Background: This is a prospective study of the clinico-etiologic profile and factors affecting outcomes in 40 children managed for necrotizing fasciitis (NF).

Materials and Methods: Demographic details, clinical characteristics, and laboratory parameters were recorded, and the Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score was calculated. Primary outcome (survival vs. nonsurvival) was noted, and prognostic factors were identified.

Results: Initiating factors included boils (45%), i.v. cannula extravasations (22.5%), and blunt trauma (17.5%). Lesion(s) were predominantly on the lower limbs (35%) and trunk (25%). Twenty-two patients (55%) had <5% body surface area (BSA) involved. Severely deranged clinical and laboratory parameters were common. Ultrasound localized fluid collections. Pus cultures showed methicillin-resistant Staphylococcus aureus (52.5%), methicillin-sensitive S. aureus (27.5%), and polymicrobial growth (20%). Blood culture was positive in 24 patients (60%). Most isolates were sensitive to clindamycin and amoxy-clavulanate. Prognostic factors for mortality (n = 6; 15%) included categorization as “Sick,” BSA involvement >10%, thrombocytopenia, raised serum creatinine, late debridement, and polymicrobial blood culture isolates. All six nonsurvivors had a LRINEC score of ≥8 and positive blood cultures. Six patients (20.7%) developed unsightly scars and 5 (17.24%) contractures across joints.

Conclusions: Pediatric NF has significant morbidity and mortality. Patients with adverse prognostic factors can benefit from early referral to a facility with a critical care unit. Adequate wound management is essential to minimize residual deformity.

Keywords: Contractures, debridement, Laboratory Risk Indicator for Necrotizing Fasciitis score, methicillin-resistant Staphylococcus aureus, necrotizing fasciitis, sepsis

INTRODUCTION

Necrotizing fasciitis (NF) is a severe, life-threatening, and rapidly progressive infection of the fascia with secondary necrosis of the subcutaneous tissues. Early diagnosis with aggressive debridement, appropriate parenteral antibiotics, and supportive therapy forms the cornerstone of management. A few distinct syndromes are recognized: Type I (polymicrobial), with a mix of aerobic and anaerobic bacteria; Type II, or group A β-hemolytic streptococcal (GAS), either alone or combined with Staphylococcus aureus; and Type III, clostridial myonecrosis or infection by Vibrio species.

Although NF is more common in adults, all age groups, including neonates, can be affected. NF is believed...
to be rare in children,\(^1\) being reported in 0.03% of hospitalization causes.\(^2\) Overall in children younger than 16 years, its incidence is 0.29 per 100,000 per year, with the highest incidence in boys older than 1 year (1.2 per 100,000 per year).\(^8\) In developing countries, the incidence of pediatric NF may be significantly higher.\(^9,13\) Common initiating factors include boils, varicella lesions, intramuscular injections, penetrating gluteal trauma, and omphalitis.\(^1\)

Most studies of pediatric NF are retrospective, and knowledge on pediatric NF is scarce.\(^14\) Lack of a standardized approach also results in delays in management and inappropriate antibiotic choice.\(^15\) Late presentation with advanced disease and improper initial management can adversely influence the outcome, especially in resource-limited environments.

**Materials and Methods**

This prospective cohort study included all patients, with NF managed from November 2016 to October 2018. NF was diagnosed clinically based on gross subcutaneous and fascial edema and necrosis detected at surgery with/without frank cutaneous gangrene on physical examination.\(^9\)

The initiating factors and presentation were recorded. At presentation, the patients were categorized as either “Sick,” defined by Pediatric Glasgow Coma Scale score <13; hypoxia (spO2 < 90% on room air); hypotension (mean blood pressure [BP] <5th centile for age or systolic BP <2 standard deviation below normal for age); and temperature instability, or “Stable”: Active and alert child; capillary refilling time <3 s; pink color; and responding well to commands.\(^16\) The site(s) and characteristics of the lesion and percentage of body surface area (BSA)\(^17\) involved were noted, and the confirmatory “Finger Test”\(^14,19\) was performed.

Laboratory investigations included complete blood counts, renal function test, serum electrolytes, blood sugar, serum lactate, C- reactive protein (CRP) and blood gas analysis. Besides these pus and debrided tissue were sent for culture and sensitivity tests. The Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score\(^20,21\) was calculated. Debrided tissues underwent histopathological examination. Ultrasound (US) examination of the affected body parts was performed.

Management included resuscitation and initial empiric antibiotic therapy with amoxicillin-clavulanate, an aminoglycoside (if renal function normal) and clindamycin. Antibiotic therapy was guided by clinical evaluation and the results of bacterial culture sensitivity. The threshold for transfusion was hemoglobin <10 g/dl and platelet count <40,000/mm\(^3\). Regular postoperative assessments were performed.

The primary outcome (survival versus nonsurvival) and its prognostic factors were identified [Tables 1 and 2]. Significant morbidity included the need for mechanical ventilation (MV), hospitalization >3 weeks, or the occurrence of sequelae. Minimum follow-up was 3 months. Assessment included condition of the wound, condition of the residual scar, need for skin grafting, contractures/restriction of movement, limping gait, or limb asymmetry.

**Statistical analysis**

Statistical analysis was performed using JASP Team 2020 (version 0.14.1) computer software. \(P \leq 0.05\) was considered statistically significant. Univariate analysis was performed, and an odds ratio with a 95% confidence interval (CI) was calculated.

**Results**

Forty cases comprised 27 males (M:F = 2.02:1) aged 0.028–14 years (median: 11.5 months). Four age groups were newborn to 28 days’ age (\(n = 9\); 22.5%); infants 28 days to 1-year age (\(n = 12\); 30%); 2–5 years (\(n = 13\); 32.5%); and 6–18 years’ age (\(n = 6\); 15%).

Initiating factors included boil(s) (\(n = 18\); 45%); intravenous extravasation (\(n = 9\); 22.5%); following blunt trauma (\(n = 7\); 17.5%); abrasions (\(n = 3\); 7.5%); and a tight diaper, perineal excoriations, and dependent edema in 1 patient each (2.5%). Older children had a higher proportion of blunt trauma as the initiating factor (1–5 years; 23.07% and >5 years; 50%). In 7 newborns (77.8%), NF resulted from a boil and in 2 (22.2%) from intravenous extravasation. The duration of symptoms ranged from 1 to 9 days (mean: 3.18 ± 1.84 days). At presentation, 13 patients (32.5%) were “Sick” and 27 patients (67.5%) were “Stable.”\(^16\)

The site of infection was the lower limbs (\(n = 14\); 35%); the chest and abdominal wall (\(n = 7\); 17.5%) [Figures 1 and 2]; perineum (\(n = 3\); 7.5%); back of the abdomen, scalp, face, neck [Figure 3], gluteal...
region, and scrotum in 2 patients (5%) each; while 1 patient (2.5%) each had NF involving the anterior abdominal wall, hand, upper limb, and labia majora. The extremities were involved in 6/20 (30%) newborns and infants and in 9/20 (45%) older children. The majority of patients \( n = 22; \; \text{55\%} \) had <5% BSA involvement, 11 (27.5%) had 5%–10% BSA involved, and 7 (17.5%) patients had >10% BSA involved.

Local examination revealed erythema and warmth with ecchymotic patches and tissue necrosis in all patients [Figures 1-3]; swelling \( n = 33; \; \text{82.5\%} \); blisters/bullae \( n = 22; \; \text{55\%} \) [Figure 1a]; cutaneous hyposensitivity/anesthesia \( n = 32; \; \text{80\%} \); severe local tenderness \( n = 17; \; \text{42.5\%} \); and tissue crepitus \( n = 7; \; \text{17.5\%} \). The “Finger Test”\(^{[18,19]} \) was positive in all cases.

Laboratory values at admission

All patients had elevated CRP levels, range 31–443 mg/L (164.46 ± 82.577 mg/L) with 26 (65%) having levels of >150 mg/L. The majority of children had anemia \( n = 26; \; \text{65\%} \), leukocytosis \( n = 32; \; \text{80\%} \), acidosis \( n = 28; \; \text{70\%} \), raised serum lactate \( n = 26; \; \text{65\%} \), and raised blood urea \( n = 21; \; \text{52.5\%} \), while 5 patients (12.5%) had high serum creatinine. Hyponatremia was present in 19 (47.5%) cases. The LRINEC score\(^{[20]} \) ranged from 0 to 13 (6.43 ± 2.79) being less than the diagnostic cutoff value (6) in 13 patients (32.5%), 6–10 in 23 (57.5%), and 11–13 in 4 patients (10%). The sensitivity of a LRINEC cutoff score of ≥ 6 in diagnosing NF was 100%, specificity: 52.9%, positive predictive value (PPV): 25%, and negative predictive value (NPV): 100%.

US showed fascial thickening with dense fluid in the fascial planes in all patients, subcutaneous tissue swelling \( n = 32; \; \text{80\%} \), air in subcutaneous and fascial planes \( n = 24; \; \text{60\%} \), and loculated collections \( n = 22; \; \text{55\%} \).

Bacteriologic studies

All cases had positive pus and tissue cultures, with 32 (80%) having monomicrobial isolates (Type II NF) and polybacterial isolates (Type I NF) in the rest. Methicillin-resistant \( S. \; \text{aureus} \) (MRSA) was 100% sensitive to clindamycin, erythromycin, and amikacin, and 95.2% to amoxycillin-clavulanate. Methicillin-sensitive \( S. \; \text{aureus} \) (MSSA) was 100% sensitive to clindamycin, 90.9% to amoxy-clavulanate. Polymicrobial growths were 100% sensitive to colistin and teicoplanin. All organisms were resistant to penicillin and cefotaxime. Blood cultures grew isolates in 24 cases (60%), with a similar culture-sensitivity profile.
Management

Antibiotics were required for 8–32 days (mean: 16.17 ± 5.21 days). Surgical debridement was performed in all as soon as possible after initial stabilization. Early debridement (<6 h from admission) was possible in 27 patients (67.5%). The number of debridements, at 24-h intervals, ranged from 4 to 13. In all patients, HPE of resected and debrided tissue confirmed the diagnosis of NF.

Table 3 summarizes the findings of the 6 nonsurvivors. The cause of death was sepsis with multi-organ dysfunction syndrome. Acute respiratory distress (RD) syndrome, deep-vein thrombosis, and disseminated intravascular coagulation were present in one patient each.

Significant morbidity and sequelae

Eleven patients (27.5%) had a hospital stay of >3 weeks. Eight patients (20%) required ventilator support, all within 6 h of admission. MV was required in 5 (71.4%) patients with >10% BSA involvement, 3 (13.6%) with <5% BSA, and in none with 5–10% BSA involvement (P = 0.001).

In 29 patients on long-term follow-up, the wounds contracted substantially over 1–3 months. The scar was either largely “acceptable” (n = 23) [Figure 3c] or “unsightly” (n = 6) [Figure 2b and c], often dense and puckered up. Two patients underwent secondary skin grafting. Contractures producing limitation of movement (n = 5) included 3 across the knee joint and 2 at the axilla [Figure 2c]. One case each developed distal lymphedema and fracture of the lower end of the femur (following minor trauma).

Prognostic factors affecting the outcome

Six patients died, a mortality of 15%. Although age did not affect mortality (P = 0.514), all 9 neonates survived, while mortality was highest in the 1–5 years’ age group (23.1%). Gender (P = 0.962) and the initiating factor (P = 0.355–0.954) did not significantly affect mortality. The significant predictors of mortality on univariate analysis are shown in Table 1. No “Stable” patient died, while 6 of 13 “Sick” patients (46.2%) died (P = 0.0022). Mortality in children with hypovolemia, hypothermia, and RD at presentation was 41.5%, 66.6%, and 71.4%, respectively, these findings being statistically significant [Table 1]. There was no mortality with head-and-neck involvement, while mortality with lesions in the extremities, torso, and genitalia/perineum was 6.7%, 25%, and 30%, respectively.

The laboratory values at admission (nonsurvivors versus survivors) are shown in Table 2. No patient with an LRINEC score of ≤7 (n = 16) died, while the mortality for scores between 8 and 10 and >10 was 4/20 (20%) and 2/4 (50%), respectively. All 6 nonsurvivors had positive blood cultures. Mortality with polymicrobial growth on blood cultures versus those with monomicrobial MRSA/MSSA growth was significantly higher (P = 0.001). The mortality rate in patients with hospital stay of >3 weeks (3/11; 27.3%), although not statistically significant (P = 0.3912), was higher than in those with <3 weeks’ hospital stay (3/29; 10.3%). Six of the 8 patients (75%) requiring MV died, the need for MV correlating significantly with mortality (P = 0.000038). The degree and form of residual scar correlated with the percentage of BSA involved. Nine percent patients (2/22) with <10% BSA involved has “unsightly” scar as compared to 57.15% (4/7) for more than 10% BSA involvement (P = 0.018).

Discussion

The high incidence of pediatric NF, with 40 children managed during a 23-month period, is probably because our center caters mainly to low-income patients in whom NF is more prevalent[2,12,13] and who are also frequently malnourished. Malnutrition has been reported as an important predisposing factor for the occurrence of pediatric NF.[2,9,1,13]

The major initiating factors identified were similar to those reported earlier, especially in studies from India[1,11]...
and other developing countries.\textsuperscript{[13]} Delayed treatment of boils and minor injuries and neglect of i.v. cannula extravasations are important initiating factors of pediatric NF in resource-poor countries.\textsuperscript{[12]} Significantly, as in other reports from India,\textsuperscript{[9,10]} no patient had postvaricella zoster NF. In contrast, in developed countries, postvaricella zoster NF is an important cause of severe, invasive NF.\textsuperscript{[14,22,23]} with up to 71% being caused by invasive group A β-hemolytic streptococci (GAS) (Type II).\textsuperscript{[22]}

The high incidence of patients being “Sick”\textsuperscript{[16]} at admission (32.5%) with deranged vital parameters testifies to the fulminant nature of the disease. Similar to the findings reported by other studies, we found that neonates and infants were more likely to be affected on the torso and older children on the extremities and face.\textsuperscript{[14,24]}

Findings on local examination were largely in concordance with earlier reports and reviews of pediatric NF.\textsuperscript{[2,6,14,24,25]} Eccymotic patches and tissue necrosis in all patients, with a positive “Finger Test,”\textsuperscript{[18,19]} also indicate advanced disease at presentation.\textsuperscript{[2,13,14]}

The LRINEC score has been used to differentiate NF from less serious soft-tissue infections.\textsuperscript{[20,21,26,27]} Wong et al.\textsuperscript{[20]} reported a PPV of 92.0% and an NPV of 96%. In our study, however, there was low specificity and a PPV of only 25%. These findings corroborate those of several other studies that the LRINEC score is too insensitive for diagnosing NF, and a high degree of clinical suspicion is mandatory for early diagnosis.\textsuperscript{[28-32]}

Dramatically elevated CRP levels (5-fold) may lead to a higher PPV for diagnosing NF without losing specificity (\( P < 0.001 \)).\textsuperscript{[33]} A case–control analysis of pediatric NF found CRP >7.0 to be 100% sensitive and 95.7% specific for diagnosing NF.\textsuperscript{[34]} Putnam et al.\textsuperscript{[35]} described a pediatric LRINEC score utilizing only CRP >20 and serum sodium <135 mEq/L (specificity = 95% [95% CI 82%–100%]) to be more accurate in predicting pediatric NSTI. In our series, only 19 patients (47.5%) had serum sodium <135 mc/L, suggesting that hyponatremia alone may be relatively insensitive for diagnosis. Only 5 patients (12.5%) had high serum creatinine, while 21 (52.5%) had high blood urea, indicating that several patients were hypovolemic and dehydrated at admission. As reported earlier,\textsuperscript{[36,37]} US was useful in aiding surgical management by localizing fluid collections and abscesses.

The higher rate of positive bacterial cultures as compared to other similar studies\textsuperscript{[6,38]} again points to more florid disease at presentation. The high incidence of monomicrobial MRSA (21/40; 52.5%) infection is significant in the light of several reports suggesting an increased incidence of invasive NF due to community-acquired MRSA infection.\textsuperscript{[39-43]} Recent reports show that MRSA is responsible for 3.6%–39% of NF cases. In six out of 8 patients with polymicrobial growth, \textit{Pseudomonas} was isolated similar to other reports.\textsuperscript{[2,24]}

Antibiotic sensitivity results of the isolates have enormous implications on management protocols. On pus-culture studies, all isolates of MRSA and MSSA and 62.5% of polymicrobial growths were sensitive to clindamycin. There was high sensitivity of MRSA and MSSA to amoxy-clavulanate and amikacin. Polymicrobial isolates were 100% sensitive to colistin and teicoplanin, while amikacin and meropenem had limited efficacy. This suggests that, as recommended

### Table 2: Laboratory values at admission (nonsurvivors versus survivors)

| Laboratory parameter (unit) (normal range) | Mean±SD | \( P \) |
|------------------------------------------|---------|-----|
| Hemoglobin (g/dL) (9.5-17)               | 8.0±1.55 | 0.083 |
| TLC (/cumm) (5000-15,000)               | 17,148.33±2984.85 | 0.457 |
| Platelet count (/cumm) (150,000-450,000) | 50,816.7±74,049.7 | 0.006 |
| CRP (mg/L) (<10)                        | 196.17±63.155 | 0.314 |
| Blood glucose (mmol/L) (3.3-7.7)        | 9.47±2.567 | 0.006 |
| pH on BGA (7.35-7.45)                   | 7.19±0.0917 | 0.001 |
| Serum lactate (mmol/L) (0.5-1.6)        | 2.917±1.0477 | 0.274 |
| Serum bicarbonate (mmol/L) (21.0-28.0)  | 20.8±4.390 | 0.831 |
| Blood urea (mg %) (10-40)               | 66.83±25.103 | 0.076 |
| Serum creatinine (μmol/L) (4.4-88.4)    | 55.33±33.963 | 0.550 |
| Serum Na+ (mEq/L) (135-149)             | 130.3±5.610 | 0.284 |
| Serum K+ (mEq/L) (3.5-5)                | 4.283±0.2229 | 0.175 |
| LRINEC score (0-13)                     | 9±1.414  | 0.018 |

SD: Standard deviation, TLC: Total leukocyte count, CRP: C-reactive protein, BGA: Blood gas analysis, LRINEC: Laboratory risk indicator for necrotizing fascitis
earlier, initial empiric therapy with clindamycin and amoxycillin-clavulanate is appropriate. Polybacterial growth is a dangerous sign, and sensitivity results should be urgently obtained. Worsening clinical or biochemical parameters may indicate the need for initiating therapy with colistin and/or teicoplanin. Penicillin and cefotaxime should not be used for empiric therapy as virtually all isolates were resistant to these drugs.

The average mortality in pediatric NF ranges from 10% to 60%, with a mean of 20%. Our figures of 15% mortality are similar to the mortality of 15.4% described by Zundel et al. in a review of 32 articles describing 53 patients with pediatric NF, as well as that reported in other series of pediatric NF. As in our series, most pediatric deaths are due to sepsis, multi-organ failure, shock, or DVIC.

Characterization as “Sick” and presence of hypothermia or hypovolemia had a significant correlation with mortality (P < 0.001), and essentially, all six nonsurvivors were “Sick” with hypothermia and hypovolemia at admission. A multivariate analysis of factors predicting mortality in pediatric NF also reported that immunosuppression, hypothermia, and hypotension were significant predictive factors, while hypothermia and hypotension could be considered terminal events. A low systolic BP at admission has been reported to significantly affect mortality (P = 0.03), while altered consciousness and RD at presentation have earlier been reported as predictive factors for eventual mortality. Similar to the findings reported by McHenry et al., patients having >10% BSA involvement had higher mortality.

Among laboratory parameters, thrombocytopenia and systemic acidosis at admission have been reported as adverse prognostic factors. Yaghoubian et al. reported base deficit (P = 0.009) and high serum lactate to be significant prognostic factors and stated that serum sodium ≥135 mmol/l with a lactate level <54.1 mg/dL was associated with a mortality of 0%. Our study also has showed that in addition, raised serum creatinine, hyperglycemia, and an LRINEC score of ≥8 being other significant prognostic factors. The prognostic value of a high LRINEC score in NF has been reported earlier.

Positive blood cultures may indicate severe disease as all six nonsurvivors had positive blood cultures. In addition, both patients with mixed Gram negative rods (GNR) growth on blood culture died, suggesting a worse prognosis for GNR infection similar to other reports. Similar to an earlier report, mortality in patients with polymicrobial growth on blood cultures was significantly higher than in those with monomicrobial MRSA or MSSA growth.

Table 3: Summary of study of nonsurvivors (n=6)

| Age | Sex | Initiating cause | Site | BSA (%) | LRINEC score | Pus culture | Tissue culture | Blood culture | Serum lactate | PRBC transfusion | Platelets transfusion | RD at admission | Ionotropes requirement |
|-----|-----|------------------|------|---------|-------------|-------------|---------------|---------------|---------------|-----------------|---------------------|---------------------|----------------------|
| Case 5 | 12 years | Female | Abrasion | Thigh | >10 | 7 | MRSA | MRSA | Ps, Kl | 2.2 | 7.1 | + | + | + | + |
| Case 13 | 8 months | Male | Perineal excoriation | Perineum | <5 | 8 | MRSA | MRSA | MSSA | 2.4 | 7.1 | + | + | + | + |
| Case 16 | 1 year | Male | Boils | Chest wall | >10 | 11 | MRSA | MRSA | MSSA | 7.2 | 7.2 | + | + | + | + |
| Case 19 | 2 years | Female | i.v. fluid extravasation | Chest and abdominal walls | <5 | 10 | MRSA | Acin, Ps | 4.6 | 7.2 | + | + | + | + |
| Case 37 | 4 years | Male | Blunt trauma | Gluteal region | >10 | 9 | MRSA | MRSA | MRSA | 7.2 | 7.2 | + | + | + | + |
| Case 39 | 11 months | Male | Boils | Abdominal wall | >10 | 9 | Ps, Kl | MRSA | MSSA | 1.8 | 7.35 | + | + | + | + |

RD at: Respiratory distress, PRBC: Packed red blood cells, BSA: Body surface area, LRINEC: Laboratory risk indicator for necrotizing fasciitis, Ps: Pseudomonas, Kl: Klebsiella, Acin: Acinetobactor, S. aureus: Staphylococcus aureus, MSSA: Methicillin-sensitive S. aureus, MRSA: Methicillin-resistant S. aureus.
The necessity for the delay in surgical debridement was associated with higher mortality \((P < 0.001)\) and this has been reported earlier.\[^{48,53,54}\] In a database review of 334 patients with pediatric NSTIs, Endorf \textit{et al.}\[^{53}\] found a long time from admission to the first debridement (median, 2 vs. 1 day, \(P = 0.03\)) to be the only significant risk factor on multivariate analysis. Advanced resuscitative modalities required for treatment of severe disease and systemic sepsis were, as expected, associated with worse primary outcomes.

Children with NF often show substantial wound contraction with a reduction in size of the ultimate scar. Legbo and Shehu\[^{13}\] reported healing by secondary intention in 46.9% of patients with direct suturing (8.3%), split-thickness skin grafting (21.9%), and local flap reconstruction being the other wound surfacing measures. Similar to our findings, however, Fustes-Morales \textit{et al.}\[^{21}\] reported sequelae in 29/32 (91%) survivors, mostly unsightly scars (72%), deformity (56%), and limitation of joint function (19%). These sequelae can be prevented by better primary and secondary wound management. In a recent study children with NF underwent skin-sparing debridement with delayed skin closure, they have reported excellent results with this technique and could be a promising line of management, especially if access to plastic and reconstructive surgery services is limited, as in our institution.

**Conclusion**

In our institutional setup, NF is not uncommon and is associated with significant morbidity and mortality, especially as patients frequently present with severe disease. Most cases result from neglected boils/abscesses, i.v. cannula extravasations, or minor trauma. Infection with MRSA and MSSA is common. All six nonsurvivors in this series needed advanced resuscitation and had an LRINEC score of \(\geq 8\) with positive blood cultures. Patients with factors predicting significantly higher mortality can benefit from the early institution of critical care and intensive monitoring. Adequate primary and secondary wound management is essential to minimize residual deformity.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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