APPLICATION OF PEDOBAROGRAPHIC MEASUREMENTS IN THE EVALUATION AND MANAGEMENT OF THE INSENSITIVE FOOT

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INTRODUCTION

It is well known that a large portion of hospital admissions of diabetic patients is for the medical and surgical treatment of foot problems. These problems are often plantar ulcerations that lead to serious morbidity and sometimes even mortality. There is currently an effort being made to better understand the risk factors pertaining to the insensitive foot, especially those due to diabetic peripheral neuropathy. The accurate measurement of plantar foot pressures has proven to be of particular importance in the evaluation and management of the insensitive foot. This measurement yields clinically useful scientific data that, in conjunction with standard clinical examination, enables the clinician to predict the site of future ulceration and monitor the care of the diabetic patient with peripheral neuropathy.

BACKGROUND INFORMATION

Using an optical pedobarograph, it has been demonstrated that 51% of diabetic patients with neuropathy display abnormally high plantar foot pressures beneath the metatarsal heads, whereas 17% of diabetic control subjects (patients with diabetes and no evidence of neuropathy) displayed abnormally elevated submetatarsal pressures. Only 7% of non-diabetic subjects displayed elevated pressures in the submetatarsal area.[1] These results indicated a reasonable threshold value for distinguishing normal from abnormal plantar pressure as 10 kg/cm^2. These results also pointed out the strong correlation between an elevated vibration perception threshold (VPT) and plantar foot ulceration. Similarly, quantification of the monofilament pressure threshold (MPT) is a valuable and readily measurable clinical parameter. Birke and Simms[2] defined the 5.10 unit monofilament as the threshold limit of protective sensation. Subsequent investigators pointed out the high correlation between elevated MPT and the presence of plantar ulceration in diabetic patients.[3]

Other useful clinical parameters known to correlate in a discriminative fashion with plantar foot ulceration are elevation of the ankle/brachial arterial pressure index (API),[4] increased skin resistance (SR) to conduction of a constant electrical current (indicative of diminished sweat gland function), and diminished sensory nerve conduction velocity. More recent studies have shown that dynamic plantar pressure analysis revealed abnormally elevated plantar pressure measurements in 36% of diabetic patients with subclinical peripheral neuropathy, all of these patients displayed neuropathic changes upon subsequent objective neu-

rological quantification (VPT, skin resistance, motor and sensory NCV).[5]

PATIENT POPULATION AND CONVENTIONAL TESTING

The criteria used to identify patients that would potentially benefit from a detailed pedobarographic gait analysis include the following clinical findings: a history of bilateral foot symptoms, (including burning pain, paresthesia, and nocturnal exacerbations of pain or cramping), an absent ankle deep tendon reflex, and clinical evidence of autonomic dysfunction, (including signs of arterial shunting and edema, increased cutaneous blood flow, and diminished cutaneous hydration). A history of previous ulceration or non-traumatic amputation is also important, particularly with respect to recurrent ulceration, or the development of transfer lesions.

Other local conditions that influence the pedobarographic assessment of the diabetic patient are orthopedic deformities such as hallux valgus, hallux limitus, ankle equinus, hindfoot varus, or any significant structural abnormality. It is important to properly assess the lower extremity vascular status with respect to pulses and symptoms of claudication, because findings related to these parameters may indicate the need for vascular consultation prior to gait analysis. Similarly, appropriate medical management and control of hyperglycemia should also be established in these patients. Patients with suspected peripheral neuropathy should be examined with the monofilament esthesiometer and other clinical tests used to document the condition.

PEDOBAROGRAPHIC GAIT ANALYSIS

Although static pedobarographic measurements can provide important data related to foot structure and function,[6] dynamic pedobarographic measurements provide a true functional assessment as the subject ambulates across the foot plate. Although there are several reliable systems available for measuring plantar foot pressure, the author's experience is with the *Musgrave Footprint*®. This pedobarograph is capable of accurately determining which areas of the plantar aspect of the foot are high pressure regions, quantifies the pressures, and provides a variety of two- and three-dimensional data representations. (Figures 1, 2) Important parameters include the peak pressure/time curve, and integration allows calculation of the total load/time curve. Integration of pressures over any zone of the foot (such as heel, midfoot, forefoot, or toes) allows the investigator to compare force/time curves, and show that there is reduced toe loading in diabetic feet (or any foot) with contracted digits such as clawtoes secondary to intrinsic pedal muscular atrophy.

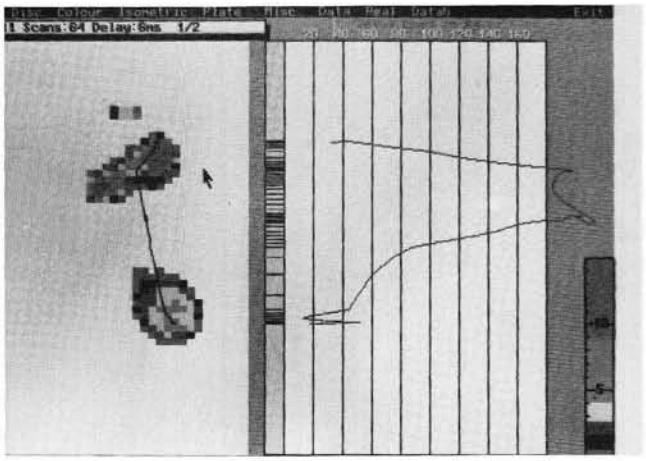

Figure 1. Two-dimensional center of pressure curve plotted on color-coded grid footprint (left) and peak pressure/time curve (right) for the left foot of a diabetic patient with peripheral neuropathy and impending ulceration beneath the tibial sesamoid. Note abnormally high plantar pressure beneath the first metatarsal head, and rapid shift of center of pressure toward the insensitive and potentially compromised area. Integration of the area under any region of the pressure/time curve can be calculated to provide quantitative data pertaining to pressure sustained in one region of the foot compared to another region.

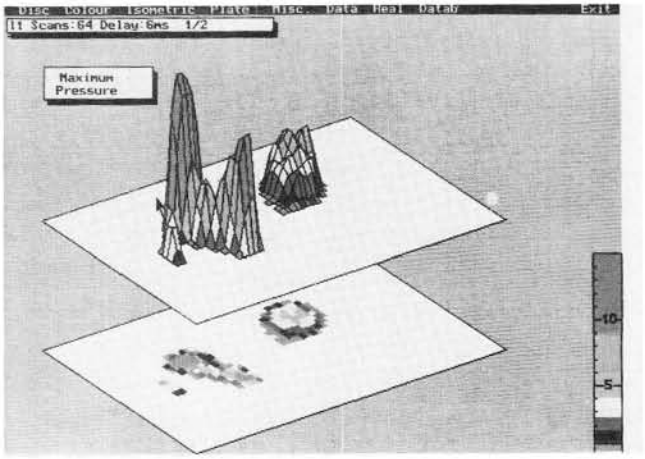

Figure 2. Three-dimensional topographic plot of peak plantar foot pressures, as well as two-dimensional plot in lower footprint, color-coded to indicate regions of abnormally high pressure. These footprints are of the left foot of the same patient noted in Figure 1, and depict dangerously high pressure localized to the first metatarsophalangeal joint.

Recommendation for Overall Evaluation and Treatment Plan

The two primary risk factors associated with plantar ulceration in the diabetic patient are loss of protective sensation, and abnormally high plantar foot pressure. The combination of conventional clinical testing for the presence of peripheral neuropathy, in combination with pedobarographic gait analysis, can allow the clinician to accurately identify these two risk factors.[7]

Basic findings include the inability to sense the 6.10 unit monofilament esthesiometer, or evidence of plantar foot pressure greater than 10 kg/cm^2. It is proposed that any patient presenting with clinical evidence of peripheral neuropathy could benefit from pedobarographic gait analysis. The information gained could then be used to predict the location of potentially compromised areas or confirm abnormal pressure in areas of previous or existing ulceration.

As a management tool, pedobarographic data can assist in determining the best way to pad or shield a compromised area, and subsequent gait analysis can aid in the assessment of ongoing therapy. At any time, isopressure contour plots can be used for patient and physician education, and provide objective information that can be included in the patient's record. Furthermore, plantar foot pressure data can provide information useful in selecting operative procedures that may be indicated, should non-surgical therapy prove to be inadequate. Pre- and postoperative pedobarographic data can also be used to assess the results of surgical intervention.

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