

Association of HbA1c with Wagner Classification in Patients with Diabetic Foot

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Abstract

Background: A diabetic foot ulcer is a significant complication associated with diabetes mellitus, leading to considerable health issues and a high risk of amputation. Inadequate management of blood sugar levels and an extended period of having diabetes are two critical elements that influence the severity of an ulcer. This study aimed to investigate the clinical features of individuals with diabetic foot ulcers and to assess the relationship between HbA1c levels and Wagner grading. **Material and Methods:** A cross-sectional study was conducted in a hospital involving 75 patients suffering from diabetic foot ulcers who were referred to the General Surgery Department. We collected demographic details, the duration of the individual's diabetes, and any additional health issues they may have experienced. We assessed HbA1c levels and applied Wagner's classification to evaluate the severity of the ulcers. We conducted a statistical analysis to explore the relationship between HbA1c levels and Wagner grade. **Results:** The mean age was 48.09 ± 10.54 years, with 62.7% of the participants being male. The typical duration of diabetes among individuals was 12.72 ± 4.06 years. The majority of individuals (86.7%) showed HbA1c levels above 7.5%. The predominant category of ulcer observed was Grade 2, accounting for 41.3%, followed by Grade 3 at 29.3% and Grade 4 at 20.0%. A significant positive correlation was observed between HbA1c levels and Wagner grading ($p = 0.001$). **Conclusion:** The HbA1c level serves as an effective measure for assessing the occurrence of ulcers and forecasting the advancement of diabetic foot ulcers in individuals. Maintaining HbA1c levels within the normal range and adhering to proper hygiene practices can effectively prevent the onset and advancement of foot ulcers associated with diabetes.

Keywords: Diabetes, Foot ulcer, Neuropathy, Wagner grade

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Introduction

The chronic condition known as diabetes is brought on by either insufficient insulin production by the pancreas or inefficient utilization of the hormone that controls blood glucose.¹ The most recent report from the International Diabetes Federation (IDF) Diabetes Atlas (2025) indicates that 11.1% – or 1 in 9 – of adults aged 20-79 are affected by diabetes, with more than 40% unaware of their condition.² The rise in diabetes cases has surged significantly across nearly all nations, with individuals from low- and middle-income regions representing 75% of the global diabetic population.³ Diabetes has many detrimental metabolic effects that exacerbate pathophysiological issues like atherosclerosis, neuropathy, and foot ulcers.⁴ A diabetic foot ulcer (DFU) is a serious and incapacitating sign of uncontrolled diabetes that typically appears as an ulcer on the plantar part of the foot. Approximately fifteen percent of people with diabetes will acquire one of these ulcers, and 14%-24% of these people will need to have their ulcerated foot amputated due to infection of the bones or other ulcer-related challenges.⁵ Wagner's

classification is a basic and generally recognized method for assessing diabetic foot lesions and successfully treating them, despite the fact that there are other classifications available for assessment.⁶ DFUs are linked to considerable health complications, such as infections and the potential for lower limb amputation, along with an increased likelihood of fatalities.⁷

A meta-analysis revealed that certain factors, including HbA1c, fasting blood glucose, white blood cells, C-reactive protein, and erythrocyte sedimentation rate, serve as predictive indicators for an increased rate of major amputations.⁸ Plasma levels of glucose, levels of HbA1c, physical activity, previous history of DFU, and per capita family income in Indian rupees were found to be significant predictors of effective foot-care knowledge and practices.⁹

The hemoglobin A1c test, sometimes referred to as glycated hemoglobin, glycosylated hemoglobin, HbA1c, or A1c, measures the person's control of glucose levels. The test indicates average blood glucose levels for the preceding 90 days,

shown as a percentage.¹⁰ Glycated hemoglobin results from the nonenzymatic attachment of glucose to the amino groups of hemoglobin. HbA1c is a specific form of glycated hemoglobin formed by the binding of glucose to the N-terminal valine of the hemoglobin β -chain.¹¹ Previous trials have unequivocally established the correlation between HbA1c levels and diabetic sequelae, including peripheral neuropathy and peripheral artery disease, which are critical risk factors for the development of diabetic foot.¹²

The primary objective of this study is to determine whether higher HbA1c levels, which reflect poorer blood sugar control, are associated with more severe foot ulcers.

Material and Methods

This cross-sectional study was conducted in the Department of General Surgery at SRM Medical College Hospital and Research Centre over one year. The research involved individuals with diabetic foot ulcers who were either receiving care in an outpatient setting or were admitted to the hospital throughout the study period. The sample size was determined from a study published in *Value in Health* (2017), which indicated that 25% of individuals with diabetes experienced DFU. We presumed that the occurrence was consistent ($p = 0.25$), utilizing a 95% confidence interval and a 20% relative error. The sample size was determined to be 300 individuals with diabetes, anticipating 75 instances of foot ulcers related to the condition.

Participants aged 18 and older, regardless of gender, with a confirmed diagnosis of diabetes mellitus (HbA1c $>6.5\%$) and a diabetic foot ulcer, were included in the study, provided they were willing to give informed written consent. Participants under 18 years, those who chose not to give consent, non-diabetic individuals, people with traumatic foot ulcers, and patients with major comorbidities such as advanced cardiovascular disease, significant kidney issues, or uncontrolled high blood pressure were not included in the study.

A semi-structured form was used to record clinical and demographic information following the acquisition of informed written consent. A venous blood sample was collected and examined in the facility's laboratory to assess the HbA1c levels. A comprehensive clinical assessment of the ulcer was conducted, and the classification of diabetic foot lesions was executed according to Wagner's system after a thorough evaluation of the wound. The collected information was organized and analyzed using suitable statistical methods.

Wagner's classification is a commonly utilized system for assessing diabetic foot ulcers, considering both the depth of the ulcer and the degree of tissue involvement. Grade 0 indicates that the skin remains intact; however, it exhibits structural issues or high-risk characteristics, categorizing it as a "foot at risk." Grade 1 indicates the presence of a superficial ulcer confined to the dermis. Grade 2 is a more severe ulcer that penetrates completely through the skin, affecting the tendons, ligaments, or joint capsule. No signs of infection or bone inflammation are present. Grade 3 signifies a severe infection that has resulted in the development of an abscess, osteomyelitis, or septic arthritis. Grade 4 shows that the condition is confined to one specific area of the foot. In contrast, Grade 5 indicates that it has extended across the whole foot, often requiring a significant surgical procedure.⁶

The Statistical Package for the Social Sciences (SPSS) version 25.0 was employed to analyze the data, which was entered into Microsoft Excel. Demographic and clinical variables were summarized using descriptive statistics. The mean $\pm$ standard deviation (SD), median, minimum, and maximum values of continuous variables, including age and diabetes duration, were reported. Frequencies and percentages were used to present categorical variables, such as gender, duration categories, HbA1c groups, and Wagner grades. The Chi-square test was employed to evaluate the correlation between Wagner grading and HbA1c levels. The intensity and direction of the correlation between HbA1c values and Wagner grades were assessed using Spearman's rank correlation coefficient (ρ), as these variables were ordinal in nature. A statistically significant p-value was defined as less than 0.05, while a highly significant p-value was defined as less than 0.01.

Results

This study was conducted among 75 individuals with Diabetic Foot Ulcer to correlate Wagner grading and HbA1C levels.

A total of 75 individuals with diabetic foot ulcers were examined. The average age of the participants was 48.09 years, with the median age recorded at 45 years. Individuals ranged in age from 28 to 65 years old. The largest cohort of individuals was in the 51–60 age category, accounting for 37.3% of the overall population. The subsequent group consisted of individuals aged 41–50 at 29.3%, followed by those aged 31–40 at 16%, individuals over 60 at 12%, and the youngest group under 30 at 5.3%. These findings show that middle-aged people endure an increased burden. In the study population, there were 47 male patients, accounting for 62.7%, and 28 female patients, making up 37.3%. This

indicates a ratio of approximately 1.7 males for every female. The mean duration that individuals have been diagnosed with diabetes mellitus is 12.72 years, with a standard deviation of 4.06 years. The average duration is 12 years, with a span from 5 to 22 years. The majority of individuals had been living with their condition for 8 to 15 years, accounting for 58.7%, while 29.3% had experienced it for over 15 years, and 12% had been managing it for less than 7 years. This indicates that a prolonged duration of diabetes increases the likelihood of developing foot ulcers associated with the condition.

Table 1: Descriptive data of participants (n = 75)				
S N o	Variables		Frequenc y	Proportio n
1	Age	< 30 years	4	5.3%
		31 – 40 years	12	16%
		41 – 50 years	22	29.3%
		51 – 60 years	28	37.3%
		> 60 years	9	12%
2	Gender	Male	47	62.7%
		Femal e	28	37.3%
3	Duratio n of DM	≤ 7 years	9	12%
		8 – 15 years	44	58.7%

		> 15 years	22	29.3%
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Figure 1 denotes Wagner's classification of Diabetic Foot Ulcer. Based on Wagner's classification, most individuals demonstrated significant levels of ulcer severity. Grade 2 ulcers were the most common, representing 41.3% (n = 31) of all cases. Following that, 29.3% (n = 22) of individuals experienced Grade 3 ulcers, while 20.0% (n = 15) presented with Grade 4 ulcers. A small fraction of individuals showed early-stage disease, with Grade 1 ulcers noted in 5.3% (n = 4) of the cases. Severe gangrene was identified in 4.0% of patients, with grade 5 ulcers present in 3 individuals.

Figure 1: Wagner Grading among patients with DFU (n = 75)

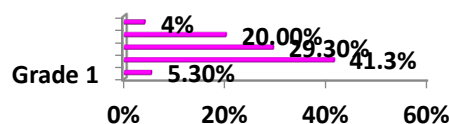


Figure 2 shows the categorization of HbA1c levels. The analysis of HbA1c levels among the study participants indicated that a majority of individuals exhibited inadequate glycemic management. Only 13.3% (n = 10) showed HbA1c levels between 6.5 and 7.5%. A significant portion, 41.3% (n = 31), showed HbA1c levels between 7.6 and 8.5%. Additionally, 24% (n = 18) exhibited levels ranging from 8.6% to 9.5%, while another 21.3% (n = 16) demonstrated levels exceeding 9.5%. A total of 86.7% of individuals exhibited HbA1c levels exceeding 7.5%, indicating that the majority of those with diabetic foot ulcers had difficulty maintaining adequate blood sugar control.

Figure 2: HbA1C levels among patients with DFU

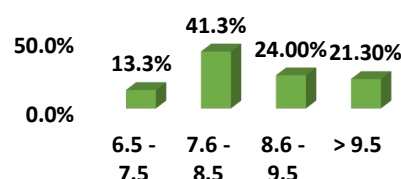


Figure 3 indicates the correlation of Wagner grading and HbA1C levels. Spearman's rank correlation analysis revealed a significant positive relationship between HbA1c levels and Wagner grade ($p = 0.774$, $p < 0.001$). This correlation was statistically

significant, indicating a significant association between poor glycemic management and the worsening of diabetic foot ulcers. The positive correlation coefficient indicates that elevated HbA1c levels are linked to increased Wagner grades.

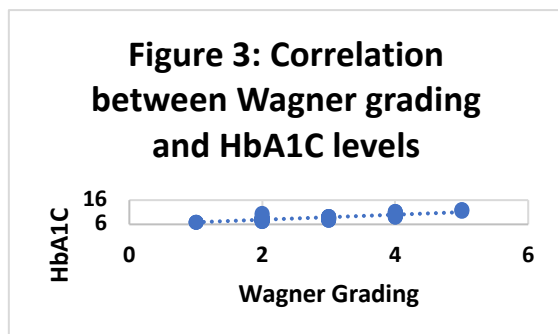


Table 2 shows the association between Wagner grading and levels of HbA1C. A statistically significant relationship has been found between Wagner grading and HbA1c levels ($p = 0.001$). Patients with lower Wagner grades exhibited improved glycemic control, whereas those with higher grades were predominantly linked to elevated HbA1c levels.

S No	Grades	6.5 – 7.5	7.6 – 8.5	8.6 – 9.5	> 9.5	p value
1	Grade 1	4 (100%)	0	0	0	0.001
2	Grade 2	6 (19.4%)	21 (67.7%)	2 (6.5%)	2 (6.5%)	
3	Grade 3	0	10 (45.5%)	12 (54.5%)	0	
4	Grade 4	0	0	4 (26.7%)	11 (73.3%)	

5	Grade 5	0	0	0	3 (100%)	
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Discussion

The present research evaluated 75 individuals suffering from diabetic foot ulcers. The mean age was 48.09 years, with a median of 45 years and a range spanning from 28 to 65 years. The largest demographic consisted of individuals aged 51 to 60, accounting for 37.3%, while those aged 41 to 50 represented 29.3%. Only 5.3% fell below the age of 30. The findings indicate that individuals in their 40s and 50s experience the highest incidence of complications related to diabetic foot within our cohort. The population consisted of a higher number of men compared to women, with men making up 62.7% and a male-to-female ratio of approximately 1.7:1. Our findings align closely with those reported by Farooque U et al.¹³ from Pakistan, who observed an average age of 47.4 ± 10.6 years, which is quite comparable to our results. The gender distribution was nearly balanced (51% males and 49% females), yet our study distinctly indicated a higher number of males compared to females. Shah et al.⁶ reported an average age of 58.96 ± 8.35 years, with the majority of individuals falling within the 61 to 70 age range and a notable male predominance at 78%. Singh et al.¹⁴ observed that their populations were predominantly older, with a greater number of men compared to women, reporting a mean age of 57.56 ± 12.5 years and a male-to-female ratio of 2.3:1. Ghanbari et al.¹⁵ (Iran) observed that the distribution of genders was nearly balanced, with 53.6% males and 46.4% females. This contrasts with numerous studies conducted in India, which indicated a higher prevalence among males. The younger average age observed in our study, compared to certain regional reports, could suggest an earlier onset of diabetes, lifestyle factors, or trends in referrals.

The average duration of diabetes mellitus in this study was 12.72 ± 4.06 years, with a median of 12 years and a range spanning from 5 to 22 years. A significant portion of the individuals, 58.7%, had been living with their condition for a duration of 8 to 15 years. Meanwhile, 29.3% had experienced it for over 15 years, and a smaller group, comprising 12%, had been affected for 7 years or less. The findings indicate that prolonged diabetes is a significant contributor to the development of foot ulcers associated with the condition. This is likely due to the deterioration of small blood vessels, peripheral nerves, and the immune system that accumulates gradually over time. Our findings align with those of Singh et al.¹⁴, who reported that 63.8% of individuals had diabetes for over a decade. This highlights the relationship between prolonged

diabetes and an increased likelihood of foot complications. It was observed that over fifty percent of the individuals experienced ulcers persisting for over a month, indicating that they were not addressed promptly and had a prolonged duration. Similarly, Farooque U et al.¹³ observed that 65.9% of individuals had diabetes for over 15 years, a figure that surpasses that of our research. This suggests that within their cohort, an extended duration of the condition may have exacerbated the ulcers.

The current study showed inadequate management of blood sugar levels in most individuals with foot ulcers related to diabetes. Our findings align with those of Farooque U et al.¹³, who reported an average HbA1c level of $9.07 \pm 1.65\%$, with 94% of the individuals exhibiting HbA1c levels exceeding 7.5%. The distribution pattern observed in their study closely resembles ours, particularly in the elevated HbA1c categories ($>8.5\%$), reinforcing the significant connection between inadequate long-term glycemic management and the onset of diabetic foot ulcers. Sharath S et al.¹⁶ observed that elevated HbA1c levels were significantly associated with delayed ulcer healing. This highlights the significance of maintaining proper glycemic levels in the management of diabetic foot issues. Abhirup H R et al.¹⁷ also found that a significant portion of the patients (35.55%) had HbA1c levels exceeding 8%, supporting the notion that elevated HbA1c is prevalent in this patient population. Ozenc et al.¹⁸ observed no statistically significant difference in HbA1c levels among diabetic patients, regardless of the presence of foot ulcers. This variation could result from discrepancies in the study designs, the traits of the samples, the trends in glycemic management, or additional elements such as peripheral vascular conditions and infection status.

Wagner grade and its correlation with HbA1C

In the current study, the Wagner classification system revealed that the majority of patients displayed moderate to severe ulcer severity. Grade 2 ulcers were the most prevalent at 41.3%, with Grade 3 following at 29.3% and Grade 4 at 20.0%. A mere 5.3% of individuals presented with Grade 1 ulcers, indicating they were in the initial phases of the condition. Conversely, 4.0% of individuals experienced severe gangrene (Grade 5). Overall, nearly 53% of individuals presented with Grade 3 or higher lesions, indicating that complex diabetic foot conditions were a significant concern upon their hospital visit. Our study revealed a reduced proportion of advanced classifications compared to the findings of Farooque U et al.¹³ Their research highlighted that Grade 4 (36.36%) and Grade 5 (22.72%) were notably common, suggesting a more severe manifestation of the disease in their

group. They also documented significant systemic comorbidities, including nephropathy (21.59%), neuropathy (14.77%), and hypertension (15.91%), emphasizing the multisystem involvement that could promote ulcer progression. In contrast, Grade 2 is the most prevalent, indicating an earlier detection in our data. The findings of our study closely align with those reported by Shah et al.⁶ in Pune, indicating that Grade II lesions were the most prevalent at 42%, followed by Grade III at 34%, with only a limited number of extensive gangrene cases at 4%. Singh et al.¹⁴ reported that Grade 2 ulcers were the most common, occurring in 40.95% of cases, followed by Grade 3 at 31.4%. These similarities suggest that in different Indian contexts, individuals often display intermediate stages of ulcer severity. Abhirup H R et al.¹⁷ observed that Wagner Grade 2 was the most prevalent at 58.88%, with neuropathy occurring in 98%, ischemia in 50%, and infection in 80%, all of which were notably frequent. The observation that neuropathy was noted less frequently in our study could be attributed to variations in diagnostic practices or record-keeping methods. Conversely, Ghanbari et al.¹⁵ discovered that Grade 4 was the most prevalent lesion (41.7%), indicating a more advanced stage of the disease, similar to the findings of Farooque et al. These variations observed between studies may be attributed to differences in access to care, patient knowledge, referral practices, blood sugar management, and local economic conditions. In summary, the observation that the majority of the ulcers in our study were classified as Grade 2 indicates that they presented with a moderate level of severity upon initial appearance. Still, the significant proportion of advanced cases indicates a pressing need to enhance initial assessments, educate patients, and implement comprehensive care strategies to prevent deterioration and reduce the likelihood of severe outcomes.

The current study revealed a statistically significant positive correlation ($p = 0.001$) between HbA1c levels and Wagner grading, indicating an established correlation between increasing severity of diabetic foot ulcers and deteriorating glycemic control. Higher Wagner grades were mainly associated with elevated HbA1c levels, whereas patients with lower grades exhibited relatively better glycemic control. This study highlights the role that chronic hyperglycemia plays in the development of diabetic foot pathology, which is most likely brought on by processes such as delayed wound healing, peripheral neuropathy, microvascular impairment, and decreased leukocyte function. Our findings correspond with research conducted by Farooque U et al.¹³, which identified a highly significant correlation ($p < 0.00001$) between Wagner classification and HbA1c levels. The notion that HbA1c serves as a reliable biochemical marker for

assessing ulcer severity is reinforced by the level of correlation identified in their study. According to Shah et al.⁶ in Pune, Wagner grading was also strongly positively correlated with advanced age, HbA1c, and the length of diabetes. This indicates that an extended period of diabetes and inadequate blood sugar management increases the likelihood of serious ulceration and potential amputation. These findings have been supported by our research, which indicates that the majority of individuals had been living with diabetes for over eight years and presented with lesions classified as Grade 3 or higher upon their initial visit. Ghanbari et al.¹⁵ also reported similar findings, indicating that average HbA1c values rose progressively with higher Wagner grades, starting from 7.35% in Grade 1 to 11.64% in more advanced grades. The trend identified in our study, indicating that Grade 4 and Grade 5 ulcers were mainly associated with HbA1c levels exceeding 9.5%, aligns with this progressive development.

Conclusion

Older age, male gender, prolonged duration of diabetes, elevated HbA1c levels, and pre-existing foot abnormalities in individuals with diabetes are identified as risk factors for foot complications. The assessment of HbA1c can assist in forecasting the occurrence of diabetic foot in the mentioned high-risk individuals, as the levels of HbA1c increase in a linear manner with the advancing stages of the Wagner classification for diabetic foot. The HbA1c level serves as an effective measure for assessing the occurrence of ulcers and predicting the progression of diabetic foot ulcers in individuals.

Limitations

- The larger sample size might be considered for generalising results.

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