

ORIGINAL ARTICLE

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# Effect of Intensive Nursing Education on the Prevention of Diabetic Foot Ulceration Among Patients with High-Risk Diabetic Foot: A Follow-Up Analysis

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## Abstract

The aim of the study was to discuss the effect of intensive nursing education on the prevention of diabetic foot ulceration among patients at high risk for diabetic foot. One hundred eighty-five diabetes patients at high risk for foot diseases were enrolled in this study and provided with intensive nursing education, including individualized education about diabetes mellitus and diabetic foot diseases, instruction in podiatric care (the right way of washing the foot, the care of foot skin, appropriate choice of shoes and socks, intense examinations and records of feet by patients themselves every day, and the assistant management of calluses). Study subjects were followed up for 2 years. Once the foot ulceration developed, the inducing factors of foot ulceration were inquired about, the ulcers were evaluated, and the incidence of foot ulceration was analyzed before and after the intensive nursing education according to self-paired data. Results showed there were highly statistically significant improvements in the intensive treatment group compared with the control group in plasma glucose, blood pressure, and high-density lipoprotein cholesterol levels. More important is that intensive nursing education helps to prevent diabetic foot ulceration and to decrease the rate of amputation among patients at high risk for diabetic foot.

## Introduction

THE RISE IN PREVALENCE of diabetes is likely to bring a concomitant increase in its complications among patients with diabetes.<sup>1</sup> One important complication of diabetes is foot problems; the diabetic foot is one of the most important reasons leading to disability or even death in diabetes patients.<sup>2</sup> It has been estimated that up to 25% of type 2 diabetes patients may develop diabetic foot ulcer once in their lifetime.<sup>3</sup> These complications constitute an increasing public health problem and are a leading cause of hospital admission, amputation, and mortality in diabetes patients.<sup>4,5</sup> In addition to causing pain and morbidity, foot lesions in diabetes patients also have substantial economic consequences. As previously reported, the cost of treatment of diabetes foot ulcers accounted for over one-third of the total

cost of diabetes and its complications.<sup>6,7</sup> In some provinces and cities of China, the average duration of hospital stay for a diabetic foot was 26 days, with a mean cost of 14,906 yuan RMB (about \$2,424 U.S.).<sup>8</sup>

Diabetic foot ulceration is preventable, and the incidence of foot ulceration may be reduced through giving the right guidance about podiatric care. Teaching diabetes patients the principles of self-examination of the feet and foot care has since long been advocated as an essential attribute of prevention strategies and is widely used in clinical practice.<sup>9–11</sup> So early identification of tissue at risk of ulcerating could enable proper preventive care, thereby reducing the incidence of foot ulceration; however, until now, there is still a lack of long-term follow-up data about the effect of intensive nursing education on the prevention of diabetic foot ulceration.

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So the aim of our study was to investigate the effect of intensive nursing education on preventing the development of diabetic foot ulceration and decreasing the rate of lower extremity amputation.

## Subjects and Methods

### Patients

From August 2004 to June 2008, 185 diabetes patients at high risk for foot diseases diagnosed in our hospital were enrolled in this study. Patients who were enrolled in the study met a high-risk profile for developing diabetes foot ulcerations. We defined high-risk patients as adult patients with diabetes with at least one of the following<sup>12,13</sup>: history of previous diabetes ulceration, callus, or foot deformity; an ankle brachial index of  $\leq 0.9$ ; diagnosed as having diabetes peripheral vascular disease according to vascular ultrasound, digital subtraction angiography, computed tomographic angiography, or magnetic resonance angiography; positive results of a 10-g monofilament nylon fiber probe test or the tuning fork test; or patients with peripheral sensory neuropathy with loss of protective sensation. These criteria are based on previously identified risk factors for foot ulcerations and amputations. All the patients were diagnosed as having diabetes mellitus according to the World Health Organization 1999 standard.<sup>14</sup> Patients with severe renal diseases, cardiovascular disease, severe vision decline, or blindness were not enrolled. Patients with diabetes who were unable to answer the questions because of altered mental state were also excluded from the study.

### Characteristics

The general information of every patient, including case history, onset of the foot complaint, medical history, complications and comorbidities, and foot ulceration history, was obtained. Physical examinations, including body mass index, waist:hip ratio, blood pressure, palpation of the foot dorsal artery pulse, and a 10-g monofilament nylon fiber probe test, were performed. Laboratory test results, including fasting blood glucose, glycosylated hemoglobin (HbA1c), blood lipids, and urinary microalbumin excretion rate, were tested. Patients were given intensive nursing education, including individualized education on knowledge about diabetes mellitus and diabetic foot diseases, instruction on podiatric care (such as the right way of washing the foot, the care of foot skin, appropriate choice of shoes and socks, intense examination and record of the foot done through the follow-up, and assistant management of calluses). At every 3-month follow-up, the patients were asked to fill out a risk questionnaire about diabetic foot ulceration. Plasma glucose, blood pressure, and foot dorsal artery pulse were also examined. HbA1c and blood lipids were evaluated once a year.

### Assessments and outcome measures

Once the patient developed foot ulceration, the inducing factors were asked about and recorded, and the ulcer condition was evaluated. All patients signed informed consents. The incidence of diabetic foot ulceration was evaluated before and after intensive nursing education. The incidence formula for baseline foot ulceration incidence is the accumulated number of subjects with foot ulceration during

paired duration (cases)/sum of person-years of the subjects' paired durations (person-year). The foot ulceration incidence after intensive nursing education is the accumulated number of subjects with foot ulceration during the follow-up period after enrollment (cases)/sum of person-years of every subject's follow-up duration (person-year).

### Statistical analyses

Normally distributed continuous variables were expressed as mean  $\pm$  SD values and were compared between two groups using a *t* test. Non-normally distributed variables were compared with the Mann-Whitney U test. Categorical data were compared using Fisher's exact test. For all statistical analyses, a value of  $P < 0.05$  was regarded statistically significant.

## Results

### Baseline characteristics

The baseline information from the diabetic foot ulceration history is listed in Table 1. The mean age of all patients enrolled was  $60.23 \pm 8.77$  years old, with a mean diabetes duration of  $8.17 \pm 7.10$  years. The median follow-up duration was 2 years. Twenty-nine patients had a diabetic foot ulceration history, whereas the other 156 patients had no such history. We further compared the baseline information between patients with and without a history of diabetes foot ulceration (Table 2). There were no significant differences in age, sex, duration of diabetes, blood pressure, or blood glucose level among patients with or without a diabetic foot ulceration history. Significant differences existed in the levels of total cholesterol, triglycerides, and low-density lipoprotein cholesterol (LDL-C), smoking history, lower limb numbness, 10-g monofilament nylon fiber probe test results, and foot dorsal artery pulse between these two groups. Although it seems that patients without a foot ulceration history had higher levels of total cholesterol, triglycerides, and LDL-C, the physical examination results of vasculopathy (foot dorsal artery pulse) and neuropathy (10-g monofilament nylon fiber test) were better than those patients with a foot ulceration history.

### Age distribution of those who first developed foot ulcer

Among the 29 patients with a foot ulceration history, those who first developed diabetic foot ulcer at the age of 40–49

TABLE 1. BASELINE CHARACTERISTICS

Characteristic	Value
Age (years)	$60.23 \pm 8.77$
Sex (male/female)	96/89
Duration of diabetes (years)	$8.17 \pm 7.10$
Follow-up duration (years)	2 (1–6)
Body mass index ( $\text{kg}/\text{m}^2$ )	$23.59 \pm 3.04$
Waist:hip ratio	$0.92 \pm 0.06$
Hypertension history (yes/no)	96/89
Smoking history (yes/no)	49/136
Callosity (yes/no)	34/151

Data are mean  $\pm$  SD values, number of patients, or mean (range) as indicated.

TABLE 2. COMPARISON OF FACTORS FOR SUBJECTS WITH AND WITHOUT A DIABETIC FOOT ULCERATION HISTORY

Factor	Foot ulceration history		P
	With	Without	
Age (years)	61.00±8.16	60.09±8.90	0.609
Sex (male/female)	18/11	78/78	0.232
Duration of diabetes (years)	8.96±6.18	8.02±7.26	0.512
Blood pressure (mm Hg)			
Systolic	138±22	137±21	0.836
Diastolic	82±11	80±11	0.347
Body mass index (kg/m <sup>2</sup> )	23.2±2.8	23.7±3.1	0.408
Waist:hip ratio	0.93±0.05	0.92±0.07	0.393
FBG (mmol/L)	9.04±4.24	9.31±3.77	0.749
HbA1c (%)	9.62±2.72	9.67±2.69	0.937
TC (mmol/L)	4.39±1.18	5.25±1.09	<0.001 <sup>a</sup>
LDL-C (mmol/L)	2.65±0.89	3.19±0.95	0.006 <sup>a</sup>
TG (mmol/L)	1.50±0.82	1.97±1.43	0.020 <sup>a</sup>
HDL-C (mmol/L)	1.12±0.34	1.22±0.36	0.165
Hypertension history (yes/no)	14/15	82/74	0.671
Smoking history (yes/no)	12/17	37/119	0.048 <sup>a</sup>
Callosity (yes/no)	5/24	29/127	1.000
Lower limb numbness (yes/no)	23/2	90/48	0.008
10-g monofilament nylon fiber test (positive/negative) <sup>b</sup>	8/21	14/142	0.011 <sup>a</sup>
Foot dorsal artery pulse (weakened or absent/normal)	18/11	61/95	0.022 <sup>a</sup>
Diabetic nephropathy (yes/no) <sup>c</sup>	11/13	41/65	0.518

Data are mean±SD values or number of patients as indicated.

<sup>a</sup>Significant difference,  $P < 0.05$ .

<sup>b</sup>For a positive 10-g monofilament nylon fiber test, the test scores were  $\leq 7/10$ .

<sup>c</sup>Diabetic nephropathy was defined as diabetic nephropathy of stage 3 or more and a urinary albumin excretion rate of  $>20 \mu\text{g}/\text{min}$ .

FBG, fasting blood glucose; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglycerides.

years accounted for 9.52% of their peers, 50–59 years for 17.93% of their peers, 60–69 years for 15.38% of their peers, and 70–79 years for 16.67% of their peers (Table 3). This indicated that diabetes patients with a high-risk foot had a significant higher incidence of diabetic foot ulceration above the age of 50 years old.

#### Comparison of levels before and after receiving intensive nursing education

We also compared the blood pressure, glucose levels, and blood lipids before and after intensive nursing education (Table 4). After patients had received intensive nursing education, systolic and diastolic blood pressures, fasting blood glucose, and HbA1c levels were all decreased significantly, and the high-density lipoprotein cholesterol level was improved over before values. However, the levels of triglycer-

ides, total cholesterol, and LDL-C, the lower limb numbness, 10-g monofilament nylon fiber test results, foot dorsal artery pulse, and the incidence of diabetes nephropathy did not show any significant change between these two groups (Table 4).

#### Comparison of foot ulceration incidence, site of ulcers, and prognosis of foot ulcers before and after intensive nursing education

Thirty-four cases developed foot ulcer during the paired duration at baseline, and the incidence was 7.00/100 person-years. After the intensive nursing education, 18 cases developed foot ulcer, and the incidence decreased to 3.70/100 person-years ( $P = 0.002$ ). Among the 34 patients with foot ulceration before intensive nursing education, 20 cases (58.8%) had a single ulceration, and the other 14 cases (41.2%) had multiple ulcerations. It has been reported that more than half of the ulcers were nonplantar and that the most frequent ulcer site was the dorsal or interdigital areas of the toes.<sup>15</sup> In our study, foot ulcers occurred on the toes in 24 cases, accounting for 48.0% of all ulcers, of which 70.8% occurred on the first toe (Table 5). We also analyzed the characteristics of foot ulceration after intensive nursing education. As shown in Table 5, the incidence of foot ulceration decreased from 41.2% to 11.1% after the intensive nursing education (a statistically significant value); however, the position of the ulcers did not change before and after intensive nursing education, with half of them being on the toes. Four cases needed amputation before intensive education, whereas after intensive education, the ulcerations improved,

TABLE 3. AGE DISTRIBUTION OF THOSE WHO FIRST DEVELOPED A FOOT ULCER

Age range (years)	Number of patients at the same age	Cases of first foot ulceration	Proportion of first foot ulceration of their peers (%)
40–49	21	2	9.52
50–59	69	12	17.39
60–69	65	10	15.38
70–79	30	5	16.67

TABLE 4. COMPARISON OF FACTORS FOR SUBJECTS BEFORE AND AFTER INTENSIVE NURSING EDUCATION

Factor	Baseline	Intensive nursing education	P
Blood pressure (mm Hg)			
Systolic	137.3±21.1	131.8±17.8	<0.001 <sup>a</sup>
Diastolic	79.8±10.8	77.4±9.8	0.011 <sup>a</sup>
FBG (mmol/L)	9.29±3.84	7.47±2.27	<0.001 <sup>a</sup>
HbA1c (%)	9.47±2.52	7.67±1.67	<0.001 <sup>a</sup>
TC (mmol/L)	5.09±1.14	5.19±1.07	0.387
LDL-C (mmol/L)	3.09±0.94	3.24±1.23	0.198
TG (mmol/L)	1.84±1.34	1.83±1.07	0.904
HDL-C (mmol/L)	1.22±0.37	1.33±0.61	0.021 <sup>a</sup>
Lower limb numbness (yes/no)	113/50 (69.3)	64/32 (66.7)	0.657
10-g monofilament nylon fiber test (positive/negative) <sup>b</sup>	22/163 (11.9)	11/120 (8.4)	0.317
Foot dorsal artery pulse (weakened or absent/normal)	79/106 (42.7)	66/112 (37.1)	0.274
Diabetic nephropathy (yes/no) <sup>c</sup>	52/78 (40.0)	44/59 (42.7)	0.675

Data are mean±SD values or number of patients as indicated.

<sup>a</sup>Significant difference,  $P < 0.05$ .

<sup>b</sup>For a positive 10-g monofilament nylon fiber test, the test scores were  $\leq 7/10$ .

<sup>c</sup>Diabetic nephropathy was defined as diabetic nephropathy of stage 3 or more and a urinary albumin excretion rate of  $>20 \mu\text{g}/\text{min}$ .

FBG, fasting blood glucose; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglycerides.

with no need of amputation. This indicates the intensive nursing education helps to decrease the incidence of foot ulceration and the rate of amputation.

## Discussion

The results of this study showed a substantial decrease in the incidence of diabetic foot ulceration in diabetes patients with a high-risk diabetic foot after intensive nursing education about the foot. The results demonstrate in our view the success and feasibility of intensive nursing education. Because many risk factors for amputations could be preventable through education, such optimization results should reduce the risk of foot ulceration.

The study results substantiate earlier reports that the prevalence of foot ulcers is approximately 4–20% in diabetes patients.<sup>16,17</sup> In our study, 15.7% of diabetes patients at high risk of diabetic foot had a foot ulceration history. In the

present study, 185 diabetes patients at high risk for diabetic foot disease were provided with intensive nursing education and followed up for 2 years. After a 2-year follow-up, the incidence of foot ulceration was significantly reduced. Through intensive education, more ulcers healed, fewer new ulcers appeared, and fewer surgical procedures were needed in patients who were educated about diabetic foot care.

Serum cholesterol and triglycerides, blood pressure, and lifestyle factors such as smoking are all known indicators of atherosclerosis. So we recorded the smoking history and the symptoms of lower limb numbness of the patients and also compared the levels of serum lipids and performed the physical examination of vasculopathy and neuropathy. Although it seems that patients without a foot ulceration history had higher levels of total cholesterol, triglycerides, and LDL-C, the physical examination results of vasculopathy (foot dorsal artery pulse) and neuropathy (10-g monofilament nylon fiber test) were better than those for patients with a foot ulceration history.

TABLE 5. FOOT ULCERATION INCIDENCE, POSITION OF ULCERS, AND PROGNOSIS OF FOOT ULCERS BEFORE AND AFTER INTENSIVE NURSING EDUCATION

Factor	Baseline		After intensive nursing education		P
	Number of cases	Of all the ulcer patients (%)	Number of cases	Of all the ulcer patients (%)	
Foot ulceration					
Single	20	58.8	16	88.9	0.06
Multiple	14	41.2	2	11.1	0.025 <sup>a</sup>
Position					0.778
Toes	24	48.0	14	51.9	
Dorsal	10	20.0	3	11.1	
Plantar (except toes)	9	18.0	6	22.2	
Ankle	7	14.0	4	14.8	
Prognosis					0.002 <sup>a</sup>
Amputation	4	11.8	0	0	
No amputation	30	88.2	18	100.0	

<sup>a</sup>Significant difference,  $P < 0.05$ .

This demonstrates that structural foot abnormalities, sensory neuropathy, and peripheral arterial disease consistently play an important role in the development of diabetic foot ulcer.<sup>18–21</sup>

Sensory neuropathy leads to a deficit or loss of the self-protection mechanism of skin. Motor neuropathy changes the plantar pressure load. Autonomic neuropathy reduces the sweating of the foot skin, which makes the skin dry and easily damaged and chapped. On the basis of these factors, a small trauma can promote the deterioration of a foot ulcer. All these mechanisms raise the risk of foot skin damage and promote ulcer formation without any sensation.<sup>22–24</sup> In our study, we took all these aspects into consideration in the intensive nursing education. Once callosity was found, assistant management of callus was applied in time. Also, we dealt with dry and chapped foot skin and guided the patients to wash the foot in the right way, including the appropriate water temperature, and the way to keep the foot dry. Beside these, we directed the patients to choose the right shoes and socks and improved their awareness of self-protection. Patients were encouraged to perform a daily inspection of their feet. Visual inspection of the skin for signs of dryness often caused by autonomic neuropathy is vital in avoiding cracks in the skin integrity.<sup>25</sup> Observing for signs of marking from socks or footwear or redness from pressure from improper footwear can highlight problems before they start to cause trouble. Checking of the color of the skin will give early warning of impending problems. It is not only possible but also highly beneficial for the patient if the feet of these patients are inspected on a regular basis. Through these ways, many small traumas were avoided, and the foot circulation was improved. At the end of the follow-up, the development of diabetic foot ulceration was prevented.

In addition, the intensive education could draw patients' attention to the control of diabetes and was beneficial to the prevention and cure of risk factors of diabetic foot diseases (such as plasma glucose, blood lipids, blood pressure, etc.), which play indirect roles in the prevention of foot ulceration. After patients received intensive nursing education, the blood pressure, fasting blood glucose, and HbA1c levels were all decreased significantly, and the high-density lipoprotein cholesterol level was improved more than before education. Overall, the intensive nursing education is feasible and easy to practice and is a multiplier to the effect of diabetic foot ulceration prevention.

China has a large population, and diabetic foot ulcer may become more common in clinical practice in the tropics with the increasing prevalence of diabetes.<sup>26</sup> However, public health resources are insufficient in many districts. Thus, prevention becomes very important, especially for diabetes patients with a high-risk foot. In our study, the foot ulceration incidence of the high-risk patients was significantly reduced, as was the multiple ulceration incidence and amputation rate. So we can conclude that emphasis on education about diabetes mellitus, diabetic foot diseases, and correct guidance in podiatric care could reduce the development of foot ulcers. Intensive nursing education is inexpensive, easy to practice, and highly feasible and can be carried out widely in hospitals at all levels, which is significantly instructive in clinical work. Larger samples, randomized controlled tests, and longer follow-up durations are still needed to further clarify the effect of intensive nursing education on diabetic foot ulceration.

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## Author Disclosure Statement

No competing financial interests exist.

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