J Korean Med Sci 2000; 15: 78-82
ISSN 1011-8934

Foot Screening Technique in a Diabetic Population

Foot complications are a well known factor which contribute to the morbidity of diabetes and increases the chance of amputation. A total of 126 consecutive diabetic patients were evaluated by diabetic foot screening. Forty-one patients showed an impaired protective sense when tested with Semmes-Weinstein monofilament 5.07 (10 g), and 92% of them showed peripheral polyneuropathy in nerve conduction study (NCS). The mean vibration score of the Rydel-Seiffer graduated tuning fork in patients with peripheral polyneuropathy in nerve conduction (NCV) study was 5.38±2.0, which was significantly different from that of patients without polyneuropathy in NCS. Among the deformities identified on examination, callus, corn, and hallux valgus were the greatest. While checking the ankle/ brachial index (ABI), we also evaluated the integrity of vasculature in the lower extremities. After extensive evaluation, we classified the patients into eight groups (category 0,1,2,3,4A,4B,5,6). The result of this study suggested that the Semmes-Weinstein monofilament test, Rydel-Seiffer graduated tuning fork test, and checking the ankle/brachial index were simple techniques for evaluating pathologic change in the diabetic foot by office screening, and that this screening based on treatment-oriented classification helps to reduce pedal complications in a diabetic population.

Key Words: *Diabetic Foot; Diabetic Angiopathies; Diabetic Neuropathies; Mass Screening*

Jung Bin Shin, Yeon Jae Seong, Hong Jae Lee, Sang Hyun Kim, Jong Ryool Park

Department of Rehabilitation Medicine, Yonsei University College of Medicine, Seoul, Korea

Received: 13 May 1999
Accepted: 1 October 1999

Address for correspondence
Jung Bin Shin, M.D.
Department of Rehabilitation Medicine, Yonsei University College of Medicine, 134 Shinchon-dong, Seodaemoon-gu, Seoul 120-752, Korea
Tel: +82.2-361-7515, Fax: +82.2-363-2795
E-mail: jbshinlim@netsgo.com

INTRODUCTION

Complications affecting diabetics are many, with some of the most catastrophic ones affecting the lower extremities. Levin and O'Neal (1) estimated that 20% of all hospital admissions for diabetes were the result of foot problems. Warren and Kihn (2), in their survey of lower extremity amputations, found that 91.8% of amputations were performed secondary to gangrene, necrosis, or ulceration. Nearly one-half of these patients were diabetic. The remarkable pathogenesis of diabetic foot were neuropathy, macrovascular and microvascular disease (1, 3-7). These processes may occur exclusively or they may occur together in varying degrees, placing patients at risk for morbidity, such as ulceration, gangrene, and infection. This is especially true if these pathologic changes are combined with a foot deformity, making patients more vulnerable to foot problems. Bauman et al. (8) demonstrated that only slight pressure over a fixed bony deformity, such as a prominent metatarsal head or a hammer toe, leads to ischemic necrosis and ulceration of the skin. For this reason, it is necessary to identify a patient at increased risk for morbidity by the screening all diabetic patients. Various tests which can be easily implemented, such as screening for neuropathy and vasculopathy, have been suggested (9-12). Kumar et al. (9) reported on the high sensitivity of monofilament test, while Lininger et al. (10) tested the Rydel-Seiffer graduated tuning fork on diabetic patients and suggested that it was a useful screening tool for vibration sensation loss. David et al. (13) emphasized that appropriate care for the feet of patients with diabetes requires a clear, descriptive classification system that may be used to direct appropriate therapy and predict the outcome.

The purpose of this study was to: 1) evaluate the utility of Semmes-Weinstein monofilament test and Rydel-Seiffer graduated tuning fork as a quantitative sensory technique; 2) document the frequency at which foot deformity exists in this population, with or without concomitant foot pathology; 3) identify a patient population at increased risk for morbidity and treat them appropriately by establishing the treatment-based classification system; and 4) re-emphasize the importance of regular and periodic foot examination and treatment of all diabetic patients and to study the effectiveness of this preventive care.

MATERIALS AND METHODS

A total of 126 consecutive of patients referred to the foot clinic of the Department of Rehabilitation Medicine at Inchon Severance Hospital participated in this study. The patients were interviewed and examined extensively and individually. The patients were examined for the presence of peripheral vascular disease, neuropathy, and foot deformity. The vascular evaluation consisted of ankle/brachial index (ABI) and observation of other clinical signs and symptoms representing vascular compromise. These included subcutaneous or dermal atrophy, dependent rubor, delayed capillary refill time, and nocturnal claudication. ABI is calculated by dividing the ankle systolic blood pressure by the brachial systolic blood pressure.

The neurologic examination consisted of testing and grading of deep tendon reflex, checking the protective sense using Semmes-Weinstein monofilament 5.07 (10 g), vibration test using a Rydel-Seiffer graduated tuning fork, and observation of other clinical signs and symptoms indicating neuropathic disease. The signs and symptoms indicating the dysfunction of the autonomic nervous system such as dried skin, fissure, and osseous hyperemia were checked. The feet were then examined for deformity. All of the various lesions were recorded and the patients' feet were classified into eight groups (Table 1). According to this category, patients were then managed and treated in our foot clinic.

Additionally, all patients involved in this study were included for electrodiagnostic study.

Statistics

The experimental results were analyzed with a SAS statistical package and expressed as mean±standard deviation. Comparisons were made using Pearson's chi-square or unpaired student's t-test. p values smaller than 0.05 were considered significant in all analyses.

RESULTS

A total of 126 patients was enrolled in this study, 58 males and 68 females, with a mean age of 57.5±10.3 years and a mean diabetic duration of 6.8±5.9 years.

Forty-one patients showed an impaired protective sense when testing using Semmes-Weinstein monofilament 5.07 (10 g), while 92% of them showed peripheral polyneuropathy in nerve conduction study (Table 2).

The mean vibration score of the Rydel-Seiffer graduated tuning fork for patients with peripheral polyneuropathy in nerve conduction (NCV) study was 5.38±2.0, which was different from that for patients without polyneuropathy in NCV study (p=0.004, Table 3).

Deformities identified on examination are listed in Fig.

Table 1. Diabetic foot category

Diabetic foot category 0: minimal pathology present Sensorium intact (Semmes-Weinstein 5.07 wire detectable or vibratory perception score >4.0) Ankle brachial index of >0.8 Foot deformity may be present No history of ulceration	Diabetic foot category 1: insensate foot Sensorium absent (Semmes-Weinstein 5.07 wire not detectable or vibratory perception score ≤4.0 Ankle brachial index of >0.8 No history of ulceration No foot deformity No history of diabetic osteoarthropathy (Charcot's joint)
Diabetic foot category 2: insensate foot with deformity Sensorium absent Ankle brachial index of >0.8 No history of neuropathic ulceration No history of Charcot's joint Foot deformity present (focus of stress)	Diabetic foot category 3: demonstrated pathology Sensorium absent Ankle brachial index of >0.8 History of neuropathic ulceration History of Charcot's joint Foot deformity present (focus of stress)
Diabetic foot category 4A: neuropathic ulceration Sensorium may or may not be intact Ankle brachial index of >0.8 Foot deformity normally present Noninfected neuropathic ulceration No acute diabetic neuropathic osteoarthropathy (Charcot's joint) present	Diabetic foot category 4B: acute Charcot's joint Sensorium absent Ankle brachial index of >0.8 Noninfected neuropathic ulceration may be present Diabetic osteoarthropathy (Charcot's joint)
Diabetic foot category 5: infected diabetic foot Sensorium may or may not be intact Infected wound Charcot's joint may be present	Diabetic foot category 6: dysvascular foot Sensorium may or may not be intact Ankle brachial index of ≤0.8 Ulceration may be present

Table 2. Semmes-Weinstein 5.07 (10 g) wire protective sense and nerve conduction study

Nerve conduction study	No. of patients (%)	
	Intact protective sense	Impaired protective sense
Normal	56 (44)	3 (2)
Peripheral polyneuropathy	29 (23)	38 (30)
Total	85 (67)	41 (32)

p=0.0032

Table 3. Vibration score of the Reidel-Seiffer graduated tuning fork and nerve conduction study

Nerve conduction study	Vibration score of the Reidel-Seiffer graduated tuning fork
Normal	6.77±0.6
Peripheral polyneuropathy	5.38±2.0

p=0.004; Values are mean±SD

1. A total of 172 deformities including callus and corn was found. As well, 53.5% of them was callus, and 27.9% was hallux valgus.

Fifty-eight patients (41%) complained of subjective sensory symptoms such as a tingling sense and hyperesthesia. Their ability to detect pressure when tesing with Semmes-Weinstein monofilament was more impaired compared to the group without subjective sensory symptoms (p=0.035). Moreover, their mean vibration score was significantly lower than that of the group without subjective sensory symptoms (5.24±1.21 vs 6.58±1.21, p=0.008). Sixty-three patients (50%) showed autonomic signs in their feet such as dried skin and fissure. Diminished ankle jerk was found in 41 patients (33%).

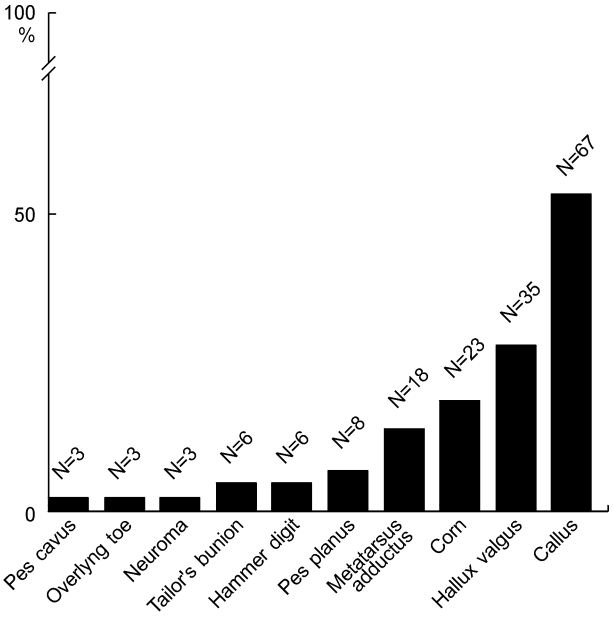

Fig. 1. Deformities identified on examination.

Table 4. Diabetic foot category

Category	No. of patients (%)
Category 0	60 (47)
Category 1	9 (7)
Category 2	24 (19)
Category 3	6 (5)
Category 4A	9 (7)
Category 4B	0 (0)
Category 5	6 (5)
Category 6	12 (10)
Total	126 (100)

After extensive examination, we classified the patients into eight groups (Table 4). Categories 0 and 2 were the largest portion (47% and 19% respectively). We could not find any patients with category 4B. The 12 patients in category 6 received vascular surgery and were consulted for definite evaluation and possible revascularization.

In this study, there were 15 patients with ulceration of neuropathic origin and 10 patients with ulceration of vascular origin. Inevitably, 3 patients of this group with ulceration have sufferred amputation because of severe infection and osteomyelitis. Infected ulcerations of 3 other patients in category 5 were treated with debridement and intravenous antibiotics. Nine patients in category 4A were treated with a dressing change program, debridement program, and offweight program with total contact cast.

All corns, calluses, and bunions which may have been the foci of stress were removed by precise and sterile methods in an out-patient foot clinic. Patients with hallux valgus, hammer digit, and pes planus were managed with custom-molded foot orthoses or extra-depth shoe accommodation. We managed 3 patients with overlying toes with interdigit-silicone application.

DISCUSSION

Foot problems are common in diabetic patients, with neuropathy and peripheral vascular disease being the main causative factors. In addition, prolonged low pressure over a small radius of curvature (i.e., corn, bunion,

hammer toe deformity, callus) is considered to be another mechanism (1, 3-7).

Identification of high-risk feet can be accomplished by using basic clinical skill and simple equipment (14).

In our study, we used Semmes-Weinstein monofilament 5.07 (10 g) and a Rydel-Seiffer graduated tuning fork for quantitative sensory testing (protective sense and vibration respectively) and as a screening tool. We found that these two tests were well correlated with the results of standard nerve conduction study and subjective symptoms of peripheral neuropathy.

Cutaneous perception threshold determination using Semmes-Weinstein monofilaments is an ideal screening tool that it is inexpensive, easily learned, and minimally time consuming, although it relies on patients' cooperation to obtain reliable results (14). Studies in patients with Hansen's disease have strongly suggested that patients who are unable to feel 10 g pressure have inadequate protective sensation (15). More recent work has shown that monofilaments are reliable and highly sensitive in screening diabetic patients at risk for ulceration (9).

The second quantitative sensory testing with office application is the use of the Rydel-Seiffer graduated tuning fork. This device is also inexpensive and simple (16). Vibratory sensation is transmitted through the large myelinated (A-β) fibers and seems to be adversely affected early in the pathogenesis of diabetic peripheral polyneuropathy. A study concerning about the utility of the Rydel-Seiffer graduate tuning fork reported that it is a useful screening tool for vibration sensation loss and that diabetic patients scoring $\leq$4.0 on the lower extremity should be considered vulnerable to ulceration, regardless of age, and should be singled out for careful training in preventive care (10).

For the evaluation of vasculopathy of the distal lower extremity, we checked the ABI. Many authors have suggested that a value of 1.0 or more is considered normal, while 0.8 or less is seen as indicating a clinically significant reduction in perfusion and values of 0.5 or less indicate severe to critical limb ischemia (11). This noninvasive technique is considered to be easily applicable to office screening. We also detected the ABI of 12 patients who were below 0.8 and referred them to vascular surgery for the precise evaluation of vasculopathy.

Various bony or structural deformities were evaluated in this study. Since these deformities can change the normal biomechanics in feet and may be a foci of pressure stress, ulceration may result from patients with insensate foot. For this reason, the surgical or pedorthotic correction which reduces this pressure area is usually necessary (17).

Eventually, we categorized all the patients involved in this study. According to this categorization, we managed patients and set an ideal treatment plan. Diabetic foot category 0 suggested in this study included subjects with intact protective sense and vasculature. As well, a foot deformity may have been present. Category 1 is representative of insensate foot, while category 2 is of insensate foot with deformity. Since these lower categories (category 0,1,2) seem to be at a preventable stage from rampant diabetic pedal complication, and many patients (73% in this study) may be in these categories, treatment programs performed in a diabetic foot clinic should focus on this group to prevent more serious complications. Although Wagner's classification has been accepted and has improved communication between medical disciplines, this classification deals with only existing ulceration, its size, depth, and bone and joint involvement (18). Our categorization is modified from the classification suggested by Armstrong et al. (13). They used toe systolic pressure added to the ABI for the evaluation of vascular integrity. Also they used vibration perception threshold and indicated impaired perception sensation when greater than 25 volts.

In conclusion, Semmes-Weinstein monofilament test, Rydel-Seiffer graduated tuning fork, and ABI are noninvasive, simple techniques for evaluating diabetic foot pathologic change in office screening. As consequence of regular and periodic examination, detection and correction of a foot deformity which may result in pedal complication must be made in all diabetic patients.

Finally, the authors suggest that this aforementioned logical, treatment-oriented classification system for a diabetic foot that evaluates the presence or absence of sensation, deformity, peripheral vascular occlusive disease. Previous history of ulceration will provide many diabetic patients with an appropriate and active foot-care program, and ultimately reduce the number of diabetes-related lower extremity amputaions.

A prospective large-scale study, however, is needed to verify the effectiveness of this organized diabetic foot-care program in the overall reduction of morbidity.

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