Fournier’s Gangrene: Therapeutic Impact of Hyperbaric Oxygen

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Many controversial issues exist surrounding the disease pathogenesis and optimal management of Fournier’s gangrene. In Fournier’s original descriptions, the disease arose in healthy subjects without an obvious cause. Most contemporary studies, however, are able to identify definite urologic or colorectal etiologies in a majority of cases. To investigate disease presentation, treatment modalities, and overall mortality, a retrospective analysis of Fournier’s gangrene from a single institution is presented.

Since 1990, 26 cases of Fournier’s gangrene have been diagnosed at the University of Tennessee. An evaluation of intercurrent disease revealed that 38 percent of the patients had diabetes mellitus, 35 percent manifested ethanol abuse, and 12 percent were systemically immunosuppressed. Fifteen patients (58 percent) presented with identifiable etiologies for their disease: 31 percent (8) urethral disease or trauma, 19 percent (5) colorectal disease, and 8 percent (2) penile prosthesis.

Management in all cases involved prompt surgical debridement with initiation of broad-spectrum antibiotics. Multiple debridements, orchietomy, urinary diversion, and fecal diversion were performed as clinically indicated. Fourteen patients received hyperbaric oxygen as adjuvant therapy. Statistically significant results were noted with mortality rates of 7 percent in the group receiving hyperbaric oxygen (n = 14) versus 42 percent in the group not receiving hyperbaric oxygen (n = 12). Overall mortality was 23 percent.

Controversy still surrounds disease pathogenesis in Fournier’s gangrene, particularly in regard to etiology. Our study corroborates current trends in that a clear focus of origin was identified in a majority of the cases. Although a grim prognosis usually accompanies the diagnosis, this study shows significant improvement combining traditional surgical and antibiotic regimens with hyperbaric oxygen therapy. (Plast. Reconstr. Surg. 101: 94, 1998.)

Necrotizing fasciitis of the genital and perineal tissues, also known as Fournier’s gangrene, is a rare but life-threatening disease process. It was first described in 1883 by Jean Alfred Fournier, a French urological, who reported five cases of “unexplained gangrene of the penis and scrotum.” In the original reports, Fournier concluded that three findings characterized the syndrome: (1) abrupt onset in a healthy young male, (2) rapid progression, and (3) absence of a specific causative agent. In contradistinction to these original findings, most current analyses identify definite urologic or colorectal etiologies, and often implicate debilitated or immunosuppressed states in the disease pathogenesis. In an effort to clarify some of these unresolved issues, this retrospective analysis focuses on disease presentation, co-morbid factors, hospital management, treatment modalities, and overall mortality.

MATERIALS AND METHODS

Twenty-six cases of Fournier’s gangrene have been diagnosed and treated at the University of Tennessee Medical Center since 1990. A comprehensive review was undertaken of each patient including detailed accounts of presentation and treatment, as well as prior medical histories. All of the patients were males, with a mean age of 57 years (range, 26 to 87). The mean hospital stay was 21 days (range, 5 to 53 days). Long-term follow-up was available on all surviving patients.

Concerning inpatient management, all patients received prompt surgical treatment once the diagnosis had been made. Multiple operative procedures were needed in 22 of the cases (85 percent), with a mean of 3 operative interventions per case (range, 1 to 10). On the basis

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of the extent of disease and its progression, various procedures were found to be necessary. Repeated debridements were needed in 18 cases (69 percent). Suprapubic urinary diversion was utilized in 16 cases (62 percent), with 15 of the 16 patients receiving such diversion at the initial procedure. Indications for suprapubic urinary diversion included (1) extensive penile and perineal debridement, or (2) periurethral abscesses. Both of these conditions were seen to have increased risk of urethral erosion with long-term in-dwelling urethral catheters. Colostomy was deemed necessary in 7 cases (27 percent), with 3 patients being diverted at the initial procedure and 4 at subsequent procedures. In all cases of colostomy, fecal diversion was recommended by general surgery consultants on the basis of large perineal and ischial wounds, which could not be appropriately managed in the face of constant fecal contamination. Testicular thigh pouches were used for gonadal preservation in 11 cases (42 percent), the majority of which were mandated at the time of an extensive initial scrotal debridement. Six of the patients (23 percent) required orchietomy—two cases at the initial debridement and four during subsequent procedures because of progressive necrosis. After surgical debridement, local wound care consisted of moist gauze dressings (saline, potassium permanganate, or Dakin’s solution) changed three times daily until healthy granulation tissue was present; subsequently, dry gauze dressings were utilized.

In addition to surgical management, all patients received broad spectrum antibiotics. Specific regimens were tailored on the basis of culture and sensitivity reports, and all patients received intravenous dosing until they remained afebrile for 24 hours.

Hyperbaric oxygen therapy was considered as an adjuvant therapy in all 26 cases. Patients were approved or disapproved for hyperbaric oxygen therapy solely on the basis of institution availability (three of five hospitals in our university medical center house hyperbaric oxygen facilities). Fourteen patients (54 percent) received adjuvant hyperbaric oxygen therapy. In all of these cases, initiation of hyperbaric oxygen began as soon as the patient was stabilized after diagnosis and initial debridement. Eleven of the 14 patients initiated therapy within 72 hours. Duration of therapy averaged 12 days. The dive parameters were 90 min at 2.4 atmospheres absolute/45 feet sea water. With only minimal deviation, patients had 2 dives per day for 7 days, followed by daily dives until therapy was terminated. Hyperbaric oxygen was continued until wounds showed complete beds of proliferating granulation tissue or until skin graft coverage had been successful.

In the surviving population (n = 20), large perineal wounds had to be addressed in follow-up. Delayed surgical closure was advocated in the majority of cases (n = 15), utilizing split-thickness skin grafts (11), local advancement flaps (2), or a combination of both (2). In the remaining cases (n = 5), wounds were allowed to heal by secondary intention.

Analysis of treatment variables and results was performed using the chi-square test, Fisher’s exact test (one-tailed analysis), and logistic regression.

RESULTS

Twenty-six consecutive cases of Fournier’s gangrene are included (see Table I). A review of intercurrent disease revealed that 10 patients (38 percent) had diabetes mellitus, 9 (35 percent) manifested ethanol abuse, 3 (12 percent) were on medical regimens of systemic immunosuppression, and one (4 percent) was receiving localized pelvic radiation therapy. Fifteen patients (58 percent) presented with identifiable etiologies for their disease: 8 (31 percent) with urethral stricture disease or trauma, 5 (19 percent) with colorectal disease, and 2 (8 percent) with penile prostheses.

At the time of presentation, cutaneous manifestations of the disease varied widely among patients from small, inconspicuous bullous lesions to more striking gangrenous necrosis of the genitalia. Intraoperative findings, however, were more consistent; all had full thickness necrosis of scrotal and perineal skin extending along fascial planes. On presentation, 58 percent were febrile with temperatures above 100°F (range, 95.4 to 103.5), and the mean white blood cell count was 18,100 c/µl (range, 3,200 to 37,800).

All patients had wound swabs or blood cultures obtained for organism identification and antibiotic sensitivity testing. Twenty-four of 26 patients had positive culture results, with 23 (96 percent) of these being polymicrobial. The most common organisms isolated were Escherichia coli (54 percent) and Bacteroides species (38 percent). Despite a preponderance of gram-negative bacteria, a significant gram-positive involvement was noted, the most com-
TABLE I
Patient Summary

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Etiology</th>
<th>Comorbid Disease</th>
<th>Delay</th>
<th>Bacteria</th>
<th>Intervention</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>Penile prosthesis</td>
<td>DM*, CAD</td>
<td>None</td>
<td><em>E. coli</em>, <em>Staph. epi.</em></td>
<td>Debr (2), SP, Colo TTP (no Orch) HBO</td>
<td>Death</td>
</tr>
<tr>
<td>42</td>
<td>USD</td>
<td>HTN</td>
<td>None</td>
<td><em>Staph. epi.</em>, <em>Bacteroides</em></td>
<td>Debr (4), SP HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>54</td>
<td>None</td>
<td>DM, CAD, HTN</td>
<td>None</td>
<td><em>E. coli</em>, <em>Strep. viridans</em></td>
<td>Debr (2), SP, Colo TTP (no Orch) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>57</td>
<td>None</td>
<td>DM</td>
<td>24 h</td>
<td><em>Diphtheroids</em>, <em>Strep. viridans</em></td>
<td>Debr (7), SP, Colo TTP (Orch) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>61</td>
<td>Colorectal disease</td>
<td>Ethanol abuse</td>
<td>None</td>
<td><em>Strep. aureus</em>, <em>E. coli</em></td>
<td>Debr (2), SP, Colo TTP (no orch) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>47</td>
<td>None</td>
<td>Ethanol abuse</td>
<td>None</td>
<td><em>Strep. Group A</em>, <em>Staph. epi.</em></td>
<td>Debr (1), SP HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>46</td>
<td>None</td>
<td>Immunosuppression (liver transplant)</td>
<td>None</td>
<td><em>Staph. epi.</em>, <em>Diphtheroids</em></td>
<td>Debr (2), Orch* Neoscrum HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>76</td>
<td>Urethral trauma</td>
<td>Nursing home</td>
<td>None</td>
<td><em>E. coli</em>, <em>Escherichia</em>, <em>Bacteroides</em></td>
<td>Debr (1), SP TTP (no Orch) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>72</td>
<td>USD</td>
<td>DM, ethanol abuse</td>
<td>48 h</td>
<td><em>Proteus species</em>, <em>Diphtheroids</em></td>
<td>Debr (2) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>51</td>
<td>USD</td>
<td>DM</td>
<td>72 h</td>
<td><em>Staph. epi.</em>, <em>Diphtheroids</em></td>
<td>Debr (2) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>75</td>
<td>USD</td>
<td>None</td>
<td>None</td>
<td><em>E. coli</em>, <em>Bacteroides</em></td>
<td>Debr (1), SP HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>27</td>
<td>Colorectal disease</td>
<td>Morbid obesity</td>
<td>None</td>
<td><em>Diphtheroids</em>, <em>Strep. viridans</em></td>
<td>Debr (3) TTP HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>65</td>
<td>Colorectal disease</td>
<td>None</td>
<td>None</td>
<td><em>Strep. epi</em>, <em>Strep. species</em> (seroile)</td>
<td>Debr (7) HBO</td>
<td>Alive</td>
</tr>
<tr>
<td>58</td>
<td>None</td>
<td>Ethanol abuse</td>
<td>None</td>
<td></td>
<td>Debr (1) HBO</td>
<td>Alive</td>
</tr>
</tbody>
</table>

*Table continued on p. 97*

common isolates being *Staphylococcus epidermidis* (29 percent), diphtheroid species (29 percent), and *Streptococcus viridans* (21 percent). Overall, 83 percent of positive cultures contained gram-positive isolates. *Clostridium* species were identified in only a single case (Table II).

Overall mortality in this series was 23 percent (Table III). In the fourteen cases that received hyperbaric oxygen, there was only one death. This involved a patient with known cardiac disease, who was progressing well without evidence of ongoing infection on postoperative day 6 from his second wound debridement. He died of a myocardial infarction in transit to a routine hyperbaric oxygen treatment. In the remainder of the hyperbaric oxygen patients, no major complications of treatment were noted, and only two patients required placement of pharyngo-esophageal tubes to tolerate hyperbaric oxygen chamber pressures. The overall survival rate in this study for patients treated using adjunctive hyperbaric oxygen was 93 percent. The mean patient age in the nonsurviving population (*n* = 6) was 68 years, whereas that of the survivors (*n* = 20) was 54 years. As would be expected, patients who died had shorter hospital courses (average, 17 days), usually succumbing to fulminant sepsis. Hospital stays among survivors averaged 26 days. Of note, three patients presented while
TABLE I (continued)

<table>
<thead>
<tr>
<th>Age</th>
<th>Etiology</th>
<th>Comorbid Disease</th>
<th>Delay</th>
<th>Bacteriology</th>
<th>Intervention</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>87</td>
<td>USD</td>
<td>Nursing home</td>
<td>None</td>
<td>Enterococcus</td>
<td>Debr (2), SP, Orch</td>
<td>Alive</td>
</tr>
<tr>
<td>34</td>
<td>None</td>
<td>DM, CAD, HTN</td>
<td>36 h</td>
<td>E. coli</td>
<td>Debr (2)</td>
<td>Alive</td>
</tr>
<tr>
<td>38</td>
<td>USD</td>
<td>Ethanol abuse</td>
<td>None</td>
<td>(sterile)</td>
<td>Debr (2), SP, TTP (no orch)</td>
<td>Alive</td>
</tr>
<tr>
<td>48</td>
<td>None</td>
<td>DM</td>
<td>None</td>
<td>E. coli</td>
<td>Debr (4)</td>
<td>Alive</td>
</tr>
<tr>
<td>66</td>
<td>None</td>
<td>DM, ethanol abuse</td>
<td>24 h</td>
<td>Staphylococcus</td>
<td>Debr (1)</td>
<td>Alive</td>
</tr>
<tr>
<td>26</td>
<td>None</td>
<td>Ethanol abuse</td>
<td>None</td>
<td>E. coli</td>
<td>Debr (3), SP, TTP (no orch)</td>
<td>Alive</td>
</tr>
</tbody>
</table>

* At the initial debridement, left orchectomy was required. Subsequently, the right testicle was successfully preserved in a split-thickness skin grafted neocrotum.

1 DM, diabetes mellitus; USD, uncontrolled diabetes; CAD, coronary artery disease; HTN, hypertension; Debr ( ), debridements (number of times); SP, suprapubic tube; Colo, colostomy; TTP, tunneled thoracic pouch; Orch, orchectomy; Pelvic XRT, pelvic radiation therapy; IVDA, intravenous drug abuse; Strep, Staphylococcus; E. coli, Escherichia coli; Staph, spp., Staphylococcus spp.; HBO, hyperbaric oxygen.

on systemic steroid regimens (liver transplant patient, metastatic prostate cancer patient undergoing radiation therapy, and a rheumatoid arthritis patient), and two of these three did not survive. Statistical analysis of survival with respect to hyperbaric oxygen therapy showed significant improvement in outcome from a survival rate of 58 percent in patients not receiving hyperbaric oxygen to 93 percent survival in the group receiving hyperbaric oxygen therapy (Fisher's exact test, one-tailed; p = 0.05). Using logistic regression, the relative risk of survival is nine times greater in the group receiving hyperbaric oxygen therapy, compared with the group not receiving hyperbaric oxygen therapy (p = 0.062). Even controlling for age, logistic regression reveals a statistically significant survival advantage for those receiving hyperbaric oxygen therapy, with a relative risk for survival being 11 times greater than that of the group not receiving hyperbaric oxygen therapy.

**Discussion**

Necrotizing fasciitis of the genital and perineal tissues remains an uncommon but life-threatening process. Controversy still exists concerning the etiology of this disease process. Whereas Fournier originally reported on a dis-
TABLE III
Analysis of Survival

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Alive</th>
<th>Dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperbaric oxygen</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Non-hyperbaric oxygen</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Chi square analysis: $p = 0.037$.
Fisher's exact test, one-tailed: $p = 0.052$.

ease “idiopathic” in nature, many recent studies have had divergent opinions on this issue. Spirnak et al.\(^2\) reported definite etiologies in 19 of 20 patients in their series (12 with urologic disease, 7 with colorectal disease). Conversely, another recent study, by Coburn et al.,\(^3\) revealed a clear focus of origin in only 31 percent ($n = 52$).

Because statistical significance is difficult to attain in small group analysis, several investigators have pooled previously reported databases in an effort to increase cohort size. In a multi-institutional review of published cases from 1978 to 1987, Salvino et al.\(^4\) noted that only 13 percent had no obvious precipitating cause ($n = 164$). Another extensive study analyzing all known cases between 1945 and 1978, by Jones et al.,\(^5\) labeled 29 percent of the cases as idiopathic. Stephens et al.\(^6\) details 389 patients reported in the literature between 1979 and 1988; no obvious cause was identified in 26 percent. These larger studies have concluded that Fournier’s gangrene is not an idiopathic process but rather a sequela of common urologic and colorectal abnormalities. In our study population, 42 percent of the cases were labeled as idiopathic. As research continues, strict attention to include only cases of true necrotizing fasciitis is imperative. Although scrotal abscesses, perirectal abscesses, and perirectal abscesses often have some tissue necrosis, the entity of necrotizing fasciitis is inherently different.

In general, necrotizing fasciitis is characterized by an infectious thrombosis of vasculature passing between the skin and deep circulation, and it usually involves a mixed microbial flora. In most studies of perineal necrotizing fasciitis, Enterobacteriaceae, Streptococcus species, and Bacteroides species are the leading isolates. Our study corroborates this finding with E. coli being isolated in 54 percent of our patients and Bacteroides species in 38 percent. Overall, 63 percent of the cultures had gram-negative isolates, 83 percent had gram-positive isolates, and 38 percent had anaerobic isolates. Despite the preponderance of gram-negative coliforms, the pervasive gram-positive involvement reiterates the need for broad-spectrum antibiotics.

Historically, management of Fournier’s gangrene has combined broad-spectrum antibiotics with wide surgical debridement of all devitalized tissue. Because of the infiltrating nature of necrotizing fasciitis, multiple surgical debridements are paramount to remove any nidus of continuing infection. Postoperatively, meticulous wound observation is crucial because only through regular examination can progressive necrosis be detected. Local wound care with gauze dressings not only serves as a sterile barrier to contamination but also assists in debridement of dead tissue with each dressing change. Since the 1980s, hyperbaric oxygen therapy has been available as an adjunctive treatment modality. Combined with local wound care, hyperbaric oxygen enhances tissue growth and viability.\(^7\)

In necrotizing soft tissue infections, regional ischemia produces hypoxia. Additionally, systemic shock from sepsis only worsens blood flow to the affected area. Hyperbaric oxygen exerts its therapeutic effects by raising the partial pressure of oxygen in these tissues, whereby it maintains tissue oxygenation in the absence of hemoglobin.\(^8\) In the hypoxic state, leukocyte functions are severely compromised, and therefore healing is greatly retarded. By reversing local hypoxia, hyperbaric oxygen stimulates the bactericidal action of leukocytes, enhances fibroblast replication, increases collagen formation, and promotes neovascularization.\(^9\) Additional studies have shown that hyperbaric oxygen inhibits toxin formation by certain anaerobes, increases flexibility of red blood cells, preserves intracellular adenosine triphosphate, terminates lipid peroxidation, and promotes more rapid growth of capillaries.\(^7\)

Relatively little has been published about the use of hyperbaric oxygen in the treatment of Fournier’s gangrene. Although the theory of its utility has been promising, few studies actually have shown significant improvements in survival. In a recent review of hyperbaric oxygen as adjunctive treatment in 30 cases of truncal necrotizing fasciitis, investigators were unable to show that hyperbaric oxygen statistically reduced mortality or hospital stay.\(^8\) Riseman et al.,\(^10\) however, presented a review of 29 cases of
necrotizing fasciitis (truncal and perineal) in which adjunctive hyperbaric oxygen improved mortality rates from 66 percent (group without hyperbaric oxygen) to 23 percent (group with hyperbaric oxygen). Also in that study, Rise- man was able to show that hyperbaric oxygen decreased the need for additional surgical debridements. In our present study, we were unable to corroborate this finding with our mean number of debridements being 2.6 and 2.3 for hyperbaric oxygen and non-hyperbaric oxygen groups, respectively; the mean number of operative procedures was 4.1 and 3.8, respectively. This decreased number of surgical interventions in the non-hyperbaric oxygen group may be explained by the shorter hospital course in the dying patients of this group (5 of 12 patients died).

In the past, hyperbaric oxygen usually has been reserved for cases in which surgery and antibiotic regimens were failing. Assessing the efficacy of hyperbaric oxygen in such a setting includes too many confounding variables and thus renders conclusions suspect. Prospective randomization in this arena is difficult but would certainly match groups concerning illness severity. In our study of perineal necrotizing fasciitis, all patients who received adjunctive hyperbaric oxygen were selected for treatment prospectively, rather than as a tertiary effort after other measures had failed. Patients were not randomized, but rather were approved or disapproved for hyperbaric oxygen solely on the basis of institution availability. All patients were considered for hyperbaric oxygen therapy, and if hyperbaric oxygen was available or could be arranged through the particular institution, then it was utilized. Eligible patients received hyperbaric oxygen while being managed from routine-care beds, as well as from intensive care/critical care beds. Selection was therefore not biased by subjective physician assessments of disease severity. In comparing our two groups, hyperbaric oxygen (n = 14) versus non-hyperbaric oxygen (n = 12), mortality rates were 7 percent and 42 percent, respectively. This represents a statistically significant survival advantage that is imparted to patients receiving adjunctive hyperbaric oxygen therapy. The improved survival associated with hyperbaric oxygen has a high confidence interval with chi square statistical analysis, \( p \approx 0.04 \). When Fisher's exact test is applied to the same independent variable, statistical significance is affirmed with \( p \approx 0.05 \) (one-tailed test). Even with multivariate analysis of the same variables, controlling for age, diabetes, and alcoholism, the statistically significant survival advantage remains unchanged. Our current recommendations for hyperbaric oxygen therapy include prompt initiation after primary surgical debridement. In the first 24 hours postoperatively, 3 hyperbaric oxygen dives are recommended, followed by 2 dives per day for 7 days. After this, daily dives should be continued until 5 days after delayed surgical closure of the perineal wounds.

Conclusions are often discounted in retrospective reviews because of disproportionate comparison groups. Treatment groups in our study hyperbaric oxygen and non-hyperbaric oxygen, are evenly matched. Comparing hyperbaric oxygen (n = 14) versus non-hyperbaric oxygen (n = 12), the mean patient age was 57 and 58 years, respectively. Although the groups seem evenly matched, it is important to note, within each group, the mean ages of the surviving and the dying populations. In the hyperbaric oxygen group, the mean age among survivors was 56 years, and the age of the single dying patient was 60 years. In the non-hyperbaric oxygen group, the mean age of the survivors was 49 years, whereas that of the dying population was 69 years. As a possible confounding variable, advanced age may be seen as having a poor outcome. Using logistic regression to analyze survival with respect to hyperbaric oxygen treatment, the relative risk of survival is nine times greater for patients who receive hyperbaric oxygen therapy, compared with those who do not receive hyperbaric oxygen therapy (\( p \approx 0.062 \)). When this same analysis is completed controlling for age, the survival benefit associated with hyperbaric oxygen therapy is 11 times greater (\( p \approx 0.066 \)), further assurance that the effects of treatment are not confounded by age. On the basis of this univariate and multivariate analysis, there is no evidence of a spurious relationship between survival and adjunctive hyperbaric oxygen therapy.

In further analyzing the treatment groups, each was affected by similar rates of comorbid disease with five (36 percent) versus five (42 percent) being diabetic, and four (29 percent) versus five (42 percent) being alcoholic. A profile of surgical management was also similar. Ten (71 percent) versus eight (67 percent) required repeated debridements. Four (29 percent) versus three (25 percent) required colos-
tomy, and eight (57 percent) versus eight (67 percent) required suprabubic urinary diversion. Univariate statistical analysis of each of these stratifiers was performed. For each stratifier, the groups are not statistically different; nor do the differences between groups even approach statistical significance ($p = 0.48$ to 0.84).

Another variable often raised in discussions pertaining to survival is "delay to treatment." We defined a delay as a period of observation greater than 23 hours preceding surgical debridement. In 10 of the 26 cases, hospital records indicate that medical teams were uncertain of the diagnosis at the time of patient admission, and as such, instituted only nonoperative in-patient management as the disease progressed to fulminant sepsis. Three of these patients received hyperbaric oxygen, and seven did not. Comparing these two groups, three of three patients that received hyperbaric oxygen survived despite their delay to surgery; five of seven (71 percent) who did not receive hyperbaric oxygen died. Investigating the fate of these patients by also considering age, one notes a mean age of 60 years for the three patients receiving hyperbaric oxygen (all of whom survived), and a mean age of 63 years for those not receiving hyperbaric oxygen (5 of 7 who ultimately died.) Although delay to treatment is an interesting confounding variable to discuss, it certainly lacks credibility as an objective, reliable factor. We have labelled 10 cases as having delays to treatment based on in-patient records; however, the remaining patients may well have had similar unrecognized delays. Patients who were treated promptly after hospital admission may have inadvertently delayed their own presentation to the hospital by failing to notice early, subtle clinical signs of the disease until the process became fulminant and obvious even to lay persons. It seems obvious that delaying medical management of this gangrenous process would prove to have poor survival rates; however, based on small numbers of patients in this category, no statistical significance could be affirmed.

CONCLUSIONS

Compared with reports from the nineteenth century, there clearly have been improvements in the clinical management of this disease process. Medical technology, with the advent of more effective antibiotics, has improved outcome. Early recognition and intervention with aggressive surgical debridement have played an important role, and in many accounts seem to be the primary determinants of successful outcomes. In this study, the clinical efficacy of hyperbaric oxygen has been affirmed with a statistically proven survival advantage for patients receiving adjunct hyperbaric oxygen therapy for Fournier's gangrene.

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