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CLINICAL AND BACTERIOLOGICAL PROFILE OF NON HEALING WOUNDS - A SOUTH INDIAN EXPERIENCE

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ABSTRACT

Background: Non-healing wounds represent a significant clinical challenge, particularly in patients with underlying comorbidities such as diabetes, peripheral vascular disease and malnutrition. This study aims to assess the clinical, bacteriological and laboratory parameters associated with non-healing wounds in a South Indian population to identify factors influencing prolonged wound healing.

Materials and Methods: A total of 100 patients with non-healing wounds were included in this observational study. Detailed clinical data, including comorbidities, wound characteristics, and bacteriological profiles, were collected. Laboratory parameters such as white blood cell (WBC) count, haemoglobin (Hb), serum albumin, blood glucose, and C-reactive protein (CRP) levels were analysed to determine their correlation with wound healing times. Bacteriological cultures were obtained to identify the most common pathogens. Patients were categorized into two groups based on wound healing times: ≤8 weeks and >8 weeks.

Results: The mean age of the patients was 55.4 ± 12.6 years, with 60% being male. Diabetes mellitus was the most common comorbidity, present in 70% of patients. Diabetic foot ulcers were the predominant wound type, accounting for 50% of cases. The most common bacterial isolates were Staphylococcus aureus (40%) and Pseudomonas aeruginosa (25%). Significant correlations were found between delayed healing (>8 weeks) and elevated WBC counts (11,500 ± 2,000 cells/µL, $p < 0.01$), lower haemoglobin levels (10.2 ± 1.8 g/dL, $p = 0.02$), reduced serum albumin (3.4 ± 0.6 g/dL, $p < 0.01$), elevated blood glucose levels (180 ± 25 mg/dL, $p < 0.01$) and higher CRP levels (12.0 ± 3.5 mg/L, $p < 0.01$). These laboratory markers of infection, anaemia, and malnutrition were strongly associated with prolonged wound healing.

Conclusion: Non-healing wounds are associated with several clinical and laboratory abnormalities, it includes elevated WBC counts, anaemia, poor nutritional status, hyperglycaemia and systemic inflammation. In this study diabetic foot ulcers were the major cause for non – healing wounds. A multidisciplinary approach aimed at infection control, nutritional support and glycemic status is essential to improve wound healing outcomes. Further research is needed to explore novel therapeutic interventions for chronic wound management.

Keywords: Non-healing wounds, wound healing, diabetic foot ulcers, laboratory markers, inflammation

INTRODUCTION

Non-healing wounds represent a significant and growing challenge in clinical practice, particularly in developing regions such as South India.[1] These wounds, which fail to progress through the normal stages of healing within an expected timeframe, are associated with considerable morbidity, reduced quality of life and increased healthcare costs. The management of non-healing wounds requires a comprehensive understanding of both clinical and microbiological factors, as the presence of persistent infection is a major barrier to wound healing. Identifying the clinical characteristics and bacteriological profile of these wounds is critical for developing effective treatment strategies and improving patient outcomes. [2]

Globally, it is estimated that 1-2% of the population will experience a chronic wound at some point in their lives, with diabetic foot ulcers alone affecting approximately 15% of individuals with diabetes [2][3] In India, the scenario is particularly dire due to the high burden of diabetic foot ulcers, which account for nearly 25% of all hospitalizations in diabetic patients. Non-healing wounds are a major source of hospital admissions, repeated surgical interventions, and amputations, which contribute significantly to the healthcare burden. The incidence and prevalence rates of non-healing wounds in South India are increasing, particularly in rural areas where access to specialized wound care is limited. [3]

The pathophysiology of non-healing wounds is multifactorial, involving prolonged inflammation, impaired angiogenesis and a disrupted balance between matrix degradation and synthesis. A critical component in the perpetuation of non-healing wounds is infection. Bacterial colonization of wounds, especially with pathogenic and resistant organisms can lead to biofilm formation, which further impedes healing by protecting bacteria from both the host immune response and antibiotic therapy. Understanding the types of bacteria that colonize these wounds and their resistance patterns is essential for guiding appropriate antimicrobial therapy. [4]

The emergence of multidrug resistant (MDR) bacteria in non-healing wounds has been a growing concern. Resistance mechanisms, such as the production of beta-lactamases, efflux pumps, and biofilm formation, render standard antibiotics ineffective, complicating the management of infections. In South India, the prevalence of MDR organisms is notably high due to factors such as inappropriate antibiotic use, lack of antimicrobial stewardship programs and poor infection control practices in healthcare settings. [5]

The clinical management of non-healing wounds is complicated by several factors, including delayed presentation, poor patient compliance and inadequate wound care practices. In many cases, patients seek medical attention only after the wound has become significantly advanced, often due to lack of awareness or financial constraints. Additionally, the presence of comorbid conditions, such as uncontrolled diabetes, peripheral neuropathy and poor vascular supply exacerbates the chronicity of these wounds. [6]

Despite the high prevalence of non-healing wounds in South India, there is limited data on the clinical and bacteriological characteristics of these wounds in this population. Most existing studies focus on diabetic foot ulcers, with insufficient attention to other types of non-healing wounds such as pressure ulcers and traumatic wounds. Additionally, the patterns of antibiotic resistance among bacterial isolates from these wounds are not well-documented, which hampers the ability to implement effective infection control measures.

This study aims to fill this gap by providing a comprehensive analysis of the clinical and bacteriological profile of non-healing wounds in a South Indian setting. By identifying the common bacteria involved, their resistance patterns and associated clinical factors, this research seeks to inform better wound management practices, tailored antibiotic use which ultimately improves patient care.

MATERIALS AND METHODS

This study was a prospective observational study conducted at a multi-speciality hospital in South India over a period of 12 months, from December 2021 – December 2022. All patients were followed up for one year after completion of scheduled treatment. The study aims to evaluate the clinical and bacteriological profile of non-healing wounds in patients presenting to the hospital's surgical and wound care clinics.

Inclusion Criteria

- Patients aged 18 years and above with non-healing wounds persisting for more than 4 weeks despite standard wound care.
- Wounds of various etiologies, including diabetic ulcers, pressure ulcers, traumatic wounds and post-surgical wounds.
- Patients who consented to participate in the study and agreed to undergo bacteriological testing of their wounds.

Exclusion Criteria

- Patients with acute wounds-less than 4 weeks duration.
- Patients on antibiotics within the last 7 days prior to sample collection.
- Immunocompromised patients (e.g., those with HIV, undergoing chemotherapy).
- Patients who did not consent to participate in the study.

Methodology

A structured data collection form was used to record the demographic and clinical details of each patient, including age, gender, comorbidities (e.g., diabetes mellitus, hypertension, peripheral vascular disease),

wound duration and wound type (diabetic ulcer, pressure ulcer, traumatic wound, etc.).

Each wound was clinically evaluated for size, depth, presence of necrotic tissue, signs of infection (redness, warmth, discharge) and surrounding skin condition. Wound swabs were collected aseptically from the wound bed using sterile cotton-tipped applicators after cleaning the wound surface with normal saline to remove superficial contaminants. Swabs were taken from the deep tissue part of the wound to ensure collection of viable organisms and were immediately transported to the microbiology laboratory in appropriate transport media.

The swabs were inoculated onto standard culture media, including Blood Agar, MacConkey Agar, and Chocolate Agar, and incubated aerobically at 37°C for 24-48 hours. In cases where anaerobic infection was suspected, samples were also inoculated onto anaerobic media and incubated under appropriate conditions. Bacterial colonies were identified based on colony morphology, Gram staining and standard biochemical tests. Automated identification systems (e.g., VITEK 2) were used for precise organism identification when necessary.

- The isolated bacteria were subjected to antibiotic susceptibility testing using the Kirby-Bauer disk diffusion method on Mueller-Hinton Agar as per Clinical and Laboratory Standards Institute (CLSI) guidelines. Commonly tested antibiotics included penicillins, cephalosporins, aminoglycosides, fluoroquinolones, and carbapenems, among others.
- Multidrug-resistant (MDR) strains were defined as those showing resistance to three or more classes of antibiotics. Extended Spectrum Beta-Lactamase (ESBL) production in Gram-negative bacteria was detected using the combined disk method.

Outcome Measures

- Primary outcome measures included the identification of the most common bacterial pathogens isolated from non-healing wounds and their antibiotic susceptibility profiles.
- Secondary outcome measures included the assessment of clinical factors associated with specific bacterial infections and resistance patterns.

Statistical Analysis

Data analysis was done using Statistical Package for the Social Sciences (SPSS) software version 25.0. Descriptive statistics were used to summarize patient demographics, wound characteristics and bacteriological findings. The prevalence of different bacterial isolates and their resistance patterns were expressed as frequencies and percentages. Associations between clinical factors (e.g., wound type, comorbidities) and bacteriological findings were assessed using chi-square tests or Fisher's exact test as appropriate. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the Institutional Ethics Committee (IEC) and written informed consent was obtained from all participants prior to enrolment in this study. Patient confidentiality was maintained throughout the study, with all data anonymized.

RESULTS

A total of 100 patients with non-healing wounds were included in the study. The demographic and clinical characteristics of the study population are summarized in Table 1. The mean age of the patients was 55.4 ± 12.6 years, with a range of 25-80 years. There was a male predominance, with 60% of the participants being male and 40% female. The most common comorbidity observed was diabetes mellitus, affecting 70% of the patients, followed by hypertension (30%) and peripheral vascular disease (20%). Diabetic foot ulcers were the most frequent type of non-healing wounds, accounting for 50% of the cases, followed by pressure ulcers (20%) and traumatic wounds (15%). [Table 1]

Bacteriological analysis showed that 95% of the wounds were culture-positive, while 5% were culture-negative. A total of 150 bacterial isolates were identified from the 95 culture-positive wounds, with 60% of the wounds being polymicrobial and 35% monomicrobial. The most common bacterial species isolated were Staphylococcus aureus (30%), followed by Pseudomonas aeruginosa (25%), Escherichia coli (15%), and Klebsiella pneumoniae (10%). Methicillin-resistant Staphylococcus aureus (MRSA) was identified in 15% of the Staphylococcus aureus isolates. [Table 2]

The antibiotic susceptibility patterns of the major bacterial isolates are summarized in Table 3. High levels of resistance were observed in Gram-negative organisms, particularly Pseudomonas aeruginosa and Escherichia coli, with multidrug resistance (MDR) identified in 40% of Gram-negative isolates. Among Staphylococcus aureus isolates, 15% were identified as MRSA. These isolates showed resistance to multiple antibiotics, including penicillin and cephalosporin, but remained susceptible to vancomycin and linezolid. Pseudomonas aeruginosa exhibited the highest resistance to ceftazidime (70%) and ciprofloxacin (50%), but remained susceptible to piperacillin-tazobactam and carbapenems in most cases. [Table 3]

Diabetic ulcers showed a statistically significant correlation with the presence of Staphylococcus aureus and Pseudomonas aeruginosa ($p < 0.01$), while Escherichia coli was more frequently isolated in pressure ulcers ($p = 0.02$). [Table 4]

As per table 5 patients with polymicrobial infections had significantly higher WBC counts (12,000 ± 2,500 cells/µL) compared to those with monomicrobial infections (9,500 ± 1,800 cells/µL, p

< 0.01). This suggests a higher degree of systemic inflammatory response in polymicrobial infections. A higher percentage of neutrophils was observed in polymicrobial infections (75 ± 5%) compared to monomicrobial infections (65 ± 4%, p < 0.01), indicating a more pronounced immune response in cases of mixed bacterial infections. Elevated ESR levels were found in patients with polymicrobial infections (55 ± 12 mm/hr) compared to monomicrobial cases (38 ± 10 mm/hr, p < 0.01), reflecting greater chronic inflammation in polymicrobial wounds. CRP levels, a marker of acute inflammation, were significantly higher in polymicrobial infections (15.0 ± 3.8 mg/L) than in monomicrobial infections (8.5 ± 2.1 mg/L, p < 0.01), indicating more severe systemic inflammation in patients with polymicrobial infections. Procalcitonin levels, which indicate bacterial infection severity, were elevated in polymicrobial infections (1.5 ± 0.4 ng/mL) compared to monomicrobial infections (0.8 ± 0.3 ng/mL, p = 0.02), suggesting that polymicrobial infections are associated with a higher bacterial load and severity. [Table 5]

As per table - 6 higher WBC counts were significantly associated with prolonged wound healing times. Patients with wounds healing in >8 weeks had the highest mean WBC count (11,500 ± 2,000 cells/µL), indicating a potential association with persistent infection and inflammation (p < 0.01). Lower haemoglobin levels were associated with delayed healing. Patients with healing times >8 weeks had a significantly lower mean Hb level (10.2 ± 1.8 g/dL) compared to those healing within 4 weeks (p = 0.02), suggesting the impact of anaemia on delayed wound recovery. Lower serum albumin levels were correlated with longer healing times. Patients healing in >8 weeks had a mean serum albumin of 3.4 ± 0.6 g/dL, indicating poor nutritional status as a contributing factor to delayed wound healing (p < 0.01). Elevated blood glucose levels were significantly associated with prolonged healing times. Patients with healing times >8 weeks had a mean glucose level of 180 ± 25 mg/dL compared to 120 ± 15 mg/dL in those healing within 4 weeks (p < 0.01), highlighting the negative impact of hyperglycaemia on wound healing, particularly in diabetic patients. Higher CRP levels, an indicator of systemic inflammation, were strongly correlated with longer healing times. Patients with wounds healing in >8 weeks had a mean CRP level of 12.0 ± 3.5 mg/L (P < 0.01). [Table 6]

Table 1: Demographic and Clinical Characteristics of Patients with Non-Healing Wounds

Characteristic	Frequency (n = 100)	Percentage (%)
Age (mean ± SD)	**55.4 ± 12.6 years**	
Gender		
Male	60	60
Female	40	40
Comorbidities		
Diabetes Mellitus	70	70
Hypertension	30	30
Peripheral Vascular Disease	20	20
Wound Type		
Diabetic Ulcer	50	50
Pressure Ulcer	20	20
Traumatic Wound	15	15
Post-Surgical Wound	10	10
Venous Ulcer	5	5

Table 2: Bacterial Isolates from Non-Healing Wounds

Bacterial Isolate	Number of Isolates (n = 150)	Percentage (%)
Staphylococcus aureus	45	30
Pseudomonas aeruginosa	37	25
Escherichia coli	22	15
Klebsiella pneumoniae	15	10
Proteus species	12	8
Enterococcus species	10	6
Acinetobacter species	6	4
Streptococcus species	3	2

Table 3: Antibiotic Susceptibility Patterns of Major Isolates

Antibiotic	Staphylococcus aureus (n = 45)	Pseudomonas aeruginosa (n = 37)	Escherichia coli (n = 22)	Klebsiella pneumoniae (n = 15)
Penicillin	85% Resistant	-	-	-
Methicillin (MRSA)	15% Resistant	-	-	-
Ciprofloxacin	20% Resistant	50% Resistant	40% Resistant	45% Resistant
Ceftazidime	-	70% Resistant	60% Resistant	50% Resistant
Piperacillin-Tazobactam	-	20% Resistant	20% Resistant	15% Resistant
Vancomycin	0% Resistant	-	-	-
Imipenem	-	10% Resistant	15% Resistant	20% Resistant
Linezolid	0% Resistant	-	-	-

Table 4: Correlation Between Wound Type and Bacterial Isolates

Wound Type	Staphylococcus aureus	Pseudomonas aeruginosa	Escherichia coli	Klebsiella pneumoniae	Proteus species	Other species	p-value
Diabetic Ulcers (n=50)	25 (50%)	20 (40%)	10 (20%)	5 (10%)	5 (10%)	3 (6%)	< 0.01
Pressure Ulcers (n=20)	5 (25%)	8 (40%)	7 (35%)	3 (15%)	2 (10%)	2 (10%)	0.02
Traumatic Wounds (n=15)	8 (53%)	3 (20%)	2 (13%)	1 (6%)	0 (0%)	1 (6%)	0.03
Post-Surgical Wounds (n=10)	4 (40%)	2 (20%)	1 (10%)	2 (20%)	1 (10%)	1 (10%)	0.12
Venous Ulcers (n=5)	3 (60%)	1 (20%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)	0.08

Table 5: Laboratory Markers of Infection in Non-Healing Wounds

Laboratory Marker	Polymicrobial Infection (n = 60)	Monomicrobial Infection (n = 35)	p-value
WBC Count (cells/µL)	12,000 ± 2,500	9,500 ± 1,800	< 0.01
Neutrophil Percentage (%)	75 ± 5	65 ± 4	< 0.01
ESR (mm/hr)	55 ± 12	38 ± 10	< 0.01
CRP (mg/L)	15.0 ± 3.8	8.5 ± 2.1	< 0.01
Procalcitonin (ng/mL)	1.5 ± 0.4	0.8 ± 0.3	0.02

Table 6: Correlation Between Laboratory Parameters and Time of Wound Healing

Laboratory Parameter	< 4 Weeks Healing (n = 30)	4-8 Weeks Healing (n = 40)	> 8 Weeks Healing (n = 30)	p-value
WBC Count (cells/µL)	8,500 ± 1,200	9,800 ± 1,500	11,500 ± 2,000	< 0.01
Hemoglobin (g/dL)	13.0 ± 1.2	11.5 ± 1.5	10.2 ± 1.8	0.02
Serum Albumin (g/dL)	4.2 ± 0.3	3.8 ± 0.5	3.4 ± 0.6	< 0.01
Blood Glucose (mg/dL)	120 ± 15	150 ± 20	180 ± 25	< 0.01
CRP (mg/L)	5.0 ± 1.2	8.5 ± 2.0	12.0 ± 3.5	< 0.01

DISCUSSION

In our study, the mean age of the participants was 55.4 ± 12.6 years, with a range from 25 to 80 years, which is consistent with the age distribution seen in studies on non-healing wounds. In a similar study conducted by Krishna et al. (2020),[1] in South India, the mean age of patients with non-healing diabetic foot ulcers was reported to be 57.2 years, showing a comparable age group of affected individuals. The predominance of males in our study (60%) aligns with the findings of Boulton et al. (2018), [2] who reported a higher incidence of chronic wounds in males, particularly due to factors such as diabetes and peripheral vascular disease.

The most common comorbidity in our study was diabetes mellitus, affecting 70% of the patients. Diabetes is well-recognized as a major risk factor for non-healing wounds, particularly foot ulcers. Studies such as those by Apelqvist et al. (2017), [3] have shown that diabetic foot ulcers account for a significant proportion of chronic wounds globally, and approximately 15-25% of diabetic patients develop foot ulcers during their lifetime. Similarly, Singh et al. (2015), [4] reported that diabetes was the predominant comorbidity in 68% of patients with non-healing wounds, emphasizing the systemic nature of the disease and its impact on wound healing.

The bacteriological profile of non-healing wounds is critical in guiding treatment strategies. In our study, Staphylococcus aureus and Pseudomonas aeruginosa were the most frequently isolated bacteria, a finding that is consistent with studies conducted by Bowler et al. (2020),[5] who highlighted these organisms as the leading pathogens in chronic wounds. In addition, Escherichia coli and Klebsiella pneumoniae were also prominent pathogens in our study, particularly in diabetic foot ulcers and pressure ulcers, which correlates with findings by Lipsky et al. (2016),[6] where Gram-negative organisms were more commonly isolated in chronic diabetic wounds.

The high prevalence of diabetes mellitus and peripheral vascular disease (PVD) in our cohort had a significant impact on wound healing outcomes. Studies have shown that patients with diabetes and PVD have impaired wound healing due to poor perfusion and neuropathy. Marston et al. (2019)[7] reported that diabetic patients with comorbidities such as hypertension and PVD exhibited prolonged healing times and a higher risk of infection and amputation. In our study, patients with diabetes and PVD had a higher incidence of multidrug-resistant organisms (MDR), further complicating wound healing and prolonging recovery times.

In our study, prolonged wound healing was significantly associated with elevated inflammatory markers such as C-reactive protein (CRP) and WBC counts. Studies by Schultz et al. (2018), [8] found that elevated CRP and WBC are strong predictors of delayed wound healing, particularly in polymicrobial infections. Our findings are in line with these observations, as patients with higher CRP levels and WBC counts had significantly longer healing times. Furthermore, serum albumin levels, which are an indicator of nutritional status, were found to be lower in patients with delayed wound healing. This supports the findings by Wilkinson et al. (2020), [9] who showed that hypoalbuminemia is associated with poor wound healing due to its role in maintaining cellular integrity and immune response.

The current study highlights the significant impact of clinical and laboratory parameters on the healing time of non-healing wounds. Several important markers, including white blood cell (WBC) count, haemoglobin (Hb), serum albumin, blood glucose levels, and C-reactive protein (CRP), were found to have strong correlations with delayed wound healing. These findings align with and build upon previous research, offering insights into the potential mechanisms behind prolonged wound healing and the management of chronic wounds.

The study found that higher WBC counts were significantly associated with longer healing times, particularly in patients with healing times >8 weeks,

who had a mean WBC count of 11,500 ± 2,000 cells/µL. This association reflects ongoing infection or inflammation. Similar findings were reported by Schultz et al. (2018) [8] who demonstrated that elevated WBC counts are a marker of persistent infection, contributing to delayed wound resolution. Their study indicated that patients with chronic, non-healing wounds often exhibit increased systemic inflammation, as evidenced by higher WBC counts. The strong association between elevated WBC counts and prolonged healing underscores the importance of infection control in wound management.

The present study also found that lower serum albumin levels were strongly associated with longer healing times. Patients healing in >8 weeks had a mean serum albumin level of 3.4 ± 0.6 g/dL, indicating poor nutritional status. Previous studies, including one by Allison et al. (2017), [10] have demonstrated that hypoalbuminemia is a marker of malnutrition and is predictive of poor wound healing outcomes.

Armstrong et al. (2019),[11] demonstrated that uncontrolled blood glucose levels contribute to poor wound healing by promoting bacterial growth, impairing leukocyte function, and reducing collagen deposition. Moreover, hyperglycaemia promotes a pro-inflammatory environment that delays wound resolution, as shown in studies by Lipsky et al. (2016)6. Optimizing glycemic control in diabetic patients is crucial for promoting effective wound healing. Pettit et al. (2020), [12] similarly observed that elevated CRP levels were predictive of delayed healing in patients with chronic wounds, emphasizing the role of inflammation in the pathophysiology of non-healing wounds. Chronic inflammation disrupts the normal wound healing process by perpetuating tissue damage and inhibiting the proliferative and remodelling phases of healing. Anti-inflammatory therapies, alongside infection control, may help to reduce CRP levels and promote wound healing in these patients.

Our study has few limitations like this was a single-centre study, and the sample size, while adequate, may limit the generalizability of the findings. Future multicentre studies with larger sample sizes would help validate these results and explore additional factors influencing wound healing. Moreover, research into novel therapies targeting the inflammatory pathways involved in chronic wound healing could offer promising new treatment options.

CONCLUSION

The present study provides a comprehensive analysis of the clinical, bacteriological, and laboratory parameters associated with non-healing wounds in a South Indian population. Key findings highlight that elevated white blood cell (WBC) counts, lower haemoglobin levels; decreased serum albumin, poor glycemic control and increased C-reactive protein (CRP) levels are significantly correlated with prolonged wound healing times.

This study confirms the critical role that systemic health markers play in wound healing and highlights the need for a multidisciplinary approach to managing non-healing wounds. Clinicians should prioritize infection control, nutritional optimization and glycemic regulation as key components of a comprehensive wound care strategy. Early identification and management of these factors can significantly reduce healing times and improve patient outcomes.

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