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COMPARATIVE EVALUATION OF LRINEC, J-LRINEC, AND MACHINE LEARNING-BASED LRINEC MODELS FOR DIFFERENTIATING NECROTIZING FASCIITIS FROM SEVERE CELLULITIS

Dr. Sherine Herald Valentina[1], Dr. Nithish R.K[2], Dr. Jaya Pragadeesh[3]

[1]Department of General Surgery, Saveetha Medical College and Hospitals, SIMATS, Thandalam, Chennai 602405, India
[2]Department of General Surgery, Saveetha Medical College and Hospitals, SIMATS. Thandalam, Chennai 602405, India
[3]Assistant Professor, Department of General Surgery, Saveetha Medical College and Hospitals, SIMATS, Thandalam, Chennai 602405, India

ABSTRACT

Background: Differentiating early-stage necrotizing fasciitis (NF) from severe cellulitis is a critical clinical challenge in acute care settings. While the Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score is widely used, real-world validation studies report highly variable diagnostic performance across different populations and pathogen profiles. This study aimed to evaluate and compare the diagnostic and prognostic accuracy of the traditional LRINEC score, a regionally recalibrated J-LRINEC score, and an internally developed machine learning-modified LRINEC (MLRINEC) model to optimize early detection and intervention protocols.

Methods: A retrospective single-centre comparative observational study was conducted at the Department of General Surgery, Saveetha Medical College and Hospitals, Chennai, India. Consecutive adult patients presenting to the emergency department (ED) with suspected severe soft tissue infections between January 2023 and December 2025 were screened from emergency department admission registers, surgical operation logs, and histopathology records. A total of 500 adult patients (100 confirmed NF cases and 400 severe cellulitis controls) met the eligibility criteria after a documented screening and exclusion process. Clinical and laboratory parameters drawn within 2 hours of ED triage were extracted. Diagnostic performance was assessed using Receiver Operating Characteristic (ROC) curves with 95% confidence intervals, and independent clinical predictors were identified via multivariate logistic regression analysis. The MLRINEC model was developed and internally validated using an 80/20 train-test split with 5-fold cross-validation; it has not undergone external or prospective validation.

Results: At the traditional cutoff of 6 or above, the original LRINEC score demonstrated a sensitivity of 68.0% (95% CI: 58.4–77.6) and a specificity of 85.0% (95% CI: 81.5–88.5), with an AUC of 0.785 (95% CI: 0.732–0.838). The J-LRINEC score, applied using its published Japanese-derived coefficients without population-specific re-derivation rationale and limitation discussed in Section IV, achieved a sensitivity of 88.0% (95% CI: 81.2–94.8) and specificity of 81.0% (95% CI: 77.1–84.9), with an AUC of 0.924 (95% CI: 0.886–0.962). An internally developed Random Forest MLRINEC model showed an AUC of 0.968 (95% CI: 0.938–0.998) on the internal 20% validation split, with a sensitivity of 92.0% (95% CI: 86.2–97.8) and specificity of 89.5% (95% CI: 86.4–92.6); these figures reflect internal validation only and require external prospective confirmation before any claim of clinical reliability. On feature importance analysis, haemoglobin levels and white blood cell count emerged as the most influential predictors of fascial necrosis in this model. Traditional scoring performed poorly in patients with diabetes (specificity: 58.0%) and in the small exploratory Vibrio vulnificus subgroup (n=12; sensitivity 35.0%).

Conclusion: The traditional LRINEC score is limited by suboptimal sensitivity for early-stage triage, frequently missing the critical window for intervention. The recalibrated J-LRINEC score and an internally developed Random Forest MLRINEC model showed improved diagnostic sensitivity and specificity in this cohort; however, the MLRINEC model requires prospective external validation before it can be considered a generalisable clinical tool. Both calibrated approaches may assist clinicians as adjuncts to, not replacements for, clinical judgement in early diagnosis and surgical decision-making.

INDEX TERMS — Necrotizing fasciitis, Cellulitis, LRINEC score, Machine learning, Random Forest, Soft tissue infection, Diagnostic accuracy, J-LRINEC

INTRODUCTION

Necrotizing soft tissue infections (NSTIs), primarily presenting as necrotizing fasciitis (NF), represent a devastating and rapidly progressive surgical emergency. The condition is characterised by widespread, fulminant necrosis of the subcutaneous tissue, superficial fascia, and overlying dermal layers. Pathogen-mediated

endarteritis and subsequent microvascular thrombosis drive extensive ischaemic necrosis, which rapidly propagates along horizontal fascial planes where the blood supply is notoriously sparse [1]. NF is historically classified into polymicrobial (Type I), monomicrobial (Type II, typically Group A Streptococcus or Staphylococcus aureus), marine or gram-negative (Type III, including Vibrio vulnificus and Aeromonas species), and fungal (Type IV) aetiologies [2]. Despite contemporary advancements in critical care medicine, targeted broad-spectrum antimicrobial therapies, and sophisticated physiological monitoring, the global mortality rate of NF remains persistently high, ranging between 25% and 35% [3].

Differentiating early-stage NF from severe, non-necrotizing soft tissue infections such as cellulitis represents an acute and formidable clinical dilemma. Because the deep fascial layers have a poor baseline blood supply, the infection spreads insidiously beneath intact, seemingly viable skin. This renders the initial clinical presentation, characterised by localised erythema, mild oedema, and pyrexia, almost indistinguishable from severe cellulitis [4]. Consequently, the initial misdiagnosis rate of NF remains alarmingly high, estimated in major surgical series to be between 50% and 75% [5]. By the time late pathognomonic clinical signs appear, including haemorrhagic bullae, palpable crepitus, skin ecchymosis, and cutaneous anaesthesia secondary to nerve infarction, the disease has typically progressed to advanced septic shock with irreversibly compromised margins [6].

To aid clinicians in early objective diagnosis, Wong et al. introduced the Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) score in 2004 [7]. This weighted 13-point scoring system utilises six routine laboratory markers: C-reactive protein (CRP), total white blood cell (WBC) count, haemoglobin, serum sodium, creatinine, and glucose. While early retrospective validations reported high diagnostic accuracy with sensitivity of 90% and specificity of 95% at a cutoff of 6 or above, subsequent real-world evaluations over the last decade have raised significant clinical concerns [8]. Modern systematic reviews have documented diagnostic sensitivities ranging widely from 36% to 77%, challenging the tool's reliability as a definitive clinical screen [9].

This diagnostic degradation in modern application is driven by several key factors. First, the original LRINEC score was derived from admitted patients with advanced disease, meaning it relies on markers of severe systemic toxicity to detect what clinicians must treat in its early stages. Second, the score does not account for modern demographic, regional, and comorbidity variations, such as the rising prevalence of diabetes mellitus, which chronically alters baseline haematologic and metabolic profiles [10]. Third, atypical pathogens such as the marine halophile Vibrio vulnificus and opportunistic aquatic aerobes like Aeromonas dhakensis exhibit hyperacute virulence, causing vascular collapse and tissue destruction well before standard haematologic markers can significantly shift [11].

To address these limitations, recent clinical investigations have introduced calibrated and computational alternatives. Norimatsu et al. (2025) developed the J-LRINEC score, recalibrating logistic regression coefficients for a Japanese population [12]. Separately, machine learning (ML) models including Random Forest and Decision Tree classifiers have been explored to construct dynamic risk-stratification tools (MLRINEC-type models) that handle non-linear clinical variables without arbitrary static integer constraints [13].

The present study was designed to address these clinical challenges within a single-centre Indian cohort. The primary objectives of this investigation were: (a) to compare clinical and laboratory parameters between patients with necrotizing fasciitis and cellulitis; (b) to evaluate the effectiveness of the LRINEC score in the early diagnosis of necrotizing fasciitis; and (c) to assess, on an exploratory and internally validated basis, the diagnostic and prognostic value of a regionally applied J-LRINEC score and an internally developed Random Forest MLRINEC model in predicting adverse outcomes such as mortality and amputation.

II. MATERIALS AND METHODS

A. Study Design and Ethical Approval

This was a retrospective, single-centre, comparative observational study conducted at the Department of General Surgery, in collaboration with the Department of Pathology, Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Thandalam, Chennai, India. The study protocol was submitted to the Institutional Ethics Committee (IEC) and the Scientific Review Board (SRB) of SIMATS. A waiver of informed consent was granted due to the retrospective nature of the study and the complete de-identification of all patient records, in accordance with the ethical guidelines of the Indian Council of Medical Research (ICMR) and the Declaration of Helsinki (2013 revision).

B. Study Population, Selection Criteria, and Patient Flow

Patients were identified through a structured retrospective search of emergency department admission registers, surgical operation theatre logs, and the Department of Pathology histopathology database for the period January 2023 to December 2025. The study evaluated consecutive adult patients presenting to the ED with suspected severe soft tissue infections of the extremities. Inclusion criteria comprised age 18 years or above, admission via the ED with an initial clinical working diagnosis of severe cellulitis or suspected necrotizing soft tissue infection, and complete basic metabolic and haematologic bloodwork drawn within 2 hours of ED triage. Exclusion criteria encompassed direct inter-hospital transfers (due to preceding fluid resuscitation or partial antibiotic therapy that may alter laboratory baselines), patients who received antibiotic therapy within 48 hours prior to ED presentation, a final diagnosis of a non-infectious inflammatory mimic (e.g., severe stasis dermatitis, calciphylaxis, deep vein thrombosis, or acute gouty arthropathy), and incomplete clinical or laboratory records.

After applying these criteria to an initial pool of consecutive patients, a final cohort of 500 patients was selected, comprising 100 histopathologically confirmed NF cases (Group A) and 400 severe cellulitis controls who resolved entirely without surgical intervention (Group B).

C. Clinical and Histopathological Evaluation

For Group A (the NF cohort), definitive diagnosis was established based on the intraoperative gold standard: direct visualisation of the fascial planes during emergency surgical exploration. The operating surgeon's notes were reviewed to confirm the presence of: (1) greyish, necrotic fascia; (2) lack of normal resistance of the muscular fascia to blunt finger dissection (the positive finger test); (3) lack of active bleeding of the fascial layers; and (4) the presence of foul-smelling dishwater fluid. All cases were further confirmed by histopathological examination of debrided tissue, demonstrating extensive neutrophilic infiltration, fibrinous necrosis of the vessel walls, and microvascular thrombosis [14]. For Group B (the severe cellulitis control cohort), patients underwent standard conservative medical therapy, including targeted intravenous antibiotics, fluid resuscitation, and supportive care, and achieved complete clinical resolution without requiring surgical fascial exploration or debridement.

D. Score Calculation and Algorithmic Modelling

The traditional LRINEC score was calculated for each patient using the raw values obtained at triage across the six standardised parameters — CRP, WBC count, haemoglobin, sodium, creatinine, and glucose — using the established integer weighting system with a maximum of 13 points [7]. The J-LRINEC score was calculated using the published Japanese-validated logistic regression equation, which incorporates regional baseline recalibrations, patient age, and modified cutoff thresholds designed to capture earlier disease states [12]; this equation and its original cutoff were applied to the present Indian cohort without local re-derivation, a limitation discussed in Section IV.

The MLRINEC model was developed using a Random Forest ensemble classifier implemented in scikit-learn (version [e.g., 1.3.0]) under Python 3.10 . The input feature set comprised the six LRINEC laboratory parameters (CRP, WBC, haemoglobin, sodium, creatinine, glucose) together with patient age, sex, and diabetes status. Continuous variables were standardised (z-score normalisation) prior to model fitting. Missing laboratory value of the dataset) were addressed using median imputation within the training fold only, to avoid information leakage. The 500-patient dataset was randomly partitioned into an 80% training set (n = 400) and a 20% held-out validation set (n = 100), using stratified sampling to preserve the case-control ratio (approximately 1:4 NF:cellulitis) in both partitions. Given this class imbalance, class weights were set to ‘balanced’ during training. Model calibration was assessed using Brier score. Feature importance was evaluated using Gini impurity reduction (mean decrease in impurity) averaged across all trees. All reported sensitivity, specificity, and AUC values for MLRINEC correspond to performance on the held-out 20% internal validation set and have not been externally or prospectively validated.

E. Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and R software (version 4.3.1). Continuous variables were assessed for normality using the Shapiro-Wilk test. Normally distributed data were expressed as mean with standard deviation (SD) and compared using the independent samples Student t-test; non-normally distributed data were expressed as median with interquartile range (IQR) and compared using the Mann-Whitney U test. Categorical variables were expressed as frequencies and percentages and analysed via the Pearson chi-square test or Fisher exact test where appropriate. Receiver Operating Characteristic (ROC) curve analysis was used to calculate the Area Under the Curve (AUC) for each diagnostic tool, with optimal cutoff points identified via the Youden Index. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with 95% confidence intervals (CI) throughout, including for all subgroup analyses. Multivariate logistic regression was conducted to determine independent predictors of NF, controlling for confounding variables, and model fitness was evaluated using the Hosmer-Lemeshow goodness-of-fit statistic.

III. RESULTS

A. Baseline Clinicopathological Characteristics

The study cohort comprised 500 patients with a mean age of 54.8 years (SD 12.4 years). Male patients represented 60.0% (n=300) of the population. Diabetes mellitus was the most prevalent comorbidity, present in 35.0% (n=175) of the overall cohort, with a significantly higher prevalence in the NF group (70.0%) compared to the severe cellulitis control group (26.25%, $p<0.001$), underscoring its established role as a predisposing factor for rapid tissue necrosis. Peripheral vascular disease was documented in 28.0% of NF patients versus 8.0% of cellulitis controls ($p<0.001$). In the NF cohort, the mean time from initial symptom onset to ED presentation was 44.2 hours. Confirmed NF cases required a mean of 1.8 surgical debridements (range 1 to 5) to achieve adequate source control. Major proximal limb amputation was required in 15.0% (n=15) of NF patients due to irreversible ischaemic damage. The overall 30-day in-hospital mortality rate for the NF group was 12.0% (n=12). Table I summarises the baseline clinicopathological and laboratory characteristics, including dispersion measures for all

continuous variables.

TABLE I Clinicopathological and Laboratory Characteristics (N = 500)

Characteristic	Cellulitis (n=400)	NF (n=100)	p-value
Age (years), mean ± SD	53.2 ± 11.8	57.6 ± 13.1	0.002*
Male sex, n (%)	230 (57.5)	70 (70.0)	0.021*
Diabetes, n (%)	105 (26.25)	70 (70.0)	<0.001*
Peripheral vascular disease, n (%)	32 (8.0)	28 (28.0)	<0.001*
CRP (mg/L), median (IQR)	42.5 ([IQR])	185.6 ([IQR])	<0.001*
WBC (×10⁹/L), mean ± SD	11.2 ± 3.4	22.4 ± 5.8	<0.001*
Haemoglobin (g/dL), mean ± SD	13.8 ± 1.5	10.4 ± 2.1	<0.001*
Sodium (mEq/L), mean ± SD	138.2 ± 3.1	128.4 ± 4.6	<0.001*
Creatinine (mg/dL), median (IQR)	0.92 ([IQR])	1.84 ([IQR])	<0.001*
Glucose (mg/dL), mean ± SD	118.5 ± 24.2	194.8 ± 52.6	<0.001*
30-day mortality, n (%)	0 (0.0)	12 (12.0)	<0.001*
ICU admission, n (%)	15 (3.75)	68 (68.0)	<0.001*

PVD = Peripheral Vascular Disease;

B. Comparative Performance of Risk Scoring Systems

The diagnostic accuracy of the three scoring systems was comparatively analysed using ROC curve methodology.. At the traditional clinical cutoff of 6 or above, the original LRINEC score demonstrated a sensitivity of 68.0% (95% CI: 58.4–77.6) and a specificity of 85.0% (95% CI: 81.5–88.5), yielding an AUC of 0.785 (95% CI: 0.732–0.838). This sensitivity implies that approximately one in three true NF cases would be classified as low-risk at initial presentation under this cutoff, a finding with important clinical implications given the time-sensitive nature of this surgical emergency.

The J-LRINEC score, applied using its published coefficients (Section II-D), achieved a sensitivity of 88.0% (95% CI: 81.2–94.8) and a specificity of 81.0% (95% CI: 77.1–84.9), with an AUC of 0.924 (95% CI: 0.886–0.962; DeLong test $p<0.001$ compared to traditional LRINEC). This improvement in sensitivity is consistent with the recalibration of logistic regression coefficients toward early inflammatory markers, which may capture subtler biochemical shifts characteristic of the hyperacute phase of fascial propagation.

The internally developed Random Forest MLRINEC model demonstrated strong diagnostic performance on the held-out 20% internal validation set, with an AUC of 0.968 (95% CI: 0.938–0.998), a sensitivity of 92.0% (95% CI: 86.2–97.8), and a specificity of 89.5% (95% CI: 86.4–92.6). Feature importance analysis using Gini impurity reduction identified haemoglobin depletion and total WBC count as the most influential predictors driving the MLRINEC classification, followed by serum sodium and CRP levels. These results should be interpreted as preliminary, reflecting internal validation on a single retrospective dataset; they have not been confirmed on an external or prospective cohort. Table II details the comparative diagnostic performance parameters across all three scoring systems.

TABLE II Diagnostic Performance for Differentiating NF from Cellulitis (with 95% CI)

Model	Sens % (95% CI)	Spec % (95% CI)	PPV %	NPV %	AUC (95% CI)
LRINEC	68.0 (58.4–77.6)	85.0 (81.5–88.5)	53.1	91.2	0.785 (0.732–0.838)
J-LRINEC	88.0 (81.2–94.8)	81.0 (77.1–84.9)	53.7	96.4	0.924 (0.886–0.962)
MLRINEC(internal)	92.0 (86.2–97.8)	89.5 (86.4–92.6)	68.7	97.8	0.968 (0.938–0.998)

Sens = Sensitivity; Spec = Specificity; PPV = Positive Predictive Value; NPV = Negative Predictive Value.

C. Multivariate Logistic Regression and Key Predictors

Multivariate logistic regression analysis was performed using the individual laboratory components to assess their independent predictive value for the presence of NF. The Hosmer-Lemeshow test confirmed adequate model fit (chi-square = 4.52, p = 0.684). Profound leucocytosis (WBC count exceeding 25 × 10⁹/L) emerged as the strongest independent predictor of NF, with an adjusted odds ratio (OR) of 5.84 (95% CI: 2.12–16.12, p<0.001), reflecting the marked systemic inflammatory response typical of fascial necrosis. Hyponatraemia (serum sodium below 135 mEq/L) was also highly predictive (adjusted OR: 4.12, 95% CI: 1.84–9.24, p=0.001), consistent with third-spacing and toxin-mediated capillary leak. Elevated serum creatinine above 1.6 mg/dL (adjusted OR: 3.60, 95% CI: 1.54–8.42, p=0.003) was consistent with sepsis-induced acute kidney injury. Blood glucose exceeding 180 mg/dL did not reach statistical significance as an independent predictor when adjusted for baseline diabetes mellitus (adjusted OR: 1.40, 95% CI: 0.68–2.88, p=0.354). Table III presents the complete multivariate regression results.

TABLE III Multivariate Logistic Regression: Independent Predictors of NF

Variable	Coeff.	OR	95% CI	p-value
CRP ≥ 150 mg/L	1.15	3.16	1.42–7.02	0.005*
WBC > 25 × 10⁹/L	1.76	5.84	2.12–16.12	<0.001*
Hb < 11 g/dL	1.02	2.77	1.18–6.52	0.019*
Na < 135 mEq/L	1.41	4.12	1.84–9.24	0.001*
Creatinine>1.6mg/dL	1.28	3.60	1.54–8.42	0.003*
Glucose > 180 mg/dL	0.34	1.40	0.68–2.88	0.354

*OR = Odds Ratio; CI = Confidence Interval; *p < 0.0*

D. Subgroup Analysis: Diabetics and Pathogen-Specific Profiles

The diagnostic accuracy of the traditional LRINEC score was further examined in two pre-specified high-risk subgroups. These subgroup findings, particularly for the pathogen-specific cohorts, are presented as exploratory observations rather than definitive conclusions, given the small sample sizes involved.

In the diabetic cohort (n=175), the traditional LRINEC score at the cutoff of 6 or above demonstrated a sensitivity of 95.0% but a specificity of only 58.0%, resulting in a positive predictive value of only 16.6%. This poor specificity is consistent with chronic baseline renal impairment (elevated baseline creatinine) and chronic hyperglycaemia, which may elevate diabetic patients' scores independent of the presence of deep tissue necrosis. Applying the standard LRINEC cutoff in diabetic patients may therefore generate a high proportion of false-positive results, with implications for unnecessary surgical consultations.

For the small exploratory subgroup of patients with histopathologically confirmed NF caused by Vibrio vulnificus (n=12), the traditional LRINEC score yielded a sensitivity of only 35.0% and an AUC of 0.614. V. vulnificus is characterised by rapid endotoxaemia and cardiovascular collapse, occurring before chronic haematologic shifts can manifest. In the exploratory Aeromonas dhakensis subgroup (n=8), three patients with drug-induced immunosuppression failed to demonstrate significant leucocytosis, resulting in falsely reassuring traditional LRINEC scores of 4 or below at admission. In these two exploratory subgroups, the J-LRINEC and internally validated MLRINEC models showed numerically higher sensitivities (MLRINEC: 83.3% for V. vulnificus and 87.5% for Aeromonas), which should be confirmed in larger, prospectively collected pathogen-specific cohorts before any firm conclusions are drawn.

E. Prognostic Associations and Clinical Outcomes

An admission traditional LRINEC score of 8 or above, or an MLRINEC predicted probability of 0.80 or above, was associated with adverse clinical outcomes in this cohort. Among NF patients, an admission LRINEC score of 8 or above was associated with a higher adjusted odds ratio for 30-day mortality of 3.42 (95% CI: 1.54–7.60, p=0.002), derived from logistic regression and an increased risk of requiring proximal limb amputation (OR: 4.12, p=0.001). Serial evaluations suggested that a reduction in scoring parameters within the first 72 hours following index surgery was associated with survival, whereas a persistent or increasing score was associated with inadequate surgical source control and the need for additional debridement procedures. Patients requiring three or more debridements had a mean admission LRINEC score of 10.2 compared with 7.4 for those requiring a single debridement (p=0.003).

IV. DISCUSSION

This single-centre retrospective comparative study examined the diagnostic and prognostic performance of traditional, regionally calibrated, and internally developed computational risk scores in a cohort of patients presenting with severe soft tissue infections. The principal finding is that while the traditional LRINEC score retains acceptable specificity, its sensitivity of 68.0% in this cohort raises concern about its suitability as a standalone triage tool in the emergency department setting, since a substantial proportion of true NF cases may be initially classified as low-risk, with potential implications for the timing of surgical exploration.

This limitation may reflect what can be described as an early-stage diagnostic paradox. The traditional LRINEC score relies substantially on markers of severe biochemical and haematologic derangement — hyponatraemia from fluid third-spacing into the fascial compartments, elevated creatinine from septic shock-induced renal hypoperfusion, and anaemia from bacterial toxin-mediated haemolysis and microvascular thrombosis [15]. Patients presenting during the early hours of fascial propagation may therefore have near-normal baseline metabolic panels, yielding falsely reassuring scores. This is broadly consistent with Fernando et al. (2019), who reported in a meta-analysis of 846 patients a pooled LRINEC sensitivity of 68.2%, closely aligned with the 68.0% observed here [16].

The reduced reliability of the traditional score was particularly evident in the diabetic subgroup, where specificity fell to 58.0%, likely reflecting chronic metabolic and renal changes that elevate baseline creatinine and glucose. Diabetes mellitus was present in 70.0% of the NF cohort, consistent with its recognised role as a major risk factor for NSTI development [17]. The WSES 2018 and 2023 guidelines note that laboratory scores should be interpreted cautiously in patients with pre-existing metabolic derangement [6]; the present data are broadly consistent with that caution, though the diabetic subgroup analysis here should also be regarded as exploratory pending confirmation of confidence intervals (Section III-D).

In the small exploratory subgroup of patients with Vibrio vulnificus infection (n=12), the traditional score's sensitivity was low (35.0%). V. vulnificus is characterised by rapid endotoxaemia and cardiovascular collapse occurring before chronic haematologic shifts can manifest [11], a pattern broadly consistent with Lee et al. (2017), who reported an AUC of 0.594 for the LRINEC score in V. vulnificus NF [18]. In this cohort, the internally validated MLRINEC model showed numerically higher sensitivity (83.3%) in the same exploratory subgroup, though this observation requires confirmation in larger, ideally multicentre, pathogen-specific cohorts.

The J-LRINEC score, developed by Norimatsu et al. (2025) for a Japanese population [12], was applied in this study to an Indian cohort using its published coefficients and cutoff, without local re-derivation. The score achieved a sensitivity of 88.0% in this cohort; however, because the underlying coefficients were derived from a different population with potentially different baseline haematologic norms, body habitus, and pathogen distributions, this finding should be interpreted as preliminary evidence of cross-population applicability rather than confirmation of equivalent performance, and ideally would be followed by a locally recalibrated version.

The internally developed Random Forest MLRINEC model showed the highest internal-validation AUC (0.968), with haemoglobin depletion and WBC surge identified as the most influential features. While this performance is encouraging, it was obtained on a single retrospective dataset using an 80/20 internal split, and therefore represents a preliminary, internally validated machine-learning LRINEC-based prediction model rather than a fully validated, deployment-ready clinical tool. The model's generalisability to other populations, laboratories, and pathogen distributions has not been established, and overfitting to dataset-specific characteristics cannot be excluded without external testing. These findings are broadly consistent with the direction reported by Suraphee (2024), who found that machine learning classifiers outperformed traditional scoring systems for soft tissue infection risk stratification in an internal validation setting [13]; however, that study likewise emphasised the need for external confirmation, a caveat that applies equally here.

The multivariate regression analysis identified profound leucocytosis (WBC > 25 × 10⁹/L) and hyponatraemia (sodium < 135 mEq/L) as the strongest independent predictors of NF, with adjusted odds ratios of 5.84 and 4.12, respectively. These associations are biologically plausible: marked leucocytosis reflects the systemic inflammatory response to bacterial toxins and tissue necrosis products, while hyponatraemia reflects extravascular fluid shift driven by toxin-mediated increases in capillary permeability [15]. Notably, blood glucose exceeding 180 mg/dL lost independent predictive significance after adjustment for diabetes status, suggesting that hyperglycaemia in this cohort largely reflects underlying diabetic comorbidity rather than an independent marker of fascial necrosis. This has practical implications for future recalibration efforts, as the glucose component of the LRINEC score may contribute relatively little independent signal in populations with high diabetes prevalence.

These findings should be interpreted in alignment with the World Society of Emergency Surgery (WSES) guidelines and established surgical principles [6]. No laboratory scoring system, regardless of computational sophistication, can replace clinical judgement. When classic physical findings are present — severe pain disproportionate to visible skin changes, wooden subcutaneous induration, rapidly spreading erythema, haemorrhagic bullae, or crepitus — the clinician should proceed directly to emergency surgical exploration regardless of score. In this framework, early diagnostic fascial debridement serves simultaneously as the definitive diagnostic test and the primary life-saving intervention. Algorithmic scoring models, including J-LRINEC and the internally validated MLRINEC, may be most useful in clinically ambiguous cases to help risk-stratify patients and guide the team toward either prompt surgical exploration or closely observed conservative management.

The prognostic findings are also clinically relevant. An admission LRINEC score of 8 or above was associated with a 3.42-fold increase in the adjusted odds of 30-day mortality and a 4.12-fold increased risk of amputation. Serial score monitoring provided additional information: score reduction within 72 hours was associated with survival, whereas persistent elevation was associated with inadequate source control. These observations are broadly consistent with the recommendations of Ramesh et al. (2024) regarding serial LRINEC monitoring to guide re-exploration decisions [19], though the present analysis would benefit from formal time-to-event

methodology if such data are available.
This study has several limitations. Its retrospective, single-centre design introduces inherent biases, including potential selection bias in chart identification. The internally developed Random Forest MLRINEC model, while showing strong performance on its internal validation split, requires external prospective validation in independent emergency department populations with differing baseline characteristics before it can be considered for clinical implementation; it should currently be regarded as a hypothesis-generating internal model rather than a validated diagnostic tool. Standard molecular pathogen confirmation was not performed for all equivocal microbiological cases. The pathogen-specific subgroups (12 V. vulnificus and 8 Aeromonas cases) are small, and the corresponding findings are presented as exploratory observations only. Future prospective, ideally multi-institutional, studies with larger and more diverse cohorts are needed to confirm the generalisability and clinical utility of the J-LRINEC score in this population and of the MLRINEC model overall.

V. CONCLUSION

The traditional LRINEC score, while historically important as one of the first objective laboratory-based tools for necrotizing fasciitis risk stratification, demonstrated suboptimal sensitivity during the early hours of presentation in this cohort, with particular limitations evident in patients with diabetes mellitus and in the small exploratory subgroup of infections caused by Vibrio vulnificus. The J-LRINEC score, applied here using its published Japanese-derived coefficients, and an internally developed Random Forest MLRINEC model both showed improved sensitivity and specificity in this cohort, suggesting they may be useful adjuncts for early identification of high-risk patients.
However, both of these calibrated and computational approaches require further validation — the J-LRINEC score through locally derived recalibration for South Asian populations, and the MLRINEC model through prospective external validation across independent centres — before either can be recommended for routine clinical deployment. Neither tool should supersede clinical suspicion or delay surgical debridement when necrotizing soft tissue infection is strongly suspected on physical examination. The integration of calibrated scoring systems, internally and externally validated machine learning models, and surgical clinical judgement remains the most promising pathway toward reducing the morbidity and mortality associated with this surgical emergency.

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VII. Funding, Conflict of Interest, Data Availability, and Author Contributions

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