of hospital stay or clinical outcome. However, they are still clinically effective and successfully used in the management of large wounds [Czymek *et al.* 2009].

Hyperbaric oxygen therapy

A modality that has shown some promise as an adjunct to treatment of FG is hyperbaric oxygen (HBO) therapy, which entails exposing the patient to increased ambient pressure while breathing 100% oxygen [Mallikarjuna *et al.* 2012]. The physiological effects are believed to be enhanced leukocyte ability to kill aerobic bacteria, stimulation of collagen formation and increased levels of superoxide dismutase resulting in better tissue survival. Several case reports have demonstrated enhanced patient survival with the use of HBO in the setting of necrotizing fasciitis when combined with surgical debridement [Jallali *et al.* 2005].

Fecal and urinary diversion

Colostomy has been used for fecal diversion in cases of severe perineal involvement. Indications for colostomy include anal sphincter involvement, fecal incontinence and continued fecal contamination of the wound's margins. Although colostomy can be beneficial with regard to wound healing by avoiding fecal contamination, it should be performed only in selected cases because it

increases morbidity. The estimated percentage of patients requiring colostomy after debridement of FG is approximately 15%, and an increased mortality has been noted in patients requiring diversion [Yanar *et al.* 2006; Mallikarjuna *et al.* 2012]. In their study of 44 patients presenting with FG, Ozturk and colleagues found that in 18 patients that required temporary stoma formation, significant increases in healthcare costs were observed without an effect on outcomes. Overall, stoma creation and closure increased costs by approximately \$6650. Therefore, it is recommended that stoma formation be reserved for patients with fecal incontinence caused by extensive damage to the anal sphincter [Ozturk *et al.* 2011]. Nevertheless, the potential need for colostomy underscores the importance of a multidisciplinary approach to the management of the patient presenting with FG [Gurdal *et al.* 2003]. In a series of 28 consecutive patients with FG, Corman and colleagues found that general surgical service was involved in 52% of the initial operations to perform perianal and sometimes perirectal debridement [Corman *et al.* 1999]. Alternatively, the Flexi-Seal Fecal Management System has been introduced for fecal diversion, which can be utilized as an alternative method to colostomy as it successfully prevents fecal contamination of the wound [Ozkan *et al.* 2014]. In regards to urinary diversion, some authors suggest cystostomy, although most suggest that urinary catheterization provides satisfactory diversion [Yanar *et al.* 2006]. In a review of 26 cases of FG treated at a university medical center, Hollabaugh and colleagues utilized suprapubic diversion in 16 cases with 15 of those patients receiving diversion at the time of initial debridement. Indications for suprapubic urinary diversion included patients with extensive penile and perineal debridement, or periurethral abscesses [Hollabaugh *et al.* 1998]. In 74 patients presenting with FG at an Egyptian medical center, adequate urinary diversion was accomplished with the use of a urethral Foley catheter in all but one patient who had experienced a urethral injury. In this series, suprapubic cystostomy was recommended in patients experiencing urethral disruption or stricture [Ghnam, 2008].

Reconstructive surgery

After extensive debridement, many patients sustain significant defects of the skin and soft tissue, creating a need for reconstructive surgery for wound coverage as well as satisfactory functional



Figure 3. Fournier's gangrene extending from the scrotum into the inguinal region after debridement. Source: Frank Burks, MD.



Figure 4. Debrided scrotum with testicular thigh pouches. Source: Frank Burks, MD.

and cosmetic results (Figure 3). As a result of these defects, ensuing exposure of the testicles in the male patient presents a substantial challenge for reconstruction. The primary goal of reconstruction in patients who have undergone genital skin loss due to necrotizing fasciitis is simple and efficient coverage. Additional goals are good cosmesis and the preservation of penile function, including erection, ejaculation and micturition. Coverage has to be achieved in a way that restores function quickly with a good cosmetic outcome and low associated morbidity and mortality. Salvaging the testes is usually achieved by using techniques such as thigh pouches, skin grafts and use of fasciocutaneous or musculocutaneous flaps [Corman *et al.* 1999; Maguina *et al.* 2003; Black *et al.* 2004; Chen *et al.* 2010; Lee *et al.* 2012].

As mentioned previously, testicular involvement in FG is rare and suggests an intraabdominal or retroperitoneal source [Eke, 2000]. Though orchietomy is rarely required, it may be necessary in situations of extensive tissue damage in the surrounding scrotum, groin and perineum leading to difficult dressing changes [Ghnam, 2008]. Temporary thigh pouches to harbor the testicles may be utilized in scenarios when significant tissue loss may preclude complex scrotal

reconstruction in the acute setting (Figure 4) [Akilov *et al.* 2013]. Chan and collages state that implantation of the exposed testicle into an adjacent subcutaneous thigh flap can provide a shorter hospital stay and reduce recovery time. However, this technique is only temporizing, allowing the patient more time to recover until definitive scrotal reconstruction can be undertaken [Chan *et al.* 2013].

The best functional and cosmetic results are achieved with primary closure of any remaining scrotum, though this is only possible with small defects (Figures 5 and 6). Closure *via* secondary intention, particularly of large defects, prolongs healing time but also leads to contraction and deformity of the scrotum [Maguina *et al.* 2003]. In a retrospective study of 28 male patients presenting with FG, Akilov and colleagues evaluated the outcomes of early loose scrotal approximation and found that approximation of the scrotal wound at the time of surgical debridement in patients with up to 50% involvement may be safely performed with successful prevention of ipsilateral testis exposure. Loose wound edge closure was achieved with a nonabsorbable monofilament suture by U-stitch approximation of the scrotal or perineal wound edges [Akilov *et al.* 2013].



Figure 5. Extensive defect from Fournier's gangrene debridement prior to primary closure.
Photo credit D. Rosenstein.

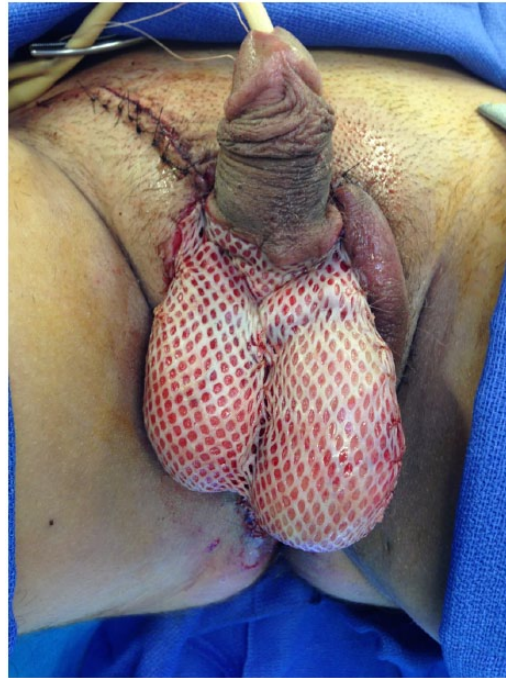


Figure 7. Significant scrotal skin loss after Fournier's gangrene debridement with meshed split-thickness skin graft.
Photo credit D. Rosenstein.



Figure 6. Primary closure of scrotum after debridement.
Photo credit D. Rosenstein.

The advantages of skin grafting are its ease of use, versatility and good take. Full-thickness skin

grafts (FTSGs) are thought to provide superior cosmetic results. However, split-thickness skin grafts (STSGs) are preferred over FTSGs for trauma, avulsions, burns and hidradenitis suppurativa because of better take in these contaminated wounds. The study of STSGs in the setting of denuded genitalia has been extensively studied and dates back to 1957 when Campbell first applied the technique to the testis after traumatic avulsion of the scrotum. Several authors have also described the use of STSGs in the setting of FG. Parkash and colleagues described the use of STSGs to provide supplemental coverage in 43 cases of FG. Furthermore, after studying several various reconstructive techniques to provide skin coverage after Fournier's debridement, Gonzales and colleagues advocated the use of STSGs as the treatment of choice for scrotal defects [Maguina *et al.* 2003; Black *et al.* 2004].

In a study of nine consecutive patients with penile skin loss, Black and colleagues reported their experience with unexpanded, meshed STSGs (Figures 7 and 8). Four of the nine patients experienced genital skin loss secondary to FG. Encouragingly, all nine patients (100%) had graft take, with an acceptable cosmetic result observed



Figure 8. Meshed split-thickness skin graft with acceptable cosmetic result.
Photo credit D. Rosenstein.

in seven patients. One patient experienced an ulceration of the graft secondary to persistent manipulation while the remaining patient, though not physically available for follow up, reported satisfaction with cosmesis. Moreover, no scars or contractures were noted, which the authors attributed to the meshing of the graft. Tightness around the corona or base of the penis during erection was reported but was found to have resolved after 6 months. Postoperative erections were achieved in four of the six patients who were able to achieve erections preoperatively. Overall, the authors conclude that meshed STSGs provide a simple and reproducible technique for skin coverage after radical skin debridement of the genitals with adequate cosmetic and functional results [Black *et al.* 2004].

Maguina and colleagues reported their experience with meshed STSGs in four patients who presented with FG with subsequent radical debridement and complete or near complete loss of the scrotum. Each patient underwent application of a 2:1 meshed STSG, which was stapled onto the denuded testicles and cords. The grafts were then covered in fine mesh gauze soaked in 5% mafenide acetate (Sulfamylon; Mylan Institutional, NV, USA). Moreover, a drain was left in place to

allow for irrigation of the graft with Sulfamylon for the first 5 days. Wound care was then subsequently performed for the next 2 weeks by the patient on an outpatient basis. In this case review, all four patients reported satisfaction with their cosmetic and functional results. Moreover, no complications involving scar contracture or scrotal retraction were noted [Maguina *et al.* 2003].

More extensive techniques also exist and have successfully been applied to postradical debridement reconstruction of patients initially presenting with FG. Lee and colleagues described the use of unilateral gracilis muscle flap reconstruction combined with the internal pudendal artery perforator flap for reconstruction of extensive penoscrotal defects. Excellent wound coverage and functional outcome was achieved in the seven patients who underwent reconstruction with this approach. Moreover, the authors found that its application may prove most useful in patients with extensive and contaminated penoscrotal defects [Lee *et al.* 2012]. In a retrospective review of 41 patients presenting with FG, Chen and colleagues found that scrotal advancement flaps provided good skin quality and cosmesis in small to medium sized scrotal defects. Meanwhile, patients with large and deep perineal defects often needed a myocutaneous or fasciocutaneous flap to eliminate dead space. Specifically, the authors found that the pudendal thigh fasciocutaneous flap, a flap based on the terminal branches of the superficial perineal artery, is indicated for reconstruction of perineal defects with good functional and cosmetic outcomes. Moreover, the flap was found to be less bulky than a gracilis flap with minimal donor site morbidity [Chen *et al.* 2010].

Conclusion

FG is a rare necrotizing fasciitis of the perineal, genital and perianal region with an aggressive clinical course. By decreasing host immunity and allowing a portal of entry, FG's predisposing and etiologic factors provide a favorable environment for the polymicrobial infection to thrive. The cornerstones of FG treatment remain urgent extensive surgical debridement of all necrotic tissues, high doses of broad-spectrum antibiotics and good supportive care. Despite progress in diagnosing and managing the disease, the mortality rate remains high. A multidisciplinary approach is often necessary as these patients may require reconstructive procedures in the future.

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