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ORIGINAL ARTICLE

Correlation Analysis of Nutritional Status of Diabetic Foot Patients with Different Wagner Grades

Munire Mutailipu[1] · Bohan Zhang[1] · Hongjuan Zhu[1]

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Abstract

Background The nutritional status of Diabetic-foot (DF) patients in clinic is not good, and there are fewer studies on the nutritional status of DF patients with different Wagner grades at home and abroad. Therefore, by exploring the nutritional status of DF patients with different Wagner grades and analyzing their related factors, this study aims to provide an effective basis for improving the nutritional status of DF patients and improving their quality of life.

Objective To explore the nutritional status of diabetic foot (DF) patients with different Wagner grades.

Methods Using a cross-sectional study method, 577 patients with DF who were hospitalized between February 2020 and January 2023 in our hospital were selected for investigation and were divided into three groups according to Wagner grading of grade 1–2, grade 3, and grade 4–5, and the simple mini-nutritional assessment scale was used to compare the nutritional status scores of patients in the three groups. The correlation between different gender, age, BMI, duration of diabetes, glycosylated hemoglobin (HbA1c), hemoglobin (Hb), albumin, prealbumin, white blood cell count (WBC), and Wagner grading was compared, and the nutritional status of patients with different Wagner grading was analyzed.

Results Of the 577 DF patients included in the study, 40.4% are malnourished and 49.0% are at nutritional risk. The score of the mini-nutrition evaluation scale was (20.93 ± 3.67) for patients with Wagner grade 1 ~ 2, (17.30 ± 5.35) for grade 3, and (14.22 ± 5.99) for grade 4 ~ 5. Among patients with different Wagner grades, age, diabetes course, glycosylated hemoglobin (HbA1c), white blood cell count (WBC), hemoglobin (Hb), albumin, and prealbumin are statistically significant ($p < 0.05$), and sex and BMI are not statistically significant ($p > 0.05$).

Conclusions The nutritional status of patients with Wagner grading 3 ~ 5 is significantly worse than that of patients with Wagner grading 1–2. Age, duration of diabetes, HbA1c, WBC, Hb, albumin, and prealbumin have important effects on the development and prognosis of foot ulcers in patients with DF. Healthcare workers should give targeted interventions and appropriate nutritional support through the screening and comprehensive consideration of relevant factors at an early stage in clinical practice in order to improve the general condition of patients, accelerate the purpose of ulcer healing, and thus improve the quality of life of patients.

Keywords Wagner grading · Diabetic foot · Nutritional status · Mini-nutritional assessment

Introduction

Diabetic foot (DF) is one of the most common complications of diabetes mellitus, characterized by high incidence, high disability rate, high mortality rate, and low cure rate, which seriously affects the health and quality of life of the nation [1]. Studies have shown that the prevalence of DF in the global diabetic population is approximately 5–9% [2]. The lifetime prevalence of DF in diabetic patients is as high as 34% [3], with a recurrence rate of 22.1% [4] and an annual morbidity and mortality rate of 11% [5].

Previous literature has reported that malnutrition is associated with difficult DF wound healing and lower extremity amputation [6] and that nutrition plays a key role in the prevention and improved clinical prognosis of foot ulcers [7]. More than 60% of patients with DF ulcers Wagner grade 0 to 5 are associated with varying degrees of malnutrition or nutritional disorders [8]. One study [9] showed that the higher the degree of the Wagner classification, the more severe the disability and

Munire Mutailipu and Bohan Zhang contributed equally to this work.

✉ Hongjuan Zhu
zhuhj456@163.com

Munire Mutailipu
1912214470@qq.com; iiiauthor@gmail.com

[1] Department of Burns and Plastic Surgery, The Fourth Medical Center of Chinese, PLA General Hospital, 51 Fucheng Road, Haidian District, 100142 Beijing, China

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the worse the nutritional status of the DF patients. Nutritional status is the basis and key to the control effect of DF [10]. Malnutrition will not only weaken the immune resistance of DF patients but also prolong the treatment time for wound infection and reduce the patient's daily activity ability. These lead to a decline in quality of life, which result in less effective treatment, increased hospital stays, medical costs, amputation (toe) rate, etc. Amputation is the key cause of death in DF patients [11]. Currently, there are insufficient domestic and foreign reports of the potential impact of malnutrition on the severity and outcome of DF [12].

Therefore, in order to fully understand and grasp the nutritional status of DF patients, this study aimed to improve the nutritional status and quality of life of DF patients by investigating the nutritional status of inpatients with DF with different Wagner grades and conducting a correlation analysis of nutritional status.

Methods and Materials

Study design

A total of 577 patients with DF who were admitted to our hospital from February 2020 to January 2023 were selected as the study subjects, including 399 males and 178 females. Age is 24 ~ 91 (63.96 ± 11.98) years. All are type 2 diabetes, with the course of the disease being 1 ~ 50 years (15.29 ± 9.23) years. Inclusion criteria are as follows: ① all patients met the relevant diagnostic criteria of the Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes (2020 Edition) [13]; ② foot ulcer grading according to Wagner grading standards [14], Wagner grade 1 ~ 5 patients (≥ 18 years old); ③ have a certain understanding and cooperation ability, and voluntarily participate in this research. Exclusion criteria are as follows: ① incomplete questionnaire information; ② patients with severe cognitive impairment, severe chronic wasting diseases, end-stage malignancy, and multi-organ failure.

Assessment of nutritional status

We used the MNA scale to assess the nutritional status of participants [15], which is recommended by the European Parenteral and Enteral Nutrition Association for the assessment of nutritional status in older adults. Velles et al. [16] suggested that the sensitivity of the MNA scale for malnutrition assessment is 96%, specificity is 98%, positive predictive value is 97%, and internal consistency confidence is 0.711. The MNA scale can screen malnutrition risk and determine the state of malnutrition, which has been widely used in clinical practice. MNA includes anthropometry, comprehensive assessment, dietary status, and subjective evaluation. There is a total of 18 items, with a total score of 30 points, with lower values representing worse conditions and higher scores indicating better nutritional status. Evaluation criteria are as follows: Malnutrition when the total score is lower than 17; potential malnutrition risk when the score is from 17 to 23.9; and well-nourished when the score is higher than 24.

Assessment of covariates

The questionnaire is designed by the investigators on the basis of a literature review and consultation with experts in related fields. The contents of the questionnaire include ① general information such as gender, age, and BMI; ② disease-related data: Wagner grade and diabetes course; ③ laboratory indicators: HbA1c, Hb, albumin, prealbumin, and WBC.

Anthropometric measurements

Height was measured using a standard height scale, accurate to 0.1 cm, and weight was measured using a metric scale, accurate to 0.01 kg. Weight, height, body mass index (BMI), middle upper arm circumference (MUAC), and calf circumference (CC) are obtained to complete the MNA.

BMI is the ratio of weight (kg) to height squared (m^2). According to the "Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults" [17], BMI < 18.5 kg/m^2 is thin, 18.5 $kg/m^2 \leq$ BMI < 24.0 kg/m^2 is normal, 24.0 $kg/m^2 \leq$ BMI < 28.0 kg/m^2 is overweight, and BMI ≥ 28.0 kg/m^2 is obese. MUAC is the midpoint between the ulnar hawk's beak and the acromion on the healthy side of the upper arm circumference at the point. CC was measured at the widest part around the calf and repeated 2 more times to take the largest measurement [15].

Data collection methods

The investigators completed the questionnaire within 24 h of admission for DF patients who met the inclusion criteria in accordance with the principle of informed consent, and the biochemical indexes were selected from the most recent values after admission, and the investigators and department subject members conducted the survey and completed it in accordance with the uniform guideline. The investigator checked and checked the validity and completeness of the completed questionnaires item by item immediately after the patients filled in the forms to ensure that the information was qualified and the questionnaires were collected in a timely manner.

Statistical analysis

SPSS 26.0 statistical software was used for data analysis. The measurement data were expressed as mean ± standard deviation ($\overline{x} \pm s$), and analysis of variance was used for comparisons between groups. The counting data were expressed as proportions or percentages, the chi-square test was used for comparison between groups, and the difference was statistically significant with $p < 0.05$.

Results

Occurrence of malnutrition in patients with different Wagner grades

The 577 patients were divided into 3 groups according to the Wagner grade. The patients with Wagner grade 1 ~ 2 accounted for 19.06% of the total number, the patients with Wagner grade 3 accounted for 38.13%, and the patients with Wagner grade 4 ~ 5 accounted for 42.8%. The nutritional scores of the three groups were compared, $F = 61.841$, $p < 0.001$, which was statistically significant, as shown in Table 1.

Comparison of clinical data of DF patients with different Wagner classifications

In this study, 19.06% of the patients had Wagner grade 1 to 2, 38.13% had grades 3, and 42.8% had grade 4 to 5, with the majority of patients in each group being male. By comparing between groups, age, duration of diabetes mellitus, and Wagner grade were correlated ($p < 0.001$), as shown in Table 2.

Comparison of laboratory indices in DF patients with different Wagner classifications

Comparison between groups showed that Hb, albumin, prealbumin, HbA1c, and WBC all correlated with the Wagner classification ($p < 0.001$), as shown in Table 3.

Discussion

The results of this study showed that the nutritional status of DF patients with different Wagner grades was not satisfactory, and there were obvious differences in nutritional status between the groups. The nutritional status of patients with Wagner grade 4 ~ 5 was worse than that of patients with Wagner grade 1 ~ 3.

Among the patients with Wagner grade 4 ~ 5, 57.89% were malnourished. Among the patients with Wagner grade 3, 35.45% were malnourished. This is similar to the results reported by Xiao Ting et al. [18] that nutritional status was inversely correlated with DF grade. With the development of foot ulcers, the nutritional status of patients continues to decline. The analysis may be that patients need to consume a large amount of nutrients during wound repair, and these missing nutrients are not replenished in time, resulting in secondary malnutrition. When the body is malnourished for a long time, it can lead to a decrease in immunity, which further increases the likelihood and severity of infection.

By comparing gender, age, duration of diabetes, and BMI in patients with different Wagner classification DF, it was found that male patients were predominant in each group, and it has been shown that women are more active in foot care and prevention of diabetes-related foot complications than male patients who prefer to seek help from others and take passive and negative measures to deal with their foot problems [19].

The mean age of the patients in each group increased as the Wagner classification increased. It has been shown that leukocyte phosphofructose activity decreases with increasing age in diabetic patients, and the bactericidal activity of leukocytes is inhibited, leading to difficulty in controlling blood glucose in patients, creating a vicious cycle that slows wound healing in patients [20]. Xiong Tian et al. [21] believe that the proportion of malnutrition and malnutrition risk in elderly patients increases significantly with age, which may be due to the gradual decline of digestion and absorption function that, in turn, affects their nutritional status. Elderly DF patients have many underlying diseases, tissue metabolic rate increases with age, infection of wounds further depletes the body's energy, the body's function is increasingly degraded, and insufficient intake leads to more

Table 1 Nutritional status comparison of DF patients with different Wagner grades

Wagner grades	Patient count	Nutrition score	Nutritional status [*n* (%)]		
			Malnutrition	Risk of malnutrition	Well nourished
1 ~ 2	110	20.93 ± 3.67	12 (10.9%)	71 (64.55%)	27 (24.55%)
3	220	17.30 ± 5.35	7 (35.45%)	121 (55.0%)	21 (9.55%)
4 ~ 5	247	14.22 ± 5.99	143 (57.89%)	91 (36.84%)	13 (5.26%)

$F = 61.841$, $p < 0.001$

Table 2 Comparison of clinical statistics of DF patients with different Wagner grades ($\overline{x} \pm s$)

Wagner grades	Gender (M/F)	Age/years	Course of diabetes/years	BMI/(kg·m^{-2})
1 ~ 2	82/28	56.53 ± 11.20	11.03 ± 8.03	24.25 ± 3.30
3	153/67	63.41 ± 11.26	16.37 ± 9.01	24.30 ± 3.51
4 ~ 5	164/83	67.75 ± 11.32	16.23 ± 9.41	24.17 ± 3.81
χ^2/F	2.395	38.148	15.240	0.081
P	0.302	< 0.001	< 0.001	0.922

deterioration of foot ulcers, eventually leading to amputation and even death.

In this study, the average duration of diabetes mellitus was also higher in the group with a high Wagner classification, and it has been pointed out [22] that the duration of diabetes mellitus is the main cause of microangiopathy in diabetic patients. The longer the duration of the disease, the greater the possibility of complications, the heavier the burden on the family and society, and the greater the psychological and emotional impact on the patient, the more pronounced the decline in quality of life, and thus the further decline in nutritional status, which repeatedly causes a vicious cycle.

In this study, there was no significant difference in BMI between groups in the Wagner grade, with BMI being generally higher. Previous studies by He Yuan et al. [23] found that the prevalence of type 2 diabetes increased with the increase of BMI in the whole Chinese population, and the risk of type 2 diabetes increased by 5.9 times after BMI increased from normal to grade 2 obesity. Obesity is considered to be prevalent in patients with diabetes, while low body weight is also common; both conditions may be manifestations of malnutrition [24]. In DF patients that are [25] overweight and obese, dietary intake of energy and nutrients was also significantly reduced. If the patient's BMI is elevated and blood glucose control is poor, energy intake should be minimized while protein intake should be optimized. A nutritionist or nurse should conduct a 24-h caloric intake review and food frequency questionnaire at each visit to ensure that the patient meets the estimated caloric needs and adjust the diet accordingly to avoid adverse effects of malnutrition on the body.

In this study, Hb, albumin, prealbumin, HbA1c, and WBC were compared with different Wagner grades of DF patients. The results show that different Wagner grades are negatively correlated with Hb, albumin, and prealbumin and positively correlated with HbA1c and WBC. Patients with DF have varying degrees of infection, and the higher the Wagner grade, the more severe the infection. And the severity of infection has a direct impact on albumin and Hb consumption [26].

Studies have shown that the prevalence of anemia in diabetic patients is twice that of non-diabetic patients, and the prevalence of anemia in DF patients is as high as 51.9 ~ 85.3% [27], and the adverse outcome rate is also higher [28]. The high prevalence of anemia is widely recognized in people with diabetes and is a common problem associated with adverse outcomes in patients with DF [29].

In addition, serum albumin is used as a composite indicator to assess nutrition inflammation, and hypoproteinemia may reflect the patient's inflammatory status, inadequate protein, and energy intake [30]. If the patient does not receive timely nutritional supplementation, the foot ulcer further worsens, thereby reducing the patient's quality of life.

Patients with longer diabetes will lead to impaired renal function, resulting in microalbuminuria, further aggravating nutrient loss. Studies have shown an inverse correlation between albumin levels and the incidence of DF; that is, the incidence of DF increases with the decrease of albumin levels, and albumin is an independent protective factor for the occurrence of DF [31].

HbA1c can reflect the average plasma glucose level of individuals in the past 8 ~ 12 weeks, and it is currently recommended clinically as an important indicator for monitoring and blood glucose control evaluation of average blood glucose levels in DM patients. Glucose metabolism is the main metabolic pathway of the body's energy supply, and amino acid metabolism is an important way of protein synthesis in the body. An abnormal elevation of HbA1c in patients with type 2 diabetes mellitus will lead to disorders of glucose metabolism and amino acid metabolism, and

Table 3 Comparison of laboratory indicators of DF patients with different Wagner grades ($\overline{x} \pm s$)

Wagner grades	Hb (g/L)	Protein (g/L)	Prealbumin (g/L)	HbA1c (%)	WBC ($\times 10^9$/L)
1 ~ 2	120.48 ± 22.58	36.50 ± 6.20	0.20 ± 0.07	8.43 ± 1.99	7.95 ± 3.41
3	110.92 ± 20.40	35.12 ± 5.35	0.16 ± 0.07	8.61 ± 2.19	9.00 ± 4.28
4 ~ 5	104.38 ± 20.63	32.61 ± 5.50	0.13 ± 0.06	9.25 ± 2.04	11.09 ± 5.18
F	22.922	22.203	40.489	8.181	22.209
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

the patient's energy supply and protein synthesis will be reduced, resulting in malnutrition [32].

As the Wagner classification increases, the proportion of severe diabetic foot infections increases, the rate of disability increases, and the prognosis of patients is worse [33]. Studies have shown that decreased homogeneous blood flow to the affected area in diabetic foot patients and abnormally elevated WBC can lead to occlusion of blood circulation vessels or arterial macrovessels, aggravating the ulcer wound healing time in patients with multidrug-resistant bacterial infections of the diabetic foot [34].

Wagner grade 1 ~ 2 foot ulcers can generally heal because they do not involve bone tissue, while Wagner grade 3 or higher indicates that the infection involves bone, and the amputation rate is 11 times higher [35]; the amputation rate is especially higher in patients with foot ulcers combined with gangrene. The insufficient protein intake of elderly DF patients coupled with frequent dressing changes, surgery, and wound infection exudation further promote albumin loss, resulting in additional malnutrition. This will reduce the patient's resistance, making inflammation easy to occur, while wound healing requires a large amount of protein. In such cases, patients often fall into the vicious cycle of hypoproteinemia, infection, and unhealed wound [36], which will lead to inevitable amputation if not improved in time.

Conclusion

The nutritional status of patients with Wagner grading 3 ~ 5 is significantly worse than that of patients with Wagner grading 1–2. Age, duration of diabetes, HbA1c, WBC, Hb, albumin, and prealbumin have important effects on the development and prognosis of foot ulcers in diabetic foot patients. Clinical healthcare professionals, as the main body of disease treatment, should assess and screen DF patients for nutritional risk according to Wagner's grading, promptly identify patients with potential malnutrition, and develop practical, individualized nutritional treatment plans, and patients with high nutritional risk should be given nutritional interventions in a timely manner to avoid or delay disease progression and improve wound healing while improving the prognosis of DF patients.

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Data Availability Data related to the results of this study are available from the first author upon request.

Declarations

Ethical clearance Ethics number:2022KY080-KS001

Conflict of Interest The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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