Chula Med J Vol. 46 No. 4 April 2002

Correlation of Semmes - Weinstein monofilament tests and electrophysiological studies of diabetic neuropathy in lower extremities

Krisna Piravej*

Sompongse Suwanwalaikorn** Erawady Mitrabhakdi**

Piravej K, Suwanwalaikorn S, Mitrabhakdi E. Correlation of Semmes - Weinstein monofilament tests and electrophysiological studies of diabetic neuropathy in lower extremities. Chula Med J 2002 Apr; 46(4): 305 - 14

Problem/background : *Diabetic neuropathy (DN) is one of the most frequent chronic complications in diabetic patients. The spectrum of nerve involvement ranges from dysfunction of predominantly, large fiber (Aα and Aβ) to small fiber (Aδ and C-fiber). The difference of nerve fiber types are usually not uniformly affected. Early diagnosis of DN can decrease patient morbidity. However, there is no single diagnostic test for the detection of DN. Methods for assessing DN in the lower extremities include clinical examination, monofilament tests, vibration perception thresholds, warmth and cold perception threshold, thermal discrimination threshold and electrophysiological study.*

Objective : *To search for the correlate of the Semmes - Weinstein monofilament tests and electrophysiological studies in peripheral diabetic neuropathy*

Setting : *Diabetic Neuropathy Research Clinic and Electrodiagnostic Laboratory, King Chulalongkorn Memorial Hospital.*

Design : *Prospective, descriptive study*

Patients : *Twenty-six NIDDM ambulatory patients, aged over 25 years were recruited into the study. All of them had diabetes and symptoms of diabetic neuropathy for more than six months.*

* Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn University

** Department of Medicine, Faculty of Medicine, Chulalongkorn University

Method : *The patients were interviewed for symptoms of diabetic neuropathy and underwent comprehensive medical and neurological evaluations, standardized bilateral sensory sural, motor common peroneal and tibial; nerve conduction studies included Semmes - Weinstein (SW) monofilament tests on both big toes.*

Results : *A total of 26 NIDDM patients, 13 males and 13 females with mean age of 54.58 ± 6.29 years were studied. The abnormality of SW monofilament test was 61.54 %. The mean SW monofilament index of rt big toe was 3.67 ± 1.17, the left was 3.92 ± 1.45. The sural latency and sensory nerve action potential (SNAP) amplitude had the highest abnormalities (92.31 %). Hence, the outcomes of SW monofilament tests and electrophysiological studies were weakly correlate.*

Conclusion : *Diabetic neuropathy may be caused by different pathogenetic mechanisms, which will need to be assessed separately.*

Key words : *Diabetic neuropathy, Semmes - Weinstein monofilament tests, Electrophysiological studies.*

Reprint request : Piravej K, Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

Received for publication. January 8, 2002.

กฤษณา พิรเวช, สมพงษ์ สุวรรณวลัยกรณ์, เอระวดี มิตรภักดี. การศึกษาความสัมพันธ์ระหว่างผลการตรวจ Semmes – Weinstein monofilament กับการตรวจไฟฟ้าวินิจฉัย ในผู้ป่วยเบาหวานที่มีอาการทางระบบประสาทส่วนปลาย. จุฬาลงกรณ์เวชสาร 2545 เม.ย; 46(4): 305 – 14

ที่มา : *อาการทางระบบประสาทส่วนปลาย เป็นภาวะแทรกซ้อนที่พบได้บ่อยในผู้ป่วยโรคเบาหวาน ซึ่งอาการแสดงจะมากหรือน้อยขึ้นกับชนิดและขนาดของเส้นประสาทที่ทำงานผิดปกติ โดยเส้นประสาทแต่ละเส้นจะสูญเสียการทำงานไม่เท่ากัน การวินิจฉัยภาวะนี้ตั้งแต่เนิ่น ๆ จะช่วยลดความเจ็บป่วย หรือทุพพลภาพของผู้ป่วยได้ อย่างไรก็ตามการวินิจฉัยภาวะนี้โดยใช้วิธีใดวิธีหนึ่งเพียงอย่างเดียวอาจจะไม่มีความแม่นยำเพียงพอ ส่วนใหญ่จึงใช้หลาย ๆ วิธีร่วมกันเช่นการซักประวัติ ตรวจร่างกาย, การตรวจโดยใช้monofilament, การตรวจ vibration perception threshold, warmth and cold perception threshold, thermal discrimination threshold และการตรวจไฟฟ้าวินิจฉัย*

วัตถุประสงค์ : *เพื่อศึกษาความสัมพันธ์ระหว่างผลการตรวจ Semmes - Weinstein monofilament กับการตรวจไฟฟ้าวินิจฉัย ในผู้ป่วยเบาหวานที่มีอาการทางระบบประสาทส่วนปลาย*

สถานที่ทำการศึกษา : *คลินิกวิจัยผู้ป่วยโรคเบาหวาน และห้องตรวจไฟฟ้าวินิจฉัย โรงพยาบาลจุฬาลงกรณ์*

รูปแบบการศึกษา : *การศึกษาเชิงพรรณนาแบบไปข้างหน้า*

วิธีการศึกษา *ทำการศึกษาผู้ป่วยเบาหวานที่มีอาการของโรคทางระบบประสาทส่วนปลาย โดยการซักประวัติ ตรวจร่างกายทางระบบประสาท, ตรวจการชักนำประสาทรับความรู้สึก sural ประสาทสั่งการ common peroneal และ tibial ที่ขาทั้ง 2 ข้าง และตรวจการรับความรู้สึกด้วย Semmes - Weinstein monofilament บริเวณนิ้วหัวแม่เท้าทั้ง 2 ข้าง*

ผลการศึกษา : *มีผู้ป่วยจำนวน 26 คน แบ่งเป็นเพศชาย 13 คน และเพศหญิง 13 คน อายุเฉลี่ย 54.58 ± 6.29 ปี ผลตรวจการรับความรู้สึกด้วย Semmes - Weinstein monofilament index พบว่ามีความผิดปกติ 61.54% โดยมีค่าเฉลี่ยที่นิ้วหัวแม่เท้าขวา = 3.67 ± 1.17 หัวแม่เท้าซ้าย = 3.92 ± 1.45 ส่วนผลตรวจทางไฟฟ้าวินิจฉัย พบว่าค่าของ sural latency และ sural SNAP amplitude มีความผิดปกติมากที่สุด (92.31 %) เมื่อนำผลตรวจทั้ง 2 วิธีมาหาความสัมพันธ์กันพบว่ามีความสัมพันธ์กันน้อยมาก*

สรุป : *พยาธิสภาพของเส้นประสาทที่ทำให้เกิดอาการของโรคทางระบบประสาทส่วนปลายในผู้ป่วยโรคเบาหวานมีความแตกต่างกันในเส้นประสาทแต่ละชนิด ดังนั้นการวินิจฉัยโรค/ภาวะนี้ให้ได้ถูกต้องแม่นยำอาจต้องใช้หลาย ๆวิธีร่วมกัน*

คำจำกัดความ : *อาการทางระบบประสาทส่วนปลาย, Semmes - Weinstein monofilament tests, ไฟฟ้าวินิจฉัย*

Diabetic neuropathies include a variety of distinctive disorders, sometimes affect individual nerves or nerve roots; their most common form is distal symmetrical sensorimotor polyneuropathy (DP) which chiefly involves the feet.[1, 2] The spectrum of nerve tissues involvement ranges from predominantly large fiber ($A\alpha$ and $A\beta$) dysfunction, characterized by depression of vibratory, proprioceptive, and tactile discriminatory sensation, to predominantly small fiber ($A\delta$ and C- fiber); their dysfunction is characterized by dysesthesia, hyperesthesia, reduced thermal sensation and dysfunction of pain perception as well as autonomic dysfunction.[3] Methods for assessing DP in the lower extremities of patients with diabetes include evaluation of symptoms,[4] neurologic examination,[5] vibration perception thresholds,[6] warmth and cold perception threshold,[7] thermal discrimination threshold[7] and electrophysiologic study.[8,9] Electrophysiological studies frequently show abnormalities in sensory and motor nerve conduction in diabetic patients even in those who clinically show no evident of neuropathy.[10,11] The notion that neuropathy is generally necessary to produce a diabetic foot ulcer has been well established. Early diagnosis of DP can decrease patient morbidity by allowing potential therapeutic interventions, including patient education and regular foot surveillance. However, there is no single diagnostic test for DP.[12] In an attempt to provide a simple, inexpensive, and reliable means of testing for DP, Semmes - Weinstein monofilament system (SW) is widely advocated as a screening tool. The SW was originally designed for measuring pressure sensation. Several studies discussed the potential clinical use of monofilaments, particularly the 10 - g monofilament, in identifying patients with the risk of foot ulceration.[13-15] The purpose of the study was to correlate the Semmes-Weinstein monofilament tests and electrophysiological studies of diabetic peripheral neuropathy in lower extremities.

Materials and Methods

The study was conducted at Diabetic Neuropathy Research Clinic and Electrodiagnostic Laboratory, King Chulalongkorn Memorial Hospital from April 1998 to December 1999. Approval from the Ethics Committee of the Faculty of Medicine was obtained before commencing the study. Informed consent for the study was given by each patient.

Patients

Twenty-six NIDDM ambulatory patients were studied. The criteria of inclusion were: (1) primary NIDDM, (2) age 25 or older, (3) duration of diabetes last longer than 6 months, and (4) presence of symptoms of diabetic neuropathy.

Methods

The patients were interviewed for symptoms of diabetic neuropathy and informed about the study. If s/he was willing to participate in the study, s/he underwent the following procedures: 1) a comprehensive medical and neurological evaluation to exclude neuropathy of other etiologies (e.g. alcoholic, nutrition, and uremic); 2) standardized bilateral nerve conduction study including sensory sural nerves and motor common peroneal and tibial nerves - performed by a physician who was blinded to the status of the subjects; 3) a Semmes - Weinstein monofilaments test conducted by an independent observer who was blinded to all other results. The

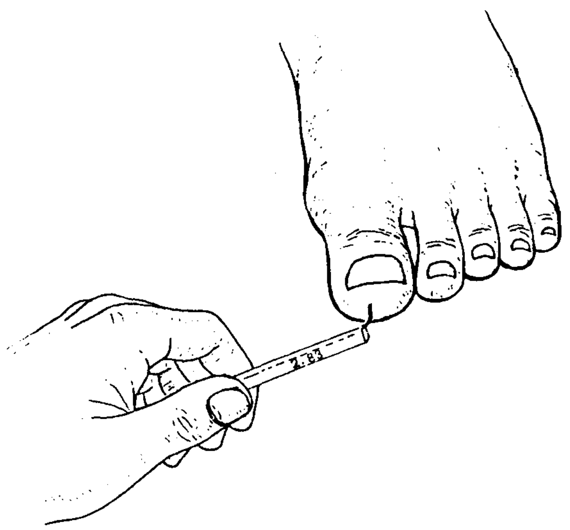

Figure 1. The Semmes Weinstein monofilament was applied to the first toe of the patient's left foot.

Semmes - Weinstein monofilaments are a set of 20 pressure - sensitive nylon filaments attached to a lucite rod. They were standardized in their length and thickness that they buckle at reproducible forces ranging from 0.0045 - 447 g. Therefore, when it was applied on the patient's skin, the amount of pressure administered would be more a function of the instrument than of the examiner. We applied the monofilament perpendicularly to the tip of big toes and slowly increased the pressure on the lucite rod until it bent. (Figure 1) At this point, the patient was asked whether there was any sensation of pressure. Of the 20 available sizes of Semmes Weinstein Monofilament, we used the size 2.83, 3.22, 4.56, 5.07 and 6.45 which produced approximately 0.080, 0.172, 4.19, 7.37 and 164.32 gram - force on bowing (North Coast Medical, Inc., Campbell, CA). The five filaments were representing changes in functional levels of touch recognition. The 2.83 filament was first used to the tip of big toes. If the patient felt the filament the examination was complete. If s/he did not respond to the 2.83 filament, the next heavier filament would be used until s/he recognized the force or until it was established that s/he did not feel even the heaviest filament. Testing was done in a quiet place away from noise and distraction. The patient's hands were rested in a comfortable position during the test and his/her vision was occluded during the test by eye closing or looking away.

Statistical Analysis All measurements were calculated as mean $\pm$ 1 standard deviation. Pearson correlation coefficient with corresponding 95 % confidence intervals (95 % CI) was used to measure the correlation of Semmes - Weinstein monofilament tests and electrophysiological studies.

Table 1. Demographic and clinical characteristics of the patients.

	Minimum	Maximum	Mean $\pm$ Std. Deviation
Age (yrs)	44	69	54.58 ± 6.29
Yrs. of diabetes	2	16	6.19 ± 5.00
Fasting plasma glucose (mg/dl)	70	426	147.81 ± 63.45
Hemoglobin A1 (%)	5.40	11.90	7.26 ± 1.51

Results

26 NIDDM patients, 13 males and 13 females were studied. The demographic profile of the patients was shown in table 1. The results of Semmes - Weinstein monofilament tests in bilateral tips of big toes, sensory and motor nerve conduction studies were demonstrated in table 2. The number and percentage of patients with abnormality of each test was shown in table 3. Our result showed that the outcome of Semmes - Weinstein Monofilament tests and electrophysiological studies in all patients were weakly correlated. (Table 4)

Table 2. The result of Semmes - Weinstein monofilament tests and electrophysiological studies.

	Rt. (Mean ± SD)	Lt. (Mean ± SD)
SW monofilament index	3.67 ± 1.17	3.92 ± 1.45
Sural distal latency (msec)	2.67 ± 1.37	2.76 ± 1.25
Sural SNAP amplitude (μV)	4.39 ± 4.14	4.45 ± 4.01
Sural NCV (m/sec)	34.52 ± 17.81	36.65 ± 16.60
Peroneal distal motor latency (msec)	4.18 ± 0.88	4.11 ± 1.42
Peroneal CMAP amplitude (mV)	2. 42 ± 1.77	2.59 ± 1.77
Peroneal NCV (m/sec)	38.59 ± 8.96	39.31 ± 9.10
Tibial distal motor latency (msec)	4.51 ± 0.78	4.24 ± 0.72
Tibial CMAP amplitude (mV)	7.84 ± 3.93	8.95 ± 4.14
Tibial NCV (m/sec)	38.49 ± 6.62	38.93 ± 4.73

Table 3. The number and percentage of patients with abnormality of Semmes - Weinstein Monofilament tests and electrophysiological studies.

	NO.OF CASE	%
SW monofilament index > 2.83	16	61.54
Sural distal latency > 2.8 msec	24	92.31
Sural SNAP amplitude <10 μV	24	92.31
Sural NCV < 45 m/sec	19	73.08
Peroneal distal motor latency >4.5 msec	13	50.00
Peroneal CMAP amplitude < 3 mV	18	69.23
Peroneal NCV < 40 m/sec	13	50.00
Tibial distal motor latency >4.5 msec	12	46.15
Tibial CMAP amplitude < 8 mV	15	57.69
Tibial NCV < 40 m/sec	13	50.00

Table 4. The pearson correlation of Semmes - Weinstein monofilament tests and Electrophysiological studies.

	S-W monofilament index	
	Rt.	Lt.
Sural distal latency	-.26	-.43
Sural SNAP amplitude	-.20	-.33
Sural NCV	-. 24	-.37
Peroneal distal motor latency	- .04	- .29
Peroneal CMAP amplitude	- .04	- .13
Peroneal NCV	- .41	- .41
Tibial distal motor latency	.47	.23
Tibial CMAP amplitude	-.41	- .53
Tibial NCV	-.27	- .32

Discussion

Diabetic neuropathy is an insidious and progressive disease that firstly involves distal and symmetrical peripheral sensory nerve fibers, and eventually progresses to autonomic and motor neurons. There are a number of criteria employed for the diagnosis of diabetic polyneuropathy. Clinical neuropathy presumably refers to patients'symptoms and signs of polyneuropathy.[13,14] In other reports, a subset of specific neurological deficit was accepted, for example absent knee and ankle reflexes and reduced perception of vibration sense.[15] Many studies provided evidence that abnormalities of nerve conduction can be related to symptoms, signs and neuropathological abnormality and therefore should be used in setting minimal criteria for the diagnosis of diabetic polyneuropathy.[15-17] The high reproducibility of both the sensory nerve and compound muscle action potentials, along with sensory and motor nerve conduction velocities led to the suggestion that these tests, which reflect actual changes in peripheral nerve pathology, should be emphasized in the diagnosis of diabetic neuropathy, and should also be used in controlled clinical and epidemiological trials.[18] Our study demonstrated that patients with clinical evidence of diabetic neuropathy of lower extremities, sural latency and sensory nerve action potential (SNAP) amplitude had the highest degree of abnormalities (92.31 %) followed by sural nerve conduction velocity (NCV) (73.08 %), peroneal compound muscle action potential (CMAP) amplitude (69.23 %), tibial CMAP amptitude (57.69 %), peroneal motor latency (50.00 %), peroneal motor NCV (50.00 %), tibial NCV amplitucle (50.00 %) and tibial latency (46.15 %). Dyck et al[16] found peroneal motor nerve had the highest abnormality, followed by sural nerve, median sensory and median motor nerves. Some authors suggested that sural sensory nerve action potential was the best single predictor of the presence of diabetic neuropathy.[19] In general, the lower extremities showed far more frequent abnormalities than the upper extremities. A fall in amplitude of the SNAP occurs mostly in sural nerve, whereas the incidence of abnormal slowing in sensory NCV of the same nerve is disproportionately low. A decrease in SNAP amplitude without a fall in sensory NCV was quite an impressive finding.[20] This sort of abnormality was usually produced by a lesion with axonal pathology, but it was possible that a low amplitude might be produced by abnormal temporal dispersion of the SNAP. Certainly, recent comparisons of sural nerve biopsies and nerve conductions in diabetic patients with clinically significant diabetic neuropathy (DN) revealed that the two key electrophysiological hallmarks of DN (decreased sural SNAP amplitude and slow peroneal motor NCV) correlated well with characteristic structural lesions of myelinated nerve fibers. The amplitude of sural SNAP correlated with the density of myelinated fibers which decreased over time in DN. Similarly, the decline in peroneal motor NCV was likely to reflect a combination of demyelination and loss of the largest myelinated fibers.[21,22]

For the detection of DN. in clinical practice a simple, sensitive, and inexpensive screening method is required. Previous studies indicated that both the Semmes Weinstein monofilaments examination (SWME) and the clinical neurological examination could be useful for diagnosing DN in clinical practice and, moreover, might even help identify patients who are at risk for amputations.[23, 24] The SWME allows a simple calibrated means of assessing protective sensation[23,25] and has been demonstrated as a prognostic risk factor for complications of neuropathy. The monofilament was clearly established as a reproducible and practical method.[25] A single prospective study to investigate the monofilament for the prediction of ulcers and amputations reported a positive likelihood ratio of 15.[24] Several case - control studies reported variable sensitivities and specificities up to 95 % and 82 %, respectively.[26-28] The results of our study however, demonstrated sixteen patients (61.54 %) had monofilaments index more than 2.83 which suggested diminished in light tough and was the earliest sign of nerve involvement. When compared with electrophysiological studies, the percentage of patients who had abnormal monofilament index was less than sural nerve conduction study. Furthermore our results showed a weak correlation of SWME and electrophysiological studied in this setting. The high reproducibility of nerve conduction studies and their close correlation with nerve fiber loss and structural insult in diabetic neuropathy make these tests sensitive indicators of the presence of neuropathy. While the SWME assesses the threshold of light touch pressure in a semiquantitative fashion.[29] The present study suggested that clinical abnormality from two or more evaluations would provide a good basis for the diagnosis of polyneuropathy. Because of excessive variability of the tests, however, it was not possible to use results from one type of evaluation to predict the others.

Conclusion

Because neuropathic symptoms and deficit may be caused by different pathogenetic mechanisms, they should be assessed separately. Simple screening strategies can be used in conjunction with more sophisticated techniques when available.

References

1. Bild DE, Selby JV, Sinnock P, Brower WS, Braverman P, Showstack JA. Lower-extremity amputation in people with diabetes : epidemiology and prevention. Diabetes Care 1989 Jan; 12 (1): 24 - 31
2. Guy RJC, Clark CA, Malcolm PN, Watkins PJ. Evaluation of thermal and vibration sensations in diabetic neuropathy. Diabetologia 1985 Mar; 28(3): 131 - 7
3. Thomas PK. Classification, differential diagnosis, and staging of diabetic peripheral neuropathy. Diabetes 1997 Sep; 46(Suppl 2): S54 - 7
4. Clements RD, Bell DS. Diagnostic, therapeutic and pathogenic aspects of diabetic neuropathy.

In: Cohen MP, Foa PP, eds. Special Topics in Endocrinology and Metabolism. New York: Alan R. Liss 1982: 2 - 33

5. The DCCT Research Group. Factors in the development of diabetic neuropathy. Baseline analysis of neuropathy in feasibility phase of diabetes control and complications trial (DCCT). Diabetes 1988 Apr; 37(4): 476 - 81
6. Zeigler D, Mayer P, Gries FA. Evaluation of thermal, pain and vibration sensation thresholds in newly diagnosed type I diabetic patients. J Neurol Neurosurg Psychiatry. 1988 Nov; 51 (11): 1420 - 4
7. Sosenko JM, Kato M, Soto R, Gadia MT, Ayyar DR. Specific assessments of warm and cold sensitivities in adult diabetic patients. Diabetes Care 1988 Jun; 11(6): 481 - 3
8. Dorchy H, Noel P, Kruger M, De Marertelaer, V Dupont E, Toussaint D, Pelc S. Peroneal motor nerve conduction velocity in diabetic children and adolescents. Relationships to metabolic control, HLA - DR antigens, retinopathy, and EEG. Eur J Pediatr 1985 Nov; 144(4): 310 - 5
9. Graf RJ, Halter JB, Halar E, Porte D Jr. Nerve conduction abnormalities in untreated maturity - onset diabetes. Relation to levels of fasting plasma glucose and glycosilated hemoglobin. Ann Intern Med 1979 Mar; 90(3): 298 - 303
10. Downie AW, Newell DJ. Sensory nerve conduction in patients with diabetes mellitus and controls. Neurology 1961 Sep; 11(9): 876 - 82
11. Lawrence DG, Locke S. Motor nerve conduction velocities in diabetes. Arch Neurol 1961 Nov; 5(11): 483 - 9
12. Feldman EL, Steven MJ, Thomas PK, Brown MB, Canal N, Greene DA. A practical two - step quantitative clinical and electrophysiological assessment for the diagnosis and staging of diabetic neuropathy. Diabetes Care 1994 Nov; 17(11): 1281- 89
13. Greenbaum D. Obsevations on the homogeneous nature and pathogenesis of diabetic neuropathy. Brain 1964; 87: 215 - 32
14. Palumbo PJ, Elveback LR, Chu CP,Connolly DC, Kurland LT. Diabetes mellitus: incidence, prevalence, survivorship, and causes of death in Rochester, Minnesota, 1945 - 1970. Diabetes 1976 Jul; 25(7): 566 - 573
15. Noël P. Sensory nerve conduction in the upper limbs at various stages of diabetic neuropathy. J Neurol Neurosurg Psychiatry 1973 Oct; 36(5): 786 - 96
16. Dyck PJ, Karnes JL, Danbe J, O'Brien P, Service FJ. Clinical and neuropathological criteria for the diagnosis and staging of diabetic polyneuropathy. Brain 1985 Dec; 108 (pt 4): 861 - 80
17. Lamontagne A, Buchthal F. Electrophysiological studies in diabetic neuropathy. J Neurol Neurosurg Psychiatry 1970 Aug; 33(4): 442 - 52
18. Dyck PJ, Karnes JL, O' Brien PC,Litchy WJ, Low PA, Melton LJ 3rd. The Rochester Diabetic Neuropathy Study: reassessment of tests and criteria for diagnosis and stage severity. Neurology 1992 Jun;42(6): 1164 - 70
19. Redmond JM, McRenna MJ, Feringold M, Ahmad BK. Sensory testing versus nerve conduction velocity in diabetic polyneuropathy. Muscle Nerve 1992 Dec;15(12):1334 - 9

20. Baba M. Di: ' ''c nerve function : its electrophysiologic... ..aluation. In: Ward J, Goto Y, eds., Diabetic Neuropathy. Chichester: John Wiley & Sons,1990: 270 - 2

21. Sima AA, Bril V, Nathaniel Y, McEwen TA, Brown MB, Lathimer SA, Greene DA. Degeneration and repair of myelinated fibers in sural-nerve biopsy specimens from patients with diabetic neuropathy treated with sorbinol, an investigational aldose reductase inhibitor. N Engl J Med 1988 Sep 1; 319(9): 548 - 55

22. Sina A, Cherian V, Albers JW. The Tolrestat Study Group. Nerve fiber loss in diabetic neuropathy correlates with impaired evoked potential amplitudes and nerve conduction velocity (Abstract). Diabetologica 1992; 35: 606

23. Kumar S, Fernando DJS, Veves A, Knowles EA, Young MJ, Boulton AJM. Semmes-Weinstein monofilaments: a simple effective and inexpensive screening device for identifying diabetic patients at risk for foot ulceration. Diabetes Res Clin Pract 1991 Aug; 13(1-2): 63 -7

24. Rith - Najarian SJ, Stolusky T, Gohdes DM. Identifying diabetic patients at high risk for lower - extremity amputation in a primary health care setting. A prospective evaluation of simple screening criteria. Diabetes care 1992 Oct;15(10):1386 - 89

25. Smieja M, Hunt D, Edelman D, Etchells E, Comuz J, Simel DL. Clinical examination for the detection of protective sensation in the feet of diabetic patients. International Cooperative Group for Clinical Examination Research. J Gen Intern Med 1999 Jul; 14(7): 418 - 24

26. Olmos P, Cataland S, O' Dorisio T, Casey CA, Smead WL, Simon SR. The Semmes - Weinstein monofilament as a potential predictor of foot ulceration in patients with noninsulin - dependent diabetes. Am J Med Sci 1995 Feb; 309(2): 76 - 82

27. Armstrong D, Lavery L, Vela SA,Quebedeaux TL, Fleischli JG. Choosing a practical screening instrument to identify patients at risk for diabetic foot ulceration. Arch Intern Med 1998 Feb 9; 158(3): 289 - 92

28. Umeh L, Wallhagen M, Nicoloff N. Identifying diabetic patients at high risk for amputation. Nurse Pract 1999 Aug; 24(8): 56 - 70

29. Bell - Rrotoski JA. Light touch - deep pressure testing using SWM. In: Hunter JM, Schmider LH, Mackin EJ, eds. Rehabilitation of the Hand. 3rd ed. St. Louis: C.V. Mosby; 1984: 585 - 93