Few studies have analyzed necrotizing fasciitis in children, and all have relied on cases of necrotizing fasciitis in the abdomen, head, and neck region. The authors sought to correlate the preoperative values of several laboratory tests previously validated in the adult literature, such as the Laboratory Risk Indicator for Necrotizing Fasciitis, with surgically confirmed necrotizing fasciitis in children to provide clinical guidance for the preoperative laboratory workup of necrotizing fasciitis.

A retrospective chart review was performed on consecutive patients younger than 18 years with a diagnosis of necrotizing fasciitis. A total of 13 patients with an average age of 7.9 years (range, 9 months–16 years) were included. Ten (76.9%) infections were found in the lower extremity and 3 (23.1%) in the upper extremity. Seven (53.8%) patients had ecchymosis on examination. All patients presented with an elevated white blood cell count. No amputations were performed, and no mortality occurred. All patients underwent surgery within 24 hours of presentation.

Elevated temperature, white blood count, erythrocyte sedimentation rate, and C-reactive protein values are typically seen in pediatric patients with necrotizing fasciitis; however, no correlation existed between other the preoperative laboratory values with the previously described scoring systems, such as the Laboratory Risk Indicator for Necrotizing Fasciitis. Aggressive monitoring of signs and symptoms is suggested, even if a patient does not meet all conventional diagnostic criteria. The authors recommend prompt surgical debridement and early administration of antibiotics, which should include clindamycin.
Necrotizing fasciitis is a rapidly progressing infection of the fascia and subcutaneous tissues. It is a rare condition, accounting for an estimated 500 to 1500 infections in the United States annually. Although uncommon, necrotizing fasciitis is a serious infection with a high risk of long-term morbidity and mortality. Treatment of necrotizing fasciitis demands prompt, aggressive surgical debridement coupled with aggressive medical resuscitation and early antibiotic therapy.

Delays in surgical treatment can result in significantly adverse consequences for the patient, including limb amputation and death. Therefore, early recognition of necrotizing fasciitis is of paramount importance, offering the best opportunity for prompt surgical debridement and adequate medical resuscitation. In its early stages, this infection process is difficult to distinguish from other soft tissue infections. Some authors have attempted to develop algorithms using laboratory studies to aid in distinguishing necrotizing fasciitis from other less severe soft tissue infections. Laboratory values, such as total white blood cell count (WBC), erythrocyte sedimentation rate, C-reactive protein (CRP), sodium, glucose, creatinine, and hemoglobin, have been studied. Scoring systems, such as the Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC), have been used to analyze such laboratory values, comparatively stratifying the diagnostic likelihood of necrotizing fasciitis in contrast to less severe soft tissue infections. The correlation of preoperative laboratory values with surgically confirmed necrotizing fasciitis in adults has been reported. However, to the current authors’ knowledge, analysis of preoperative laboratory values in the setting of surgically confirmed necrotizing fasciitis in pediatric orthopedic patients has not been reported. Variables, including causative bacteria, antibiotic sensitivities, amputation rate, and mortality, have not been adequately delineated for this population. The goals of the current study were 2-fold. First, the authors sought to analyze the preoperative values of several laboratory tests previously validated in the adult literature with regard to the pediatric population, correlating these values to surgically confirmed necrotizing fasciitis in children and to provide clinical guidance for the preoperative laboratory workup of necrotizing fasciitis. The second goal was to describe the epidemiology, microbiology, morbidity, and mortality of necrotizing fasciitis in children.

**MATERIALS AND METHODS**

After obtaining institutional review board approval, the authors performed a retrospective chart review of consecutive patients younger than 18 years with a diagnosis of necrotizing fasciitis treated at an urban, pediatric Level I trauma center (Nationwide Children’s Hospital). Between 1997 and 2011, a total of 20 patients were identified. Operative reports were reviewed to confirm intraoperative findings and postoperative diagnoses consistent with necrotizing fasciitis. Inclusion criteria were patients younger than 18 years at presentation with extremity involvement and intraoperative findings consistent with a necrotizing soft tissue infection. Exclusion criteria were involvement of the abdomen, head, and neck region, failed surgical confirmation, and incomplete medical records. Seven patients were excluded, yielding a total of 13 patients for review.

The authors initially analyzed the correlation of the following preoperative variables with surgically confirmed necrotizing fasciitis: total WBC and differential of the WBC, erythrocyte sedimentation rate, CRP, hemoglobin, platelets, sodium, potassium, creatinine, and temperature. The authors then focused on the epidemiology of pediatric necrotizing fasciitis. Variables analyzed included age, sex, location of infection, physical examination, and radiographic findings, possible causative factors, number of debridements, and the need for flap coverage or amputation. Microbiology results and antibiotic susceptibilities were recorded.

Statistical analysis was performed using a nonparametric method Kruskal-Wallis test to compare continuous variables, and a Wilcoxon 2-sample test to compare groups (SAS version 9.2; SAS Institute, Inc, Cary, North Carolina).

**RESULTS**

A total of 13 patients with an average age of 7.9 years (range, 9 months-16 years) were reviewed, of whom 5 (38.5%) were boys and 8 (61.5%) were girls. Ten (76.9%) of the 13 infections were found in the lower extremity, and 3 (23.1%) occurred in the upper extremity. All 13 patients had documented tenderness and erythema. Twelve (92.3%) of 13 patients had an elevated temperature on examination. One patient had bullae, and 7 (53.8%) patients had appreciable fluctuance. Seven (53.8%) patients had ecchymosis on examination. No crepitus or paresthesias were reported.

Six (46.2%) patients had an antecedent trauma to the area. Two (15.4%) patients had been bitten at the area: 1 from a dog and the other from an insect. Three (23.1%) patients reported a previous small abscess or boil that rapidly worsened. One (7.7%) patient had a previous history of an open reduction and internal fixation of the ankle at the site of the infection. Seven (53.8%) patients were admitted with the diagnosis of cellulitis, 2 (15.4%) with a diagnosis of abscess, 1 (7.7%) with a diagnosis of pain, 1 (7.7%) with a diagnosis of swelling, and 2 (15.4%) with a diagnosis of necrotizing fasciitis.

Eleven (84.6%) patients had a temperature higher than 100.5°F (mean, 102.1°F; range, 98°F-104°F) at presentation. Eight (61.5%) patients had radiographs available for review, with soft tissue or subcutaneous edema seen in all patients. Subcutaneous air was observed in 2 (25%) of these 8 patients. Two (15.4%) patients had an ultrasound; both showed subcuta-
neous edema and 1 showed subcutaneous air. Four (30.8%) patients had magnetic resonance imaging of the affected area. All scans showed evidence of subcutaneous edema and edema and inflammation along the fascia, and 1 of the 4 scans showed evidence of subcutaneous air.

Nine of 13 patients presented with an elevated WBC. Average WBC count at presentation was 22.9 x 10^9 cells/L (range, 11.4-47.3 cells/L), with an average differential count of 67% neutrophils (range, 38%-91%), 16% lymphocytes (range, 5%-33%), and 15% bands (range, 2%-42%). Erythrocyte sedimentation rate was recorded for 6 (46.2%) patients and was elevated in all, with an average value of 47 mm/hr (range, 22-100 mm/hr). Average CRP for the 8 patients with a CRP recorded was elevated above normal at 10.1 mg/L. Average platelet count was 302 x 10^9 cells/L (range, 125-469 x 10^9 cells/L). Platelets were considered within normal limits for 8 patients, above normal in 2, and low in 3.

Hemoglobin values were obtained for 11 (84.6%) of 13 patients, with an average of 11.6 g/dL (range, 7.4-14.4/L). These values were considered below normal range in 5 patients, within normal range in 5, and elevated in 1. Average sodium was 136 mmol/L (range, 133-141 mmol/L), recorded for 6 patients. Average potassium was 3.5 mmol/L (range, 2.8-4.1 mmol/L) in the 6 patients in which it was recorded. Average creatinine was 0.52 mg/dL (range, 0.35-0.73 mg/dL) in 4 recorded patients and average glucose for 6 patients was 114 mg/dL (range, 73-133 mg/dL).

Primary patient data are shown in Table 1. No significant difference existed between the sexes with respect to all measured variables. Statistical significance was demonstrated with consideration to platelet count, hemoglobin, and WBC count, indicating that these values varied significantly from the normal range in the study population (Table 2).

Blood cultures were evaluated for 12 (92.3%) of the 13 patients. Eleven of the 12 patients had negative blood cultures, but 1 had blood cultures that were positive for methicillin-sensitive *S aureus*. Overall, 6 (46.2%) patients showed the presence of Group A beta hemolytic streptococcus on

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Location</th>
<th>Temperature at Presentation, °F</th>
<th>Fever Greater than 100.5°F</th>
<th>WBC, x10^9 cells/L</th>
<th>Neutrophil, % of WBC</th>
<th>Lymphocyte, % of WBC</th>
<th>Bands, % of Neutrophil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/14 101</td>
<td>UE/forearm</td>
<td>101</td>
<td>Yes</td>
<td>Elevated; 24.8</td>
<td>38</td>
<td>15</td>
<td>40</td>
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<tr>
<td>2/F/2 101.2</td>
<td>Right thigh</td>
<td>Yes</td>
<td>Normal; 11.4</td>
<td>51</td>
<td>29</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3/F/2 101.4</td>
<td>LE</td>
<td>Yes</td>
<td>Normal; 12.9</td>
<td>70</td>
<td>22</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4/M/1 98</td>
<td>B LE/groin</td>
<td>No</td>
<td>Normal; 14.7</td>
<td>56</td>
<td>25</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>5/M/3 102</td>
<td>Groin/B LE</td>
<td>Yes</td>
<td>Elevated; 20.4</td>
<td>79</td>
<td>17</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6/F/16 102.8</td>
<td>LE</td>
<td>Yes</td>
<td>Elevated; 35.5</td>
<td>70</td>
<td>2</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>7/M/12 104</td>
<td>LE</td>
<td>Yes</td>
<td>Elevated; 47.3</td>
<td>91</td>
<td>3</td>
<td>2</td>
<td></td>
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<tr>
<td>8/F/10 103.2</td>
<td>LE</td>
<td>Yes</td>
<td>Elevated; 20.1</td>
<td>82</td>
<td>9</td>
<td>4</td>
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<tr>
<td>9/F/13 100.1</td>
<td>LE</td>
<td>No</td>
<td>Elevated; 21</td>
<td>54</td>
<td>19</td>
<td>22</td>
<td></td>
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<tr>
<td>10/F/8 102</td>
<td>LE</td>
<td>Yes</td>
<td>Normal; 14.9</td>
<td>48</td>
<td>7</td>
<td>42</td>
<td></td>
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<tr>
<td>11/M/16 104</td>
<td>LE</td>
<td>Yes</td>
<td>Elevated; 24.6</td>
<td>82</td>
<td>5</td>
<td>7</td>
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<tr>
<td>12/F/9 mo 103.2</td>
<td>LE</td>
<td>Yes</td>
<td>Elevated; 18.9</td>
<td>42</td>
<td>33</td>
<td>26</td>
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<td>13/F/6 104</td>
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<td>Yes</td>
<td>Elevated; 31</td>
<td>64</td>
<td>15</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: B LE, bilateral lower extremity; LE, lower extremity; UE, upper extremity; WBC, white blood cell count.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD, Median</th>
<th>Elevated</th>
<th>Low</th>
<th>Normal</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelets</td>
<td>486±24, 486</td>
<td>131±7, 129</td>
<td>320±77, 320</td>
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<tr>
<td>Hgb</td>
<td>14.5±NA, 14.5</td>
<td>9.74±1.39, 10.3</td>
<td>12.84±1.83, 13</td>
<td>.0328</td>
<td></td>
</tr>
<tr>
<td>WBC</td>
<td>27.07±9.38, 24.6</td>
<td>NA</td>
<td>13.48±1.65, 13.8</td>
<td>.0069</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: Hgb, hemoglobin; NA, not available; WBC, white blood cell.
their final culture. All had sensitivity to clindamycin. Three (23.1%) of the 13 patients grew methicillin-resistant *S. aureus* on surgical cultures. All were sensitive to clindamycin. Two (15.4%) of the 13 patients grew methicillin-sensitive *S. aureus*; both patients were sensitive to clindamycin. The 2 (15.4%) remaining patients cultured polymicrobial growth.

All patients underwent debridement within 24 hours of presentation. Average number of debridements was 3.5; average number of debridements in patients with Group A beta hemolytic streptococcus was 4; and average number of debridements for non–Group A beta hemolytic streptococcus infections was 3. Three (23.1%) patients underwent flap coverage of their wounds. Two of these patients were in the Group A beta hemolytic streptococcus group. No patients underwent amputation as a result of their wounds, and no mortality occurred.

Although it was not a primary outcome measure in the current analysis, the authors noted that no patients reported a significant history of hemodynamic compromise, mental status change, or altered activity level prior to the onset of symptoms. One patient had received further examination at the time of admission to rule out leukemia based on preliminary physical examination findings (including considerable ecchymosis). The suspected diagnosis was not substantiated.

**Discussion**

Pediatric necrotizing fasciitis can affect children of any age or sex. Although the average age in this study was 7 years for girls and 9 years for boys, the authors did not find that a more significant number of patients fell within a specific age range. Girls represented 62% of the patients; however, a generalization about sex predilection cannot be made given the findings. In a review of the literature, the authors found neither sex to be disproportionately affected. Therefore, a certain predication of sex-related susceptibility to necrotizing soft tissue infections is unlikely.

Nearly half of the patients reported some antecedent trauma to the involved area, lending support to the theory that necrotizing soft tissue infections may arise after damage to the overlying skin and soft tissues.

The most common symptoms on presentation, including tenderness, erythema, and warmth, have been reported in the adult literature. Seven (53.8%) of the current patients had appreciable fluctuance and ecchymosis, with 1 (7.7%) demonstrating bullae on examination. Bullae, which have been reported to be pathognomonic for necrotizing fasciitis, were rarely present in the current study. Although fluctuance, ecchymosis, and bullae are components in the classic description of necrotizing fasciitis, the current findings suggest these components are not present in the majority of cases. These physical examination findings should place a surgeon on high alert for a necrotizing infection, but their absence does not support reduced vigilance. The most common findings in a necrotizing soft tissue infection are similar to those of severe cellulitis; thus, it is important to maintain a high index of suspicion for necrotizing fasciitis when evaluating any soft tissue infection.

Examination of the admission diagnoses of this group of patients confirmed the difficulty in diagnosing such a condition based on initial presentation: only 2 (15.4%) patients were admitted with a diagnosis of necrotizing fasciitis. The majority (n=7; 53.8%) were admitted with a diagnosis of cellulitis.

The reported incidence of fever as a sign of active necrotizing infection has been inconsistent. Some studies have reported rates of fever at less than 50% of patients, whereas others have reported a fever in nearly all patients. Average temperature on presentation in the current study was 102.1°F, with 11 (84.6%) having fevers higher than 100.5°F. This suggests that a febrile inflammatory reaction is commonly a part of a necrotizing soft tissue infection, although afebrile patients may still present with an underlying necrotic process. Although high fevers should further raise concern for necrotizing fasciitis, the lack of a fever should not provide a false sense of security.

In the adult population, certain studies have suggested that WBC counts of greater than 20,000 or 25,000 cells/L should raise suspicion for a severe necrotizing infection. The average WBC count in the current study was almost 23,000 cells/L, which is consistent with the previous literature. However, 38.5% of the current patients had WBC counts of less than 20,000 cells/L, showing this laboratory value as an inconsistent predictor as well.

Wong et al reported the LRINEC. This scale uses several preoperative laboratory values to construct a diagnostic score that correlates with the risk of having surgically confirmed necrotizing fasciitis, including WBC count, hemoglobin, sodium, glucose, creatinine, and CRP. Laboratory values collected for 9 of the 13 patients in the current study were insufficient to complete the LRINEC assessment. However, 2 of the 13 patients with incomplete data had a LRINEC score that was highly suggestive of necrotizing fasciitis. In contrast, for 2 patients with incomplete data, the addition of the highest scores for their missing laboratory values would not have put them into a numeric category suspicious for necrotizing fasciitis. As a result, the authors are unable to comment on the accuracy of the LRINEC in their patients and could not validate the score as a tool to aid in the diagnosis of pediatric necrotizing fasciitis.

Three (23%) patients were diagnosed with methicillin-resistant *S. aureus*. To the authors’ knowledge, this is the first description of methicillin-resistant *S. aureus*-related necrotizing fasciitis in the pediatric population. All of these patients were susceptible to clindamycin. Of the remaining patients, 46% grew Group A beta hemolytic streptococcus. All were susceptible.
to clindamycin. Only 2 (15.4%) of the 13 patients had a polymicrobial infection that included anaerobes, and both patients were sensitive to clindamycin. As a result, the authors recommend that clindamycin should be a part of early antibiotic regimens for necrotizing fasciitis in pediatric patients. This recommendation is similar to previous literature regarding necrotizing fasciitis in adults.Obtaining blood cultures proved to be of low yield, with only 1 (7.7%) patient showing positivity.

Analysis of imaging data showed the most routine finding on radiographs and ultrasound to be subcutaneous edema. Magnetic resonance imaging studies showed this subcutaneous edema and edema and inflammation of the fascia. However, only 2 patients showed the commonly described classic sign of subcutaneous air on any type of imaging, suggesting that the absence of such a finding does not rule out necrotizing fasciitis. Although the presence of subcutaneous air on imaging should be highly concerning, this was not present in the majority of cases in the current series.

Analysis of surgical data revealed that pediatric patients with necrotizing fasciitis may require multiple debridements. In the current study, the average number of debridements was 3.5. A trend may exist toward more debridements in patients with the so-called flesh-eating Group A beta hemolytic streptococcus infections, suggesting that this bacteria may cause more clinically severe infections compared with other bacteria. Only 3 (23.1%) patients needed flap reconstruction. No amputations were performed, and no mortality occurred. All patients underwent surgery within 24 hours of presentation. As in other studies, this suggests that prompt recognition of necrotizing fasciitis with early, aggressive surgical debridement provides the greatest opportunity to salvage lives and limbs.

**CONCLUSION**

Few studies have analyzed necrotizing fasciitis in children, and all have relied on cases of necrotizing fasciitis in the abdomen, head, and neck region. This study only included pediatric cases involving extremities and described several preoperative laboratory values that correlate with surgically confirmed necrotizing fasciitis. Elevated temperature, WBC, erythrocyte sedimentation rate, and CRP values are typically seen with pediatric necrotizing fasciitis; however, no correlation of other preoperative laboratory values with previously described scoring systems, such as the LRINEC, was seen. Physical examination, radiographic findings, and laboratory values are highly variable in this patient population. Aggressive monitoring of the signs and symptoms of necrotizing fasciitis is suggested, even if a patient does not meet all of the conventional diagnostic criteria. The authors recommend prompt surgical debridement and early administration of antibiotics, which should include clindamycin. The addition of multiple surgical debridements and possible soft tissue coverage may be indicated to optimize treatment outcomes.

**REFERENCES**