CONTRIBUTION OF ARTERIOPATHY AND NEUROPATHY IN THE DEVELOPMENT OF DIABETIC FOOT GANGRENE

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The prevalence of diabetes and diabetic complications increase worldwide rapidly. The gangrene is one of the most feared complications of diabetic foot, often ending with amputations. It is important to screen the patients with diabetes in order to identify those with high risk for foot ulceration. A few steps are useful in the screening: medical history, MNSI questionnaire, foot clinical examination for neuropathy (sensory, motor, autonomic) and arteriopathy, plantar footprints (Podotrack). Using "Scottish foot ulcer risk score" we can stratify the degree of risk for foot ulcers into low, moderate and high. Moderate and high risk patients require additional measures to prevent foot ulcer.

Key word: diabetic foot gangrene; neuropathy; arteriopathy; food ulcer.

INTRODUCTION

The prevalence of diabetes indicates an alarming increase, in the last years, so that we can say that we expect a real pandemia. The International Working Group on the Diabetic Foot (IWGDF) notes that in 2025 the estimated number of people with diabetes worldwide will reach 380 million, representing 7.1% of the adult population.

Diabetes leads to many complications and diabetic foot is among them. Patients with diabetes develop various foot complications and 15% of patients develop foot ulcers. About half of the ulcers become infected and 20% of them will end up with lower extremity amputation[1]. Each year over one million people lose a leg as a result of diabetes or in other words, every 30 seconds a leg is amputated somewhere in the world[2]. Foot ulcerations are responsible for 85% of lower limb amputations in patients with diabetes. Lower limb amputation is 15-40 times higher in diabetics versus non-diabetics and at least 50% higher in men versus women[3].

Diabetic gangrene is the consequence of chronic diabetic complications arteriopathy and neuropathy, frequently associated with foot infection. It is one of the most feared diabetic foot lesions, often ending with amputation, if not diagnosed and treated in time.

Diabetic gangrene definition – International Consensus on the Diabetic Foot – continuous necrosis of the skin and underlying structures (muscles, tendons, joints, bones)[2].

The cause of diabetic gangrene is the impaired circulation (macro and / or microcirculation) associated or not with neuropathy and infection. Different diabetic foot lesions (ulcers, plantar fissures- heels, interdigital fissures, corns, plantar calluses) if untreated can progress to gangrene, when impaired circulation is present. The gangrene represent the stages 4 and 5 in Wagner classification[3,4] (Table 1).

Table 1

Wagner classification of foot gangrene

Grade 0	No open lesions; may have bone deformity or hyperkeratosis
Grade 1	Superficial ulcer without deep tissue penetration
Grade 2	Deep ulcer with extension to tendons, bones, joints
Grade 3	Tendinitis, osteomyelitis, deep abscess or cellulitis
Grade 4	Local gangrene of a toe, forefoot or heel -is most commonly associated with infection
Grade 5	Extensive foot gangrene associated with joint damage and soft tissue infection

Diabetic gangrene classification[4,5]

Dry Gangrene

– due to peripheral artery disease (absent pluses)

– the skin is cold, the color changes in evolution from red → cyanotic→ black

Wet Gangrene

– due more to venous flow blockade rather than arterial flow, caused by thrombosis or embolism

– the skin is warm, swelling, red → black

– frequently infected and malodorous

Gas Gangrene

– produced by anaerobic bacteria infection →crepitus

The screening to identify patients at increased risk for diabetic foot ulcers has several steps:

I. Medical history collect general data that are useful in achieving patient at risk profile for foot lesions: age, sex, BMI, duration and type of diabetes, HbA1c and chronic diabetes complications (retinopathy, diabetic kidney disease), associated cardiovascular risk factors (smoking, dyslipidemia), associated cardiovascular disease (hypertension, ischemic heart disease, myocardial infarction, stroke, peripheral arterial disease)[3,6].

II. MNSI neuropathy screening questionnaire (Michigan Neuropathy Screening Instrument)

It can be administrated by the physician or by the patient[7,8].

The answer "**YES**" on items 1-3, 5-6, 8-9, 11-12, 14-15 are each counted as one point.

A "**NO**" response on items 7 and 13 counts as 1 point.

Item 4 is a measure of impaired circulation and item 10 is a measure of general asthenia. Both are counts with 0 points and are not included in the score, because these two questions do not evaluate the neuropathy.

MNSI questionnaire Total score = 13 Table 2.

Table 2

Michigan Neuropathy Screening Instrument (MNSI) questionnaire

	YES	**NO**
1. Are you legs and/or feet **numb**?	1	0
2. Do you ever have any **burning pain** in your legs and/or feet?	1	0
3. Are your feet **too sensitive** to touch?	1	0
4. Do you get **muscle cramps** in your legs and/or feet?	**0**	**0**
5. Do you ever have any **prickling** feelings in your legs or feet?	1	0
6. Does it **hurt** when the bed covers **touch** your skin?	1	0
7. When you get into the tub or shower, are you able to tell the **hot water** from the **cold water**?	0	1
8. Have you ever had an **open sore** on your foot?	1	0
9. Has your doctor ever told you that you have **diabetic neuropathy**?	1	0
10. Do you feel **weak** all over most of the time?	**0**	**0**
11. Are your **symptoms** worse at **night**?	1	0
12. Do your **legs hurt** when you walk?	1	0
13. Are you able **to sense** your feet when you **walk**?	0	1
14. Is the **skin** on your feet so **dry** that it cracks open?	1	0
15. Have you ever had an **amputation**?	1	0

III. LOCAL CLINICAL EXAMINATION OF DIABETIC FOOT[3,6,9].

1. SCREENING OF SENSORY NEUROPATHY

• 10 g Semmes Weinstein monofilament to test tactile-pressure perception to the great toe, the 1-st and 5-th metatarsal heads, calcaneal and midfoot.

• 128 Hz Tuning fork Rydl-Seiffer to test vibration perception on a bony part -on the dorsal side of the distal phalanx of the big toe or the 1-st metatarsal head.

• Type-Therm = device with 2 heads, one cold on metal and other warmer on plastic, to test thermal perception.

• Pin-prik (Neurotips) to test pain perception in the same plantar areas suitable for testing tactile perception.

2. SCREENING OF MOTOR NEUROPATHY

• Achilles and patellar reflexes

• PRESENCE OF FOOT DEFORMITY caused by interosseous muscle atrophy, tendons and ligaments fibrosis – pes planus, pes cavus, hallux valgus, hallux rigidus, prominent metatarsal heads, claw and hammer toes, Charcot foot

• Presence of plantar calluses in the areas with high plantar pressure.

3. SCREENING OF AUTONOMIC NEUROPATHY

• **Neuropad** a blue patch with a color indicator, which applied to the foot, switch to the pink color when the skin has a normal hydration or remain blue if your skin is dry, stained pink and blue color indicates plantar sweat gland dysfunction

• plantar cracks (often calcaneal), wet or excessively dry plantar skin.

Local neurological examination ends with the calculation of **MNSI score** (Table 3) to diagnose the neuropathy[7,8].

4. SCREENING OF ARTERIOPATHY

• palpation of foot pulses- tibial posterior and dorsal pedis

• foot skin aspects -cyanotic, pale, cold.

5. MEASUREMENT OF PLANTAR PRESSURES IN PATIENTS WITH MOTOR NEUROPATHY, DEFORMITIES AND CALLUSES

Plantar footprint **PressureStat (Podotrack)** are used to identify the areas with high pressure (Fig. 1) It is a semiquantitative method that measures plantar pressures on a color scale ranging from white (p = 0–0.5 kg/cm²) to dark black (p = 9–15 kg/cm²). The value can be converted into international units (kPa) with the formula:

$$1\ kg/cm^2 = 98.07\ kPa$$[10,11,12].

Table 3

Michigan Neuropathy Screening score

1. APPEARANCE OF BOTH FEET	**YES**	**NO**	
NORMAL	0	1	
If "NO" check all that apply			
Deformities			
Dry skin, callus			
Infection			
Fissure			
Other			
2. ULCERATION	PRESENT	ABSENT	
	1	0	
3. Ankle reflexes	PRESENT	REINFORCEMENT	ABSENT
	0	0.5	1
4.Vibration perception	PRESENT	DECREASED	ABSENT
	0	0.5	1
5. Monofilament	NORMAL	DECREASED	ABSENT
	0	0.5	1
Over 2 points from 10 =NEUROPATHY			

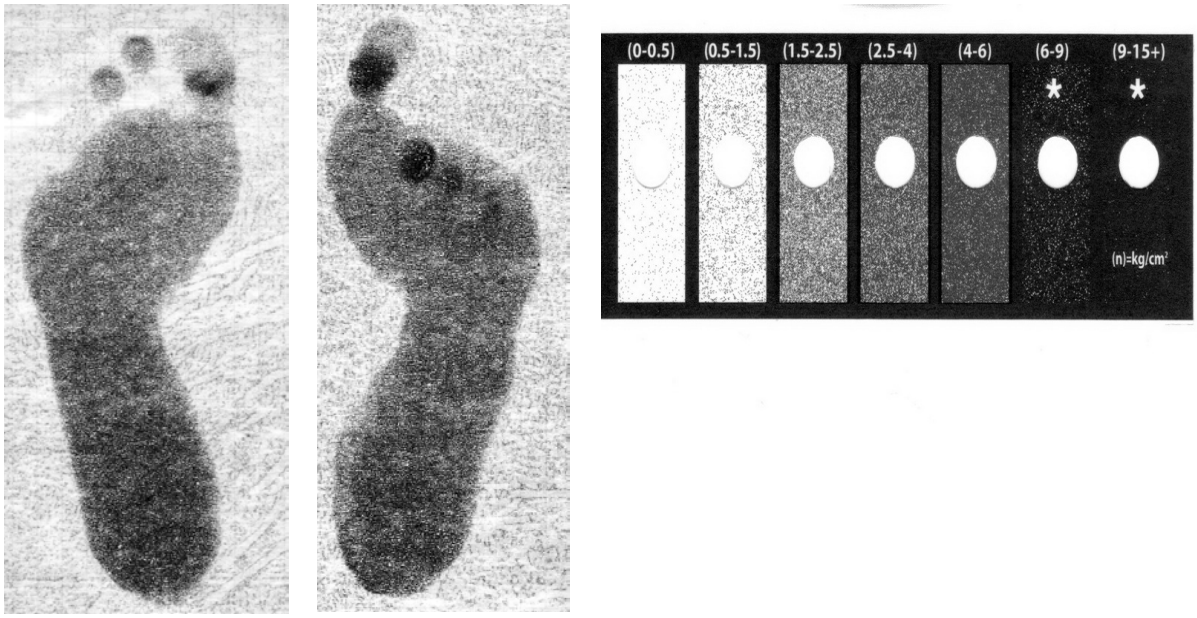

Fig. 1. Plantar footprint **PressureStat in** 64 years, insulin-treated Type 2 diabetic patient.

Very high plantar pressures under both great toe base and under the 2-ed metatarsal head on right foot (9-15 kg/cm²) High pressures (6-9 kg/cm²) under metatarsals head 3, 4 on right foot, tip toes 2,3 on left foot, no marks of 2-5 right toes and 4.5 left toes (claw toes) Associated with absence of tactile-pressure, thermal and vibration perception, absent ankle reflexes, calluses in areas with high pressure, absent palpable pulses both feet, high risk score for ulceration

Sometimes the toes have no mark due to an abnormal position -axis deviation or dorsiflexion of the proximal phalanx on the metatarso-phalangeal joint. Plantar footprint differs with foot shape (pes planus, pes cavus) and can be associated with different toes deformations (claw toes, hammer toes, hallux valgus) (Fig. 2 and Fig. 3).

Plantar footprint help to measure arch high by calculating **arch index =midfoot area (B) / whole foot ground contact area excluding the toes (A+B+C)** (Fig. 4).

Arch index ≤ 0.21 high arch

Arch index between 0.21 and 0.26 normal arch

Arch index ≥0.26 flat or low arch

Fig. 2. Example of pes cavus.

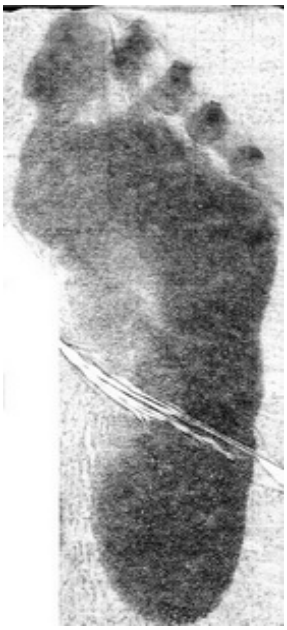

Fig.3. Example of pes planus+halluxvalgus.

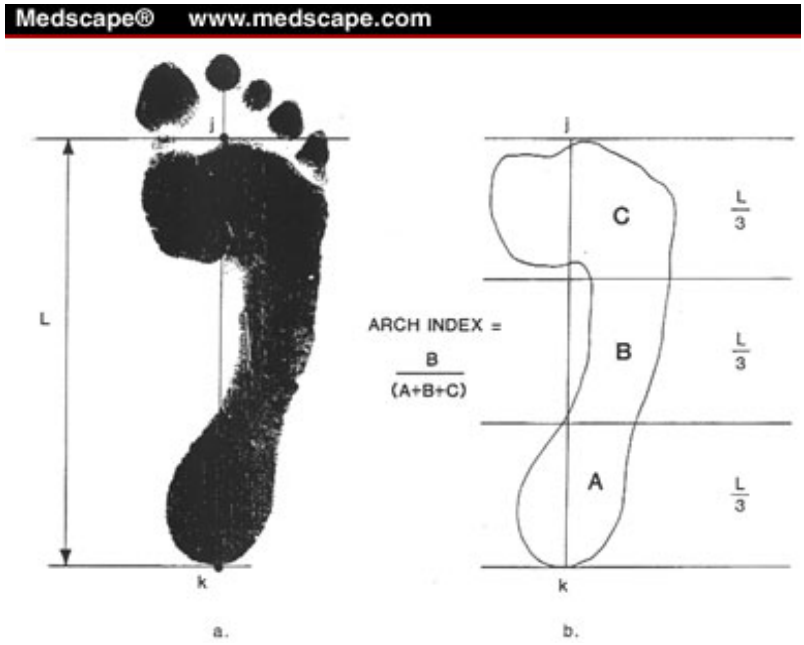

Fig. 4. Plantar footprint.

In some cases, we can identify feet with high arch which has no typical, discontinuous foot print (Fig. 5).

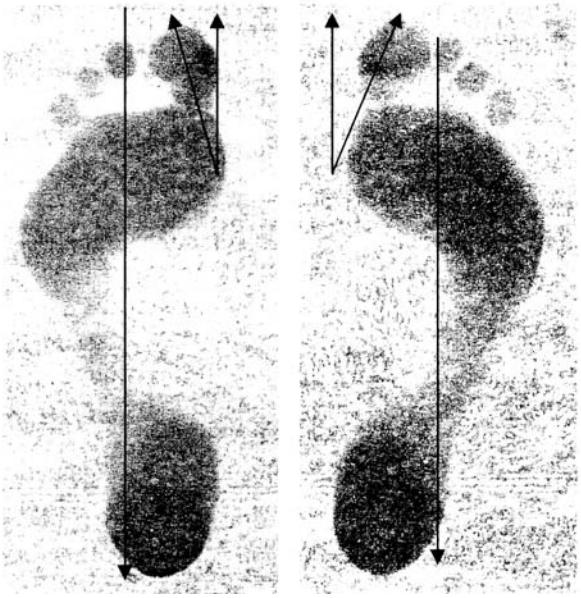

Fig. 5. Plantar foot print in a 54 years, Type 2 Diabetic patient with Discal hernia L4-L5 surgical treated, Right ankle fracture surgical treated Very high plantar pressures under both great toe and heel (9-15 kg/cm²), no mark under the 5-th toes, pes cavus, hallux valgus and interosseous muscle atrophy both feet, tactile- pressure, thermal and vibration perception absent on right foot and present on left foot, absent ankle reflexes on both feet, absent palpable pulse both feet, high risk score for ulceration.

Plantar footprint help to analyze foot axes, heel and hallux deviation. Normal foot axe (plantar foot axe) line from the 2nd toe to the middle of the heel. When the line is exterior to the heel this one is in inversion.

An example of lateral great toe deviation is seen in hallux valgus (Fig. 6).

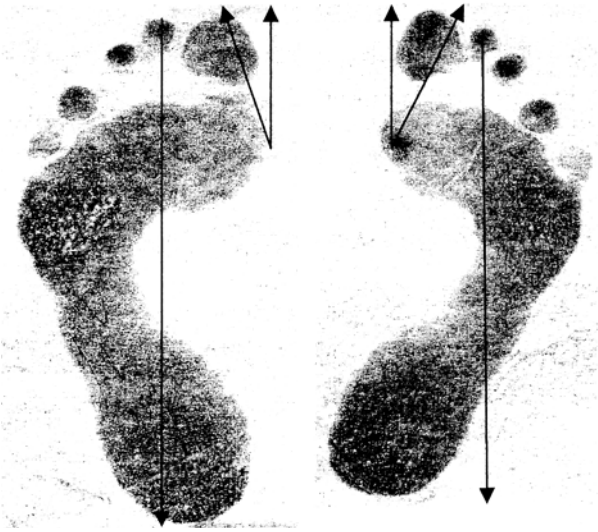

Fig. 6. Plantar footprint with deviation in hallux valgus.

A Scottish Foot Ulcer Score for stratification of the risk for developing foot ulcer[13–15] is presented in Figure 7.

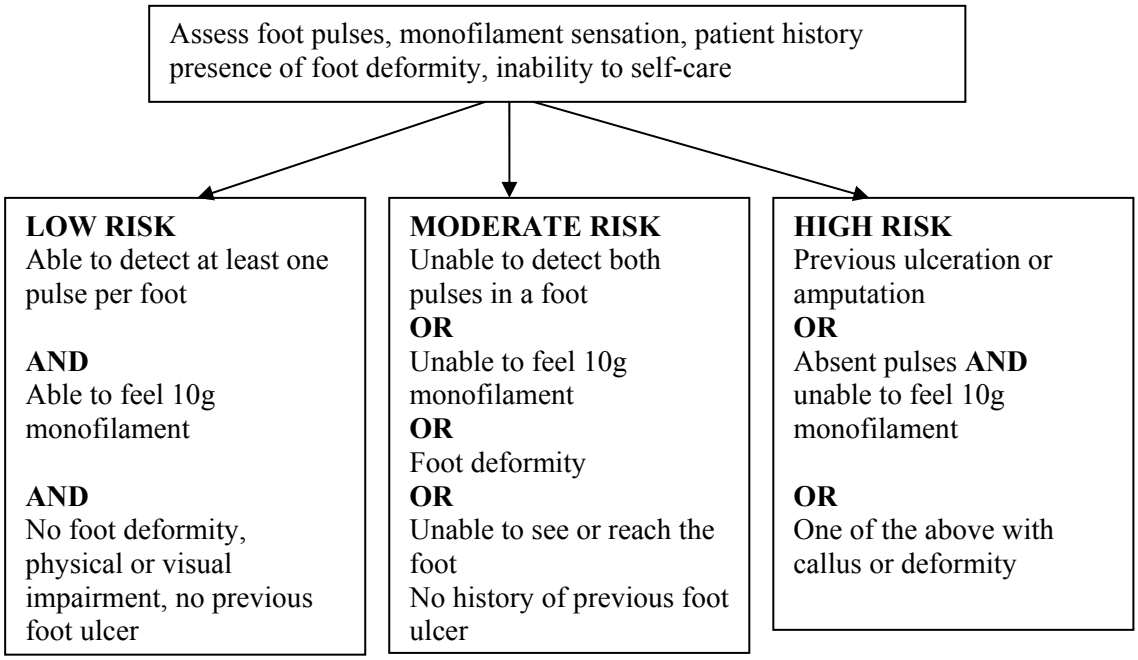

Fig. 7. Stratification the degree of risk for developing foot ulcers: Scottish Foot Ulcer Risk Score.

A high and a moderate risk patients require additional measures[3,9,16] to **prevent** foot ulcer, taking the following actions:

• reinforced education

• frequent evaluation by specialized physician

• control of cardiovascular risk factors, smoking cessation, treatment for dyslipidemia and for associated cardiovascular diseases

• good diabetes control

• patients with peripheral arterial disease should be referred to cardiovascular surgery in order to perform arteriography and revascularization

• patients with high plantar pressure should be referred to specialized centers for manufacture foot orthoses to decrease plantar pressure and for custom molded footwear for major foot deformity (*e.g.*, Charcot foot).

For patient follow-up the stratification in **four risk groups** is useful[16]:

0–normal – every year evaluation

1–peripheral neuropathy – every 6 months evaluation

2–neuropathy, foot deformities and/or peripheral artery disease – every 3 months evaluation

4–history of ulceration or amputation – every 1–3 months evaluation.

In conclusion, in order to prevent foot ulcer and to reduce the number of amputation, a careful screening for this complication must be had in view, in diabetic patients yearly, and in patients with high risk, every 6 month.

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