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RISK FACTORS FOR DIABETIC FOOT ULCERATION-FOOT DEFORMITY AND NEUROPATHY

Vesna Bokan

Interaction of the sequels of neuropathy in the foot leads to ulcers and leg amputations in individuals with diabetes mellitus. The purpose of this study was to explore the relationship between neuropathy, foot deformity, plantar pressure and limited joint mobility for predicting the occurrence of ulcers. A total of 20 patients, with mean age of 61 years and duration of diabetes type 2 of 12,5 (SD 6,54) years, participated in the prospective study. Inclusion factors were neuropathy, which was defined by electrophysiological examinations, and foot deformity. At follow-up, the patients were examined by performing: neuropathy disability score (NDS), measurement of the first metatarsophalangeal joint and ankle joint range of motion, estimation of foot deformity and application of 10-g monofilaments. Plantar foot pressure was measured using Rothbaler Scan System. We noted the NDS score 7,7 and SD 1,66.

A significant association was found between limited mobility of the first metatarsophalangeal joint (MTPH 1) and claw great toe deformity (75%).

The loss of protective sensation is defined as insensitivity in the great toe, the first, the second and the third metatarsal heads (MTH 1, MTH 2, MTH 3). There was a significant interaction between peak plantar pressure and insensitivity in the region of the great toe and MTH 1 and MTH 3 (87%: 100%), $p< 0,05$.

Neuropathy, foot deformity, plantar pressure and limited joint mobility are significant risk factors for development of foot ulceration. *Acta Medica Medianae 2010; 49(4):19-22.*

Key words: *diabetes, plantar pressure, peripheral neuropathy*

Clinical Center of Montenegro, Center for Physical Medicine and Rehabilitation, Podgorica, Montenegro

Contact: Vesna Bokan
Bulevar M. Lalića 4/18, Podgorica, Montenegro
E-mail: b-vesna@t-com.me

Introduction

Diabetic foot ulceration is one of the major causes of nontraumatic lower limb amputation (1-4). The central place in every prevention plan and programme of diabetic amputation deter the whole risks for development foot ulcer. Team approach in the prevention and treatment of risks factors diminish the possibility of foot ulcer by 40-85% (2). Foot ulcer risks involve: neuropathy, peripheral vascular desease, foot deformity, limited joint mobility, increased plantar foot pressure, history of earlier ulceration or amputation (5). The presence of sensory neuropathy has already been described as the most important risk factor (6,7). The absence of the protective sensations in diabetic polineuropathy leads to repetetive trauma and deminishes patient ability to react properly to prevent potential injury. Plantar surface of the foot is the most common area for developing neuropathic ulcer, especially in the area of high pressure such as head metatarsal bones (MT). The most common places of foot ulcer development are the first, second and third head of metatarsal bones (MT 1, MT 2, MT 3) and great toe. Holewski et al. in their study about the prevelance of diabetic foot have identified the relationship between foot deformity and increased plantar pressure; claw toes and hammer toes are highlighted as significant risk. The prevalence of hammer toes ranges from 32 to 45%; predominantly, there is the great toe affection, and the changes are in the form of hyperextension of metatarsophalangeal joint (MTPH), flexion of the proximal joint and hyperexstension of the distal interphalangeal joint. Apart from these there are: varus and valgus deformity, pes cavus, hallux valgus etc. Motor neuropathy is one of the referred causes of foot deformity and it leads to atrophic changes in the foot musculature and this causes reduced MTPH joint mobility, and distal migration of the metatarsal fat pad which is placed below metatarsal bones (7-9). These changes increase foot vulnerability during the gait; this mechanism of ulcer development has been explained with constant and repetitive stresses on the prominence of bones during static and dynamic pressure of the foot. Different types of foot biomechanic abnormalities result in identifiable patterns callus formation, fissures and deformities. The limited joint mobility is the common manifestation in

patients with diabetes mellitus (DM), and this occurs in 30% of diabetic patients. Limited mobility in ankle joint and MTPH is caused by thickness and progressive stiffening of the collagen-containing tissues and the consequence is the loss of joint mobility and greater plantar pressure (7).

Boulton and Research Group for diabetic foot and for ulcer development risks cite that 51% of DM patients and neuropaty have altered plantar pressure (9-11). Many strategies are used to off-load high presure of the foot during stance and gait, through total contact (insoles and comfortable footwear). Plantar pressure information is useful in predicting the location of ulcer development and determining the risk point.

Aim

The aim of the study was to evaluate the risk factors in DM patients for development of foot ulcer. The further purpose of this case study was the possibility to predict higher risk area through relationship between foot deformity, lack protective sensation on plantar surface of the foot and increased plantar pressure.

Research design and methods

This study was conducted in the Center of Physical Medicine and Rehabilitation in the Clinical Center of Montenegro in 2009. The study was approved by the Ethic Committee of Clinical Center of Montenegro. This prospective study includes the group of 20 DM patients type 2, age range from 18 to 70 years, both sex included. The subjects were chosen upon the following criteria: exsisting foot deformity and sensory neuropathy, from the group of 70 patients with diabetic distal sensorimotor polyneuropathy treated by physical therapy. The presence of polyneuro-pathy in all patients was confirmed by electro-mioneurographic examination.

Reaserch protocol

Detailed neurological examination includes vibration perception threshold of the great toe of 128-Hz, temperature perception on dorsum of the foot and pin-prick perception. Scoring was recorded using NDS (Neuropathy Disability Score): 0 - normal; 1 - abnormal. Achilles tendon reflex was examined and scored through NDS: 0 - present, 1 – present with reinforcement and 2-absent. Joint mobility evaluation included mobility MTPH 1 and ankle joint. The examination was measured by using goniometer and scored 0 – normal, 1 - ruduced and 2 - completely limited mobility. Joint mobility examination is simple, unexpensive and fast; with the patient supine and the ankle joint in neutral position, a vertical line was marked on the patient's skin from heel to midcalf, and the maximum range of talar flexion and extension in passive motion was measured with goniometer; regarding the first MTPH joint the patients were also in supine position and a horisontal line was drawn from the first toe to the heel. The range of motion from maximal passive plantar flexion to maximal passiv dorsal flexion was measured. In this manner, we are informed not only about segment mobility but as well as general patient mobilty. Very often, diabetic patients could not follow the task standing on heels. Motoric neuropathy very often leads to foot musculature weakness and disballance of flexors and extensors of the foot, but the paradox is often seen, where the motoric neuropathy and good musculature strenght is absent, patients could not stand on their heels.

Foot deformity by inspection

In theory, different types of deformities cause increased plantar pressure and calus forming (halux valgus, varus, hammer toes, claws toes, pes cavus, etc.) Deformities can be scored separately by points from 1 -3.

Maximal plantar foot pressure

Rothballer Scan System was used to measure the static plantar foot pressure. The patients stood without shoes and maximal plantar foot pressure. This process was recorded for three times. In the researches conducted so far, both static and dynamic plantar foot pressure were measured, with variations amounting to 30%. The advantage of the static examination is the knowledge of geometrical information of foot and the disadvantage is the absence of complete information in comparison to other methods (MRI, UZ).

Evaluation of changes in sensitivity at the tested sites on the plantar foot aspect

Monofilament was applied in ammount of 10g on the plantar aspect of great toe, MT 1 head, MT 2 head, MT 3 head , MT5 head and heel.

Statistical analysis: for statistical data processing, mean and standard deviations (SD) were used in testing significance: Pearsons's chi-square test and Fisher's exact test. The level of significiance was $p<0,05$. A multiple linear regression analysis was carried out to test a multivariate correlation between variables.

Results

We screened 20 patients (12 male and 8 female), average age 61 years (SD 9,87). Clinical variables were: duration of diabates 12,5 years (SD 6,54), duration of diabetic neuropathy 5,2 years (SD 3,94), hemoglobin A1c (HbA1c) < 9,5mmol/l. Neuropathic symptoms were recorded using NDS score, with the result of the score as high as 7,7 (SD 1,66).

Table 1. Distribution of foot deformity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Clawed great toe	4	20,0	20,0	20,0
	Varus	3	15,0	15,0	35,0
	Valgus	8	40,0	40,0	75,0
	Hamer	3	15,0	15,0	90,0
	Cavus	2	10,0	10,0	100,0
	Total	20	100,0	100,0	

Table 2. Ratio between impaired sensibility and plantar pressure on MT1 head

			PIMT		Total
			0,00	1,00	
s.t. MT1	0,00	Count	14	1	15
		% within s.t. MT1	93,3%	6,7%	100,0%
		% within PIMT	87,5%	25,0%	75,0%
	1,00	Count	2	3	5
		% within s.t. MT1	40,0%	60,0%	100,0%
		% within PIMT	12,5%	75,0%	25,0%
Total		Count	16	4	20
		% within s.t. MT1	80,0%	20,0%	100,0%
		% within PIMT	100,0%	100,0%	100,0%

Table 3. Ration between impaired sensisbility and plantar pressure on MT3 head

			PIII MT		Total
			0,00	1,00	
s.t. MT3	0,00	Count	11	0	11
		% within s.t. MT3	100,0%	0,0%	100,0%
		% within PIII MT	73,3%	0,0%	55,0%
	1,00	Count	4	5	9
		% within s.t. MT3	44,4%	55,6%	100,0%
		% within PIII MT	26,7%	100,0%	45,0%
Total		Count	15	5	20
		% within s.t. MT3	75,0%	25,0%	100,0%
		% within PIII MT	100,0%	100,0%	100,0%

In the evaluation of functional status, the results showed that 45% of patients had limitied ankle joint and 70% of patients had limitied MTPH 1 joint mobility.

Table 1 shows the percentage of patients with some types of foot deformity; 40% of diabetic patients had valgus deformity, other deformities were present in almoust equal percent. The relationship between foot deformity and reduced joint mobility was found in 75 % of patients, such as hammer great toe and limitied joint mobility MTPH 1.

Monofilament examination showed that patients were inable to feel the 10 g pressure applied on the plantar aspect of the great toe, MT1 head, MT2 head and MT3 head; that is considered to be indicative of being at high risk for foot ulceration.

Comparisons between sites of increased plantar pressure with sites of "loss of protective sensation" are presented in Table 2 and Table 3. Statistically significant interaction between this variable was in the areas of great toe 87,5%, MT 1 head 75% ($p<0.05$) and MT 3 head 100%. ($p<0,001$).

Discussion

In this study, we investigated the relationship between risk faktors for foot ulcerations. The examination showed that patients with hammer great toe and sensory neuropathy are more susceptible to ulceration. For example, William R. Ledoux et al. reported that correlations were found between sensory neuropathy, hamer toe and muscle weaknes (12-14).

An important correlation was shown between the lack of protective sensation and high-pressure areas of the great toe, MT 1 head and MT 3 head, and it could be responsible for the development of foot ulceration.

Abouesha et al. investigated static foot structure using three - dimensional (3 D) scanning and ultrasaund to look "inside the foot" to quantify foot structure and soft tissue (12). Our results correlated with Abouesha about the areas under higher plantar pressure (MT 1, MT 2, MT 3), but the area of the highest pressure in our research is MT 3 head, Abouesha reported MT 1 head. Sicco et al. suggested that motor neuropathy leads to musle atrophy, weakness and imbalance between intrinsic and extrinsic muscles across the MTP and interphalangeal joints. One of these factors may be pathology of the plantar aponeurosis - an important connective tissue structure that contributes to MTPH joint stability (11). The condition of plantar aponeurosis and ligaments has not been clearly elaborated in neuropathic foot, without taking into account the reportings on ruptures of plantar aponeurosis in diabetic patients. Finally, it can be concluded that the presence of sensory neuropathy is crucial fot the pathology of diabetic foot (13,14).

Reduced joint mobility has been less examined compared to other risk factors, due to fewer disabilities and symptoms it causes. However, this cannot diminish its importance. Stefan Zimny et al. (6), in their research, found a significant link between reduced joint mobility in ankle TLC, and MTPH 1 and defect of vibration perception in the great toe. In our research, there is a correlation between the increased plantar pressure and reduced joint mobility of ankel, but it is not significant.

Conclusion

Specific evaluations of foot in definitive diabetic neuropathy may predict the place of foot ulcer development. The common risk factors increase the possibility of ulcer development.

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FAKTORI RIZIKA ZA NASTANAK ULCERACIJE STOPALA KOD DIJABETIČARA - SENZITIVNA NEUROPATIJA I DEFORMITETI STOPALA

Vesna Bokan

Neuropatske promjene na stopalu kod dijabetičara komplikuju se nastankom ulceracije stopala i amputacije na donjim ekstremitetima. Cilj rada bio je ispitivanje međusobnog odnosa faktora rizika: senzorne neuropatije, deformiteta stopala, ograničenog obima pokreta zglobova i plantarnog pritiska na stopalu, radi determinacije mjesta nastanka ulceracije. Prospektivnom studijom obuhvaćen je uzorak od 20 bolesnika sa diabetes mellitus-om (DM) tip 2, prosječne starosti 61 godina i trajanjem DM 12,5 godina (SD 6,54). Uključujući faktor za odabir bolesnika bio je: prisutni deformiteti stopala i senzorna neuropatija potvrđena elektromioneurografskim ispitivanjem. Bolesnici su ispitivani neuropatskim skorom (NDS), mjerenjem obima pokreta skočnog i prvog metatarzo-falangealnog zgloba (MTPH), evidentiranjem tipa deformiteta, kompjuterskim skeniranjem stopala (Rothballer Scan Sistem) i 10-g monofilamentima. Vrijednost NDS se kretala 7,7 sa SD 1,66. Rezultati pokazuju da su predilekciona mjesta za nastanak ulceracije palac i regija glave prve i treće metatarzalne kosti (MT 1 i MT 2). Značajna je korelacija ograničenog obima pokreta u prvom MTPH i kandžasti palac u 75% slučajeva. Kod 87% bolesnika u regiji palca i glave MT 1 prisutna je udruženost povećanog plantarnog pritiska i oštećenje senzibiliteta. U ispitivanju udruženosti povećanog plantarnog pritiska i oštećenja senzibiliteta u regiji glave MT 3 nađena je visoka značajnost, $p<0,001$. Udruženost faktora rizika značajno povećava mogućnost predviđanja rizičnog mjesta ulceracije stopala kod dijabetičara. *Acta Medica Medianae 2010;49(4):19-22.*

Ključne reči: dijabetes, plantarni pritisak, periferna neuropatija