Multidisciplinary Approach in Managing Diabetic Foot Ulcers: Correlation between Imaging Findings, Laboratory Markers, and Nursing Interventions in a Tertiary Hospital

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Abstract

Background: Diabetic foot ulcers (DFUs) are a common complication of diabetes and often lead to severe infections and amputations. A multidisciplinary approach, including radiological imaging, laboratory markers, and nursing care, is critical for effective management.

Objective: This study aimed to investigate the correlation between imaging findings, laboratory markers, and nursing interventions in managing DFUs in a tertiary hospital.

Methods: A retrospective observational study was conducted with 120 patients diagnosed with DFUs. Data were collected from radiological imaging (X-rays, MRI), laboratory markers (CRP, WBC), and nursing care records. Correlation analysis was performed to assess the relationship between these factors and patient outcomes.

Results: MRI detected osteomyelitis in 62% of cases and soft tissue infections in 45%. Elevated CRP levels were found in 70% of patients, and there was a significant correlation between MRI findings of osteomyelitis and elevated CRP ($r = 0.65$, $p < 0.001$). Frequent wound assessments by nursing staff were associated with a higher healing rate (70%).

Conclusion: The study highlights the importance of combining imaging, laboratory markers, and nursing interventions in the comprehensive management of DFUs. A multidisciplinary approach is essential for improving diagnostic accuracy and patient outcomes.

Keywords: Diabetic foot ulcers, imaging, MRI, CRP, nursing interventions, multidisciplinary care, osteomyelitis

Introduction

Diabetic foot ulcers (DFUs) represent one of the most severe and costly complications of diabetes mellitus, affecting approximately 15% of individuals with diabetes during their lifetime (Boulton et al., 2009). These ulcers significantly increase the risk of infection, lower limb amputation, and mortality, while also placing a substantial financial burden on healthcare system (Kerr, 2012). Early diagnosis and prompt management of DFUs are essential to prevent complications such as osteomyelitis, gangrene, and, ultimately, amputation (Nather et al., 2008). The management of DFUs typically requires a multidisciplinary approach involving radiologists, clinical chemists, and nurses, each playing a vital role in patient care.

Radiological imaging is indispensable in assessing the extent of soft tissue involvement, bone infection, and vascular complications. Modalities such as X-rays and magnetic resonance imaging (MRI) have proven valuable in diagnosing conditions like osteomyelitis and guiding surgical interventions (Lew and Waldvogel, 2004; Chatha et al., 2005). However, imaging alone may not provide a complete picture of the underlying pathology. Laboratory biomarkers, including inflammatory markers like C-reactive protein (CRP), white blood cell count, and blood glucose levels, offer important insights into the systemic nature of infections and metabolic control, providing essential data to guide treatment plans (Lipsky et al., 2012; Game, 2013).

In this multidisciplinary context, nursing care plays a pivotal role in managing wound care, educating patients on diabetes control, and implementing infection prevention measures. Nurses are often the first to assess wound status and coordinate care between specialists, ensuring that treatment strategies are tailored to the patient's needs (Schaper et al., 2016). By combining imaging findings, laboratory results, and nursing interventions, clinicians can optimize the management of DFUs, reduce healing time, and improve overall patient outcomes.

This study aims to explore the correlation between radiological imaging, laboratory markers, and nursing interventions in the management of diabetic foot ulcers in a tertiary hospital. By analyzing these interrelated factors, we hope to provide a more comprehensive understanding of how a multidisciplinary approach can enhance patient care for individuals with DFUs.

Literature Review

Imaging Modalities in DFU Management

Radiological imaging plays a crucial role in the management of diabetic foot ulcers (DFUs), particularly in assessing the extent of infection and detecting underlying bone and soft tissue involvement. X-rays are typically the first-line imaging modality used in evaluating DFUs, as they can detect gas in tissues, foreign bodies, and changes indicative of osteomyelitis (Lipsky et al., 2012). However, the sensitivity of X-rays in detecting early bone infections is limited. Magnetic resonance imaging (MRI) is considered the gold standard for assessing the extent of soft tissue infection and osteomyelitis, offering superior resolution in differentiating between cellulitis, abscesses, and necrosis (Chatha et al., 2005).

Studies have demonstrated that MRI is highly accurate in detecting bone marrow edema and early osteomyelitis, making it invaluable in cases where early intervention may prevent further complications (Game,2003). Computed tomography (CT) scans and nuclear imaging techniques such as bone scintigraphy are less frequently used but may be beneficial in cases where MRI is contraindicated or unavailable. In addition, ultrasound is gaining recognition for its ability to evaluate soft tissue abscesses and vascular status, though it remains limited in bone assessment (Alavi et al., 2014).

Laboratory Markers in DFU Management

Laboratory biomarkers provide complementary data to imaging in the diagnosis and management of DFUs. Blood glucose levels, glycosylated hemoglobin (HbA1c), and white blood cell count (WBC) are routinely monitored in diabetic patients to assess glycemic control and identify infection (Nather et al., 2008). However, more specific inflammatory markers such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) are widely used to detect the presence and severity of infections in DFUs (Lipsky et al., 2016). Elevated levels of these markers have been shown to correlate with the extent of infection and tissue damage, guiding clinicians in their management strategies.

Wound cultures are often used to identify pathogens responsible for infections, particularly in cases where antibiotics are required (Bader, 2008). The combination of imaging and laboratory markers has been found to be more effective in diagnosing osteomyelitis and differentiating between mild and severe DFUs. Studies have shown that when CRP and ESR levels are elevated alongside positive imaging findings for osteomyelitis, there is a greater likelihood of bone infection (Ong et al., 2015).

Nursing Care in DFU Management

Nurses play an integral role in managing patients with DFUs by providing wound care, educating patients about diabetes management, and implementing infection prevention strategies. Wound care involves regular assessment, debridement, dressing changes, and monitoring of healing progress. The selection of appropriate dressings and debridement techniques is crucial for promoting wound healing and preventing further complications (Frykberg et al., 2006).

A multidisciplinary approach involving nursing interventions has been shown to improve patient outcomes by reducing the risk of infection and amputation. Nurses are also responsible for educating patients on glycemic control, proper foot hygiene, and the importance of early detection and treatment of ulcers (Aalaa et al., 2012). This patient education is critical in preventing recurrence and promoting long-term foot health. Studies have highlighted the importance of nurses' roles in preventing pressure injuries and promoting wound healing through individualized care plans and patient engagement (Morey-Vargas and Smith, 2015).

Multidisciplinary Approach to DFU Management

The integration of radiology, clinical chemistry, and nursing care is essential in the comprehensive management of DFUs. A study by Lipsky et al. (2012) demonstrated that a combination of imaging and laboratory markers led to earlier diagnosis of infections and improved healing outcomes (Apelqvist, 2012). Similarly, other studies have shown that collaborative efforts between radiologists, clinical chemists, and nurses are crucial in formulating and executing effective treatment plans for patients with DFUs (Bentley and Foster, 2007). The collaborative management of DFUs helps bridge the gap between diagnostic findings and clinical care, ensuring that patients receive timely and effective interventions (Barshes, et al., 2013)

Methodology

Study Design

This study employed a retrospective observational design to analyze the correlation between imaging findings, laboratory markers, and nursing interventions in the management of diabetic foot ulcers (DFUs). The study was conducted over a 12-month period at a tertiary care hospital specializing in multidisciplinary diabetic care. Ethical approval was obtained from the hospital’s ethics committee prior to data collection.

Participants

A total of 120 patients diagnosed with diabetic foot ulcers were included in the study. Eligible participants were selected based on the following inclusion criteria:

- Adult patients aged 18 and above with a confirmed diagnosis of diabetes mellitus (type 1 or type 2).
- Presence of at least one active diabetic foot ulcer at the time of hospital admission.
- Availability of complete clinical, imaging, and laboratory data in patient records.

Exclusion criteria included patients with non-diabetic foot ulcers, incomplete medical records, or those who had undergone major limb amputations prior to hospital admission.

Data Collection

1. Imaging Data

Radiological imaging data were obtained from the hospital's imaging database. Imaging modalities used for the assessment of DFUs included plain radiographs (X-rays), magnetic resonance imaging (MRI), and, in some cases, computed tomography (CT) scans. Each patient's imaging records were reviewed by a team of radiologists to evaluate the extent of soft tissue involvement, bone infection (osteomyelitis), and other complications such as abscess formation. The following variables were recorded from the imaging reports:

- X-ray findings: Presence of osteomyelitis, soft tissue gas, and periosteal reaction.
- MRI findings: Soft tissue infection, bone marrow edema, and abscess formation.
- CT findings (when applicable): Bone and joint destruction, abscesses, and gas in tissues.

All imaging reports were reviewed independently by two radiologists, and any discrepancies were resolved through consensus.

2. Laboratory Data

Clinical laboratory data were retrieved from the hospital's electronic medical records. The following laboratory markers were analyzed for each patient:

- Blood glucose levels: To assess glycemic control.
- Hemoglobin A1c (HbA1c): To evaluate long-term glucose control.
- C-reactive protein (CRP): To measure systemic inflammation.
- White blood cell count (WBC): To identify infection.
- Wound cultures: To determine the presence of bacterial infection and antibiotic susceptibility.

Laboratory values were collected at the time of hospital admission and during follow-up visits as part of routine care.

3. Nursing Care and Interventions

Nursing interventions were documented from patient care records. Data on wound care practices, including dressing changes, debridement, and infection control measures, were collected. Additionally, the following nursing interventions were recorded:

- Patient education: Education on glycemic control, foot care, and wound care.
- Wound assessment frequency: The number of wound assessments and dressing changes performed during the hospital stay.
- Infection prevention: Measures such as sterile dressing techniques and the use of prophylactic antibiotics.

Each patient's adherence to the recommended nursing care protocols was assessed through a review of nursing notes, and this data was correlated with healing outcomes.

Data Analysis

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences), version 25.0. Descriptive statistics were used to summarize patient demographics, imaging findings, laboratory values, and nursing interventions. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as means and standard deviations.

The following statistical tests were applied:
- Pearson's correlation coefficient was used to assess the correlation between imaging findings (e.g., presence of osteomyelitis on MRI) and laboratory markers (e.g., elevated CRP or WBC levels).
- Multivariate logistic regression was used to determine the predictive value of combined imaging and laboratory markers for DFU healing outcomes (e.g., wound healing, surgical intervention, or amputation).
- Chi-square tests were performed to analyze the association between specific nursing interventions (e.g., frequency of wound care) and patient outcomes.

Statistical significance was set at $p < 0.05$.

Outcome Measures
The primary outcome measure was the correlation between imaging findings (e.g., soft tissue infection, osteomyelitis) and laboratory markers (e.g., CRP, WBC). Secondary outcome measures included:
- Wound healing rate: Defined as the percentage of patients whose ulcers healed within the study period.
- Rate of complications: Including the need for surgical intervention (e.g., debridement or amputation) and the occurrence of systemic infections.
- Length of hospital stay: The number of days each patient spent in the hospital during treatment.
- Patient adherence: To the nursing care protocols, assessed through wound assessment records.

Ethical Considerations
All patient data were anonymized to protect privacy, and informed consent was waived due to the retrospective nature of the study. Ethical approval was granted by the hospital's ethics review board.

Findings
This section presents the results of the study, analyzing the correlation between imaging findings, laboratory markers, and nursing interventions in managing diabetic foot ulcers (DFUs) in patients treated at the tertiary hospital.

Patient Demographics
A total of 120 patients were included in the study. The mean age of the patients was 61.4 ±12.7 years, with 64% being male and 36% female. The majority of the patients had type 2 diabetes (88%), while the remaining 12% had type 1 diabetes. The average duration of diabetes was 15.6 ±8.3 years.

Patient Characteristics	n (%)
Total patients	120 (100%)|
Age (Mean ±SD)	61.4 ±12.7 years
Gender	
Male	77 (64%)
Female	43 (36%)
Type of Diabetes	
Type 1	14 (12%)
Type 2	106 (88%)
Duration of Diabetes (Mean ±SD)	15.6 ±8.3 years

Imaging Findings

Out of the 120 patients, 62% had radiological evidence of osteomyelitis on MRI, while 45% had soft tissue infections visible on MRI. X-ray imaging revealed bone destruction in 52% of cases. MRI was the most sensitive imaging modality in identifying the extent of infection, particularly in cases where osteomyelitis was suspected.

Imaging Modality	Findings	n (%)
X-ray	Bone destruction	62 (52%)
MRI	Osteomyelitis	74 (62%)
	Soft tissue infection	54 (45%)
CT Scan (if applicable)	Abscess formation	18 (15%)

Laboratory Markers

Elevated inflammatory markers were common among the cohort. C-reactive protein (CRP) levels were elevated (>10 mg/L) in 70% of the patients, and 65% had elevated white blood cell (WBC) counts (>11,000 cells/µL), indicating active infection. Blood glucose control, as indicated by hemoglobin A1c (HbA1c), was poor, with a mean HbA1c level of 9.2% ±1.3%.

Laboratory Markers	Mean ±SD	Elevated Levels n (%)
Blood Glucose (mg/dL)|	238.1 ±55.3	84 (70%)
HbA1c (%)	9.2 ±1.3	-
C-reactive Protein (CRP) (mg/L)	14.7 ±5.6	84 (70%)
White Blood Cell Count (WBC) (cells/µL)	12,300 ±3,200	78 (65%)|
Wound Culture (Positive)	-	89 (74%)

Nursing Interventions

Nursing interventions, particularly regular wound assessment and debridement, were essential in managing DFUs. Patients who received wound care interventions every 2 days (41%) had a significantly higher healing rate than those who had wound assessments less frequently. Patient education on foot care and glycemic control was provided to 80% of the patients.

Nursing Interventions	n (%)
Wound assessment frequency	
Every 2 days	49 (41%)
Every 3-4 days	33 (28%)
Every 5-7 days	38 (31%)
Patient education provided	96 (80%)
Debridement performed	86 (72%)

Correlation between Imaging, Laboratory Markers, and Outcomes

The correlation analysis revealed a significant positive correlation between MRI findings of osteomyelitis and elevated CRP levels ($r = 0.65$, $p < 0.001$). Similarly, patients with elevated WBC counts and positive

wound cultures had a higher prevalence of osteomyelitis on MRI. Nursing interventions, particularly frequent wound care, were significantly associated with improved healing outcomes.

Correlation	Correlation Coefficient (r)	p-value
MRI-detected osteomyelitis vs. CRP	0.65	<0.001
WBC count vs. MRI-detected infection	0.58	<0.01
Wound care frequency vs. healing rate	0.48	<0.05

Outcomes

The overall healing rate for DFUs was 58%, with a higher rate (70%) in patients who received MRI and intensive wound care compared to those with less frequent imaging and nursing interventions. Complications, including minor amputations, occurred in 22% of patients, while major amputations were required in 8% of the cases. The average length of hospital stay was 14.2 ±6.1 days.

Outcomes	n (%)
Wound healing rate	70 (58%)
Complications	
Minor amputations	26 (22%)
Major amputations	10 (8%)
Length of hospital stay (Mean ±SD)	14.2 ±6.1 days

Summary of Findings

The findings of this study highlight the importance of a multidisciplinary approach to the management of diabetic foot ulcers. MRI proved to be the most effective imaging modality for detecting osteomyelitis, while elevated laboratory markers such as CRP and WBC were strong indicators of infection. Frequent wound assessments and patient education provided by nursing staff were associated with improved healing outcomes.

Discussion

This study aimed to explore the correlation between imaging findings, laboratory markers, and nursing interventions in the management of diabetic foot ulcers (DFUs) at a tertiary hospital. The findings highlight the importance of a multidisciplinary approach, combining radiological assessment, laboratory monitoring, and consistent nursing care to optimize patient outcomes.

Interpretation of Key Findings

Imaging Findings and Their Clinical Relevance

The results confirm that MRI is the most sensitive imaging modality for detecting osteomyelitis and assessing the extent of soft tissue infections in DFU patients. In our study, 62% of the patients had radiological evidence of osteomyelitis on MRI, while 45% had soft tissue infections visible. These findings align with previous studies, which have emphasized MRI's high sensitivity in detecting early bone involvement before it becomes visible on X-rays (Game, 2013). Given its superior diagnostic accuracy, MRI should be considered early in the diagnostic workup of patients with DFUs, especially when osteomyelitis is suspected.

X-ray imaging, while useful for detecting advanced bone destruction, was less effective in identifying early infections, with bone destruction observed in only 52% of the cases. This underscores the limitations of X-rays, particularly in the early stages of infection, and supports the recommendation that MRI be used for more detailed evaluations (Chatha, 2005). This study's findings reinforce the role of imaging as a critical component in assessing the severity of DFUs and guiding treatment strategies.

Laboratory Markers and Infection Monitoring

Laboratory markers, particularly C-reactive protein (CRP) and white blood cell (WBC) count, were found to be valuable in detecting infections and correlating with the severity of osteomyelitis. Elevated CRP levels (>10 mg/L) were present in 70% of the patients, and a positive correlation ($r = 0.65$, $p < 0.001$) was observed between elevated CRP and MRI-detected osteomyelitis. These findings are consistent with previous research indicating that CRP is a reliable marker of systemic infection in DFU patients (Ong et al., 2015).

Similarly, elevated WBC counts were noted in 65% of the patients, and this marker was significantly associated with MRI findings of infection ($r = 0.58$, $p < 0.01$). These correlations highlight the usefulness of combining imaging results with laboratory markers to form a comprehensive understanding of the extent of infection in DFUs (Ong et al., 2015. The presence of positive wound cultures in 74% of patients also highlights the high infection burden in this population, underscoring the importance of early and aggressive treatment.

Impact of Nursing Interventions on Patient Outcomes

Nursing interventions, particularly frequent wound assessments and patient education, played a crucial role in the management and healing of DFUs. Patients who received wound care interventions every two days had significantly higher healing rates (70%) compared to those with less frequent wound assessments. These findings highlight the importance of consistent wound care and the role of nurses in preventing the progression of infections (Aalaa et al., 2012).

Previous studies have shown that regular wound assessment and debridement promote faster healing by removing necrotic tissue and reducing bacterial load (Alavi, 2014). Our study confirms these findings and suggests that enhancing the frequency of wound care interventions may lead to better outcomes. Additionally, patient education on glycemic control and foot care, provided to 80% of the patients, was associated with improved self-management and prevention of DFU recurrence.

Implications for Clinical Practice

The findings of this study have several important implications for clinical practice. First, they highlight the need for early and comprehensive diagnostic workups in patients with DFUs, incorporating both advanced imaging techniques such as MRI and laboratory markers like CRP and WBC. The combination of these tools can help clinicians accurately assess the severity of infection and guide timely interventions.

Second, the study emphasizes the critical role of nursing interventions in DFU management. Frequent wound care assessments, debridement, and patient education were shown to be associated with better healing outcomes, underscoring the importance of nursing care in a multidisciplinary approach. Hospitals and clinics managing DFU patients should ensure that nursing staff are adequately trained and resourced to provide frequent and high-quality wound care.

Lastly, the study points to the importance of patient education in promoting self-care behaviors, such as regular foot inspections and glycemic control. Empowering patients with knowledge and tools to manage their condition can reduce the risk of DFU recurrence and long-term complications (Apelqvist, 2012).

Limitations

Several limitations of this study should be acknowledged. First, the retrospective nature of the study may have introduced selection bias, as only patients with complete imaging and laboratory records were included. Additionally, variations in the frequency of wound assessments and interventions among patients may have influenced the healing outcomes, making it difficult to generalize the results across all DFU patients. Future studies could benefit from a prospective design to control for these variables and assess the long-term impact of imaging and nursing interventions on DFU management.

Second, while the study included a substantial number of patients, it was conducted in a single tertiary hospital, which may limit the generalizability of the findings to other healthcare settings. Multi-center studies could provide more robust data on the effectiveness of multidisciplinary DFU management across different patient populations.

Future Research

This study highlights several areas for future research. First, further investigation into the cost-effectiveness of using advanced imaging modalities like MRI in the routine management of DFUs could help determine the optimal use of healthcare resources. Additionally, exploring the long-term outcomes of patients who receive regular wound care and education interventions would provide valuable insights into the prevention of DFU recurrence and reduction of complications.

Moreover, future studies could examine the role of novel biomarkers and advanced imaging technologies, such as positron emission tomography (PET) or ultrasound elastography, in the early detection of infections and monitoring of treatment response. Finally, there is a need for interventional studies that assess the effectiveness of standardized nursing protocols in improving DFU outcomes, particularly in resource-limited settings.

Conclusion

In conclusion, the results of this study underscore the importance of a multidisciplinary approach in the management of diabetic foot ulcers. The combination of advanced imaging techniques, laboratory markers, and consistent nursing care was shown to improve the diagnosis of infections and enhance wound healing outcomes. A coordinated effort between radiologists, clinical chemists, and nurses is essential to ensure optimal patient care, prevent complications, and reduce the burden of DFUs on healthcare systems.

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