CURRENT THERAPY IN PODIATRIC SURGERY

Jay

CURRENT THERAPY IN PODIATRIC SURGERY

RICHARD M. JAY, D.P.M., D.A.B.P.S., F.A.C.F.O., F.A.C.F.S.

Associate Professor
Department of Orthopaedics
Director
Pediatric Orthopaedics
Pennsylvania College of Podiatric Medicine
Director of Podiatric Residency Programs
Graduate Hospital
Chief, Podiatric Surgery
Mt. Sinai Hospital
Philadelphia, Pennsylvania

1989

B.C. Decker Inc • Toronto • Philadelphia

Publisher

B.C. Decker Inc
3228 South Service Road
Burlington, Ontario L7N 3H8

B.C. Decker Inc
320 Walnut Street
Suite 400
Philadelphia, Pennsylvania 19106

Sales and Distribution

United States and Possessions
The C.V. Mosby Company
11830 Westline Industrial Drive
Saint Louis, Missouri 63146

Canada
The C.V. Mosby Company, Ltd.
5240 Finch Avenue East, Unit No. 1
Scarborough, Ontario M1S 5P2

United Kingdom, Europe and the Middle East
Blackwell Scientific Publications, Ltd.
Osney Mead, Oxford OX2 OEL, England

Australia and New Zealand
Harcourt Brace Jovanovich Group (Australia) Pty Limited
30–52 Smidmore Street
Marrickville, N.S.W. 2204
Australia

Japan
Igaku-Shoin Ltd.
Tokyo International P.O. Box 5063
1–28–36 Hongo, Bunkyo-ku, Tokyo 113, Japan

Asia
Info-Med Ltd.
802–3 Ruttonjee House
11 Duddell Street
Central Hong Kong

South Africa
Libriger Book Distributors
Warehouse Number 8
"Die Ou Looiery"
Tannery Road
Hamilton, Bloemfontein 9300

South America
Inter-Book Marketing Services
Rua das Palmeriras, 32
Apto. 701
222–70 Rio de Janeiro
RJ, Brazil

NOTICE

The authors and publisher have made every effort to ensure that the patient care recommended herein, including choice of drugs and drug dosages, is in accord with the accepted standards and practice at the time of publication. However, since research and regulation constantly change clinical standards, the reader is urged to check the product information sheet included in the package of each drug, which includes recommended doses, warnings, and contraindications. This is particularly important with new or infrequently used drugs.

Current Therapy in Podiatric Surgery

ISBN 1–55664–047–1

Library of Congress catalog card number: 87–73454

10 9 8 7 6 5 4 3 2 1

CURRENT THERAPY IN PODIATRIC SURGERY

Surgical Titles in the Current Therapy Series

Bayless:
Current Management of Inflammatory Bowel Disease
Callaham:
Current Therapy in Emergency Medicine
Cameron:
Current Surgical Therapy
Charles, Glover:
Current Therapy in Obstetrics
Ernst, Stanley:
Current Therapy in Vascular Surgery
Fazio:
Current Therapy in Colon and Rectal Surgery
Foley, Payne:
Current Therapy of Pain
Garcia, Mastroianni, Amelar, Dubin:
Current Therapy of Infertility
Garcia, Mikuta, Rosenblum:
Current Therapy in Surgical Gynecology
Gates:
Current Therapy in Otolaryngology—Head and Neck Surgery
Grillo, Austen, Wilkins, Mathisen, Vlahakes:
Current Therapy in Cardiothoracic Surgery
Jay:
Current Therapy in Podiatric Surgery
Long:
Current Therapy in Neurological Surgery
Marsh:
Current Therapy in Plastic and Reconstructive Surgery
Parrillo:
Current Therapy in Critical Care Medicine
Resnick, Kursh:
Current Therapy in Genitourinary Surgery
Rogers:
Current Practice in Anesthesiology
Spaeth, Katz:
Current Therapy in Ophthalmic Surgery
Trunkey, Lewis:
Current Therapy of Trauma
Torg, Welsh, Shephard:
Current Therapy in Sports Medicine

This book is dedicated to my *best* friend.
She puts rhythm in my heart and fills the pages of my life with beautiful love songs.
Thanks Roz.

π

CONTENTS

Tendon Surgery

Digital and Nail Surgery

Implants

First Ray Surgery

PREOPERATIVE EVALUATION

PREOPERATIVE VASCULAR EXAMINATION

ANTHONY S. KIDAWA, D.P.M., F.A.S.P.M.

In contemplating any pedal procedure, the podiatrist needs to evaluate the medical and vascular status of the patient. Since many medical conditions, too numerous to be discussed in this chapter, can affect the outcome of a procedure, only the vascular examination is discussed. The state of the patient's circulatory system can readily be determined in the office by interview and physical examination to include noninvasive vascular testing. This evaluation informs the podiatric surgeon as to the probability of normal healing, wound dehiscence, or gangrene necessitating local or more proximal amputation.

The age of a patient is often relied on as an index of the individual's circulatory status. This deductive process is discouraged, for the young are predisposed to vasospasticity, leading to prolonged healing; the middle-aged population has residual spastic tendencies with early preclinical arteriosclerosis allowing wound dehiscence; the elderly have various stages of advancing organic disease with significant risk for gangrene.

ELICITATION OF SYMPTOMS

The patient is interviewed for any symptoms referrable to the circulation at the time of systems review or during the vascular examination. Initially, the symptom of claudication is determined. If the patient admitted to leg muscle fatigue, the *claudication distance* is determined, in terms of city blocks or sets of stairs, as well as the *time of ischemia* when the symptoms abate after rest. If the patient is capable of ambulating when experiencing muscle fatigue or cramping, the differential diagnosis of neurogenic or sciatic claudication must be considered.

Any experience of nocturnal cramping is also elicited, as well as the posture assumed to attain relief or prevent this form of rest pain. Because many hours of shallow, reduced breathing leads to decreased oxygenation for even basal muscle metabolism, significant stenosis causes early morning cramping. This is opposed to cramping on retiring, which is a result of uneven relaxation of antagonistic muscles, usually overused with biomechanical faults. Other causes, such as anemia and electrolyte imbalance (e.g., calcium and potassium), must be considered in the differential diagnosis.

Symptoms of numbness and acroparesthesias (e.g., burning and tingling) are also investigated, as well as their relationship to observed skin color changes. These are associated with decreased flow through the vaso nervorum and can be identified in cases of organic vessel disease with decreased perfusion pressure or in spastic conditions with intermittent decreased flow resulting from vessel wall constriction. The differential diagnoses include peripheral neuropathy, which may be constant, organic vessel disease, which may be positional, and vasospasticity, which has intermittent symptoms with color changes and is provoked by anxiety or decreased ambient temperature, with or without a history of cold injury.

INSPECTION FOR SIGNS

The lower extremities are observed from at least the level of the knees for signs of nutritional disturbances. All surfaces are examined for scars, healed ulcers, active infected or noninfected ulcers, and amputated parts. Notation is made of other trophic changes such as loosening of the skin over the joints, scaliness of the forefoot or digits, or thinning of the skin (onion skin) over most surfaces of the foot or leg.

Alterations in hair growth are also identified. Absence of hair resulting from friction of clothing, shaving, or use of depilatories must be considered. Thickening of toenails, in the absence of candidal or mycotic infection or a history of trauma, as well as slow nail growth also indicate decreased perfusion.

The skin is also observed for changes in underlying hues, irrespective of melanotic coloration. The normal pink hue is associated with rapid turnover of well-oxygenated blood, whereas a ruberous foot indicates slow velocity of flow and intermediate oxygenation of the hemoglobin with mild stenosis. Cyanosis is observed with sluggish flow and low hemoglobin oxygen tension and is associated with significant vessel obstruction and multilevel disease.

The examination should also note any staining of the skin in the supramalleolar areas, particularly on the medial surface. This is most commonly associated with hemosiderin deposition from a former untreated or insufficiently managed episode of deep thrombophlebitis. This sign of postphlebitic syndrome alerts the surgeon to apply a thigh tourniquet, a pedal Esmarch's bandage, or a digital Penrose drain to effect hemostasis intraoperatively rather than to further traumatize the veins with an ankle tourniquet.

Stressing the peripheral vascular tree with elevation and dependency certainly adds to the evaluative process. If pallor is observed in the sole of the foot after the venous blood is milked out with multiple flexions of the toes or ankle in the elevated position, negligible flow against gravity is demonstrated. This is referred to as Samuel's test. Allen's test is an extension of this procedure that identifies which of the pedal vessels is obstructed. The examiner alternately compresses the dorsalis pedis and posterior tibial arteries with the patient flexing the toes or foot. For example, if pallor is detected while the dorsalis pedis artery is compressed by the examiner's fingers, then the posterior tibial artery is stenosed.

The foot is then placed in the dependent position, and the filling of the superficial veins on the dorsum of the foot is timed. If this venous filling time is more than 10 to 15 seconds, arterial compromise is evident. The longer the refilling beyond this normal range, the greater the stenosis is. If the veins refill without palpable pulsations, collateral circulation has developed; however, if the veins do not refill, near end-stage ischemia is evident.

Finally, the foot is allowed to hang dependent for a brief time, and its coloration is noted again. If dependent rubor is observed, arterial compromise is usually suspect, although venous backflow must be considered in the differential. When the arterial blockage is proximal, the dependent rubor is observed on the plantar surface; however, if the blockage is distal in the extremity, the rubor is noted to involve all surfaces of the toes and distal foot in a stocking distribution.

An index of the cutaneous circulation can also be derived by viewing the coloration of the digital skin or that of the nail bed. This normally is pink and should return to pink within 1 second after being blanched by pressure of a finger with the lower extremity in the phlebostatic horizontal position. This subpapillary plexus filling time returns to normal in 2 to 3 seconds with the extremity in the elevated stressed position. Any prolongation of these times indicates arterial compromise.

PALPATION

The extremities are palpated for temperature assessment from the level of the knees to the toes. The limbs must have stabilized to the room temperature (ideally 68 to 70°F) for at least 20 minutes. Spotlights should be eliminated from the vicinity of the limbs, to preclude artificial warming of any part. All exposed surfaces are evaluated with the back of the examiner's hand or fingers. Should it be necessary to examine the back of the legs, the patient must dangle them for several minutes to preclude heat retention from the examination chair or table. The temperature is expected to decrease gradually from proximal to distal, with the coolest segment being the toes. This is natural because the more distal the part, the greater the concentration of sympathetic fibers is, causing constriction of the cutaneous vessels. Excessive digital cooling with associated hyperhidrosis indicates excessive sympathetic tone and spasticity.

The lower extremity arteries are palpated routinely, including the popliteal and pedal vessels. If these are abnormal, the examination proceeds to the common femoral and aortoiliac system. The vessels are evaluated as to symmetry of pulsations at the pedal level, since organically diseased arteries prolong transmittal time. They are also observed for amplitude of pulsation and graded on a 0 to 4 scale. In any such arbitrary scaling system, the notation should be in fractional form, with the numerator expressing the ascribed value and the denominator identifying the maximum value in the scale employed, e.g., +2/4 (normal). If any palpated sites have significant turbulence of flow, a vibrating thrill should also be noted. Such a site is also stethoscopically auscultated to identify any bruits.

OSCILLOMETRY

This modality has withstood the test of time and remains as informative to the practitioner today as it was several decades ago. Today's technology of pneumoplethysmography or segmental plethysmography is identical to the recording oscillometer of the 1950s. Its application continues to be the objective instrumental evaluation of excursions of peripheral arteries with pulsatile flow that can be documented.

The cuff is applied over the most superficial vessel at various levels, i.e., foot, ankle, below knee, above knee, and groin. The cuff is inflated to suprasystolic pressure, and recordings are noted at decrements of 10 mm Hg until the widest excursion of the needle is observed. The reading is charted as a fractional expression with the numerator designating the amount of maximum deflection and the denominator indicating the pressure at which the excursion was best.

Comparisons are made between levels as well as across levels of the contralateral extremity. Values cannot be absolutely defined because the readings can vary between individuals based on stature, and hence vessel size, as well as on systemic blood pressure. However, the oscillometric indices should increase proximally and should be comparable at similar levels between limbs. A marked deviation at one site, as compared to the pathology-free companion limb, indicates the level of a hemodynamically significant stenosis. It must be noted that no oscillometric readings are attainable for collateral vessels, which are nonpulsatile, even though such flow can perfuse the lower extremities to within normal limits.

Upon completion of the screening examination, the podiatric patient may or may not be vascularly cleared for surgical intervention. If any of the signs or symptoms listed in Table 1 are elicited, noninvasive testing of the arterial and/or venous circulation is indicated.

THERMOMETRY

The thermocouple has the advantage over manual palpation of skin temperature of providing an objective recording that is documentable and reproducible. Its readings are also comparable from one visit to another in evaluating the patient's progress with antibiotic, anti-inflammatory, or uricosuric therapy. Cutaneous temperatures provide an index of the degree of skin flow through the microcirculation.

Temperature gradients are determined for the digital, dorsum of foot, lateral leg, and anterior thigh levels. Because the degree of vessel tonicity and blood flow vary between individuals, there is no absolute normal reading. However, the following translates descriptive terms into temperature ranges for the foot and toes: hot (over 100°F), warm (99 to 91°F), tepid (90 to 85°F), cool (84 to 75°F), and cold (less than 74°F). The temperature decrease from thigh to toe levels should be gradual, not exceeding a 6-degree Fahrenheit difference at any level.

Temperatures in the cold range indicate marginal cutaneous perfusion and warrant special precautions or classification of the patient as being at risk (relatively or moderately, depending on other clinical or vascular findings) for surgery. It is prudent to record the ambient room temperature with the same instrumentation to compare the cutaneous readings for interpretation and comparison at the time of future evaluations.

SEGMENTAL SYSTOLIC PRESSURES

All hemodynamically significant lesions affect the artery's capacity to transmit the forward systolic head of pressure beyond that site. Plaques decrease the pressure whereas advanced arteriosclerosis, particularly the calcifying stage, registers an increased pressure reading as the artery resists cuff compression.

TABLE 1 Indications for Noninvasive Testing

Symptoms	*Signs*
Claudication	Trophic changes
Nocturnal cramping	Coldness with hyperhidrosis
Paresthesias	Cutaneous ulcers
Cold sensitivity	Absent/diminished pulses
Rest pain	Abnormal functional studies

The procedure involves placement of a 10-cm cuff at sequential sites of the ankle, below the knee, above the knee, and at the groin. The evaluation can be conducted expeditiously by placing a full series of cuffs at the aforementioned sites. Autoinflators with battery-operated compressors are also available. Some of these have memory capacity and can compute ischemic indices.

Identification of flow is made by means of the Doppler flow meter or photoplethysmography. The Doppler technique has the advantage of evaluating the pressure of each vessel in the leg, whereas the photocell plethysmograph applied to a toe gives only the pressure of the best vessel in the tibial-peroneal system.

With the cuff applied at a given level, a pedal artery of interest is insonated with the Doppler probe until the best signal is heard. The cuff is then inflated until flow ceases and gradually deflated until the first pulsation of flow is heard. This is recorded as the systolic pressure of the level and the vessel occluded by the cuff. It must be remembered that the Doppler probe's location serves only as a listening post for flow identification. Therefore, with the cuff at the ankle and the probe over the dorsalis pedis, the pressure determined is that of the anterior tibial artery at the ankle level.

Pressure readings are documented for all levels. Normally, these readings should be within 10 mm Hg at the same level of the contralateral limb, or within 20 to 25 mm Hg from one level to the next in the ipsilateral limb. Values outside these ranges indicate moderate to marked stenosis. Normal healing may be anticipated if the ankle pressures exceed 100 mm Hg in the diabetic and 85 mm Hg in the nondiabetic patient.

Toe pressures can also be determined with 19-mm digital cuffs applied to the base of the toe. Because flow levels are usually too low for auscultation with Doppler, a photocell probe is applied to the plantar tuft of the toe. The plethysmographic monitor is activated, and the digital cuff is inflated to a suprasystolic level. The cuff is then gradually deflated, and the monitor is observed for the first return of pulsations. This return of flow is noted as the digital segmental pressure.

ISCHEMIC INDICES

Because the size of the arteries as well as the circumference are comparable at the ankle and the arm, the pressure of the vessels at these sites should be identical. Hence, the ankle/arm ischemic index has been noted to approximate 1.00. When the ankle pressure, described previously, is divided by the arm pressure, determined by stethoscope or Doppler, the value should be near 1.00, i.e., 1.00 to 1.20. Values of 0.90 to 0.50 are consistent with moderate occlusion and are associated with claudicatory symptoms. Values in the 0.49 to 0.30 range are associated with marked stenosis and rest pain, and values below 0.30 indicate multilevel stenoses with attendant tissue necrosis. Values progressively above 1.20 indicate advancing stages of arteriosclerosis with calcification.

Another important index is the toe/ankle index, which reflects the status of the pedal circulation. The value resulting from dividing these pressures should be 0.60 or greater. A digital ischemic index value of less than 0.60 indicates marked pedal or digital arteriosclerosis inconsistent with normal healing.

DOPPLER ARTERIAL STUDIES

The Doppler effect, applied to medical diagnosis more than two decades ago, allows the practitioner to evaluate the characteristics of flow in blood vessels. Because it uses ultrasound, a coupling agent must be applied on the skin overlying the vessel to be evaluated. The sound, originating from an emitting crystal, passes through the skin, all the underlying soft tissue, and the vessel wall to be reflected by the blood cells and platelets. The sound traverses the same tissue and is detected by the receiving crystal, which amplifies the signal and presents it audibly through an amplifier or converts it into a scribed analog tracing for permanent record.

The pedal arteries are insonated, and if abnormal flow characteristics are detected, the study continues to evaluate the popliteal and femoral arteries. The audible signal is heard unless flow is obstructed or retarded to less than 7 cm per second, which is filtered out, or the device is not located over the vessel.

The reflected signal, aside from identifying patency, is also evaluated for several other parameters. The pitch, as a function of velocity, is studied and compared to the expected normal value for each vessel. The amplitude is directly proportional to the volume of blood and is also compared to previous studies of normality. The phasicity, as a function of directionality of flow, is counted for each pulse. The first signal reflects the pulsatile forward motion of blood; the second records the momentary hesitation of blood in early diastole as the artery wall recontracts with elasticity; the third sound demonstrates the continued forward flow through the artery during late ventricular diastole. Finally, the character of the Doppler signal is identified and labeled in descriptive terms, e.g., rough, knocking, muffled, or pistol shot.

Analog tracings are also recorded with attention to labeling the graph paper as to vessel name and sensitivity of the recorder. In nondirectional Dopplers, all waves are scribed in the positive axis, i.e., above the baseline; in directional Dopplers, the second reflected wave is scribed below the baseline. A normal double signal (biphasic) is scribed with two continuous waves; the second is of shorter amplitude, while the triphasic three-signal wave is recorded with three continuous waves, each shorter than the one preceding it. A single monophasic signal is traced as a bell-shaped curve indicative of lower amplitude of flow and loss of arterial wall elasticity. This form of signal is characteristic of significant arteriosclerosis.

PLETHYSMOGRAPHY

Two formats of plethysmography are commonly used in the podiatric profession for arterial diagnoses, pneumatic for segmental (or digital) evaluations, and photocell for digital and cutaneous studies. Both forms present with identical wave morphology in the tracing. Impedance plethysmography is usually reserved for evaluation of venous capacitance and maximum venous outflow in detecting deep thrombophlebitis.

Segmental plethysmographic studies are conducted at the ankle and below and above the knee. Studies may also be conducted at the midfoot level, but these require smaller cuffs. The cuffs are sequentially inflated to a predetermined pressure, recommended by the manufacturer, and tracings are made at all levels.

The scribed tracings are evaluated for crest times, presence or absence of dicrotic notching, sharpness or rounding of peaks, cleanness of morphology, and amplitudes. The time the wave takes to reach its crest should be less than 35 percent of the wave length, to indicate normal vessel elasticity in accepting a pulsatile volume of blood. The crest or peak should be sharp, indicating good transition from systole to diastole. The catacrotic limb of the wave (descending part of wave) should have a dicrotic notch consistent with good arterial elasticity in recoiling after maximal stretching. The wave must also be smooth, without any erratic components to indicate normal vessel wall dynamics, and the amplitudes should be comparable and adequate as a function of good flow volume.

The digital photocell or pneumatic studies normally scribe the same wave characteristics as were described earlier. The amplitudes should normally be 2 to 5 mm, or at least 2 mm, with or without dilation, to ensure adequate healing of surgical sites. The digital circulation may also be stressed to determine whether or not additional dilation or constriction is attainable. Functionality of the sympathetic nervous system is demonstrated by means of the vasovagal test by having the patient inspire and hold his or her breath. If autosympathectomization has not occurred, or if the arterioles are not in maximum spasm, additional constriction should be noted. To identify the capacity for dilation, and hence justification for vasodilators, one of the following is done: administering 1 oz of alcohol in a mixer of choice, administering a posterior tibial nerve blockade, or conducting the postocclusive reactive hyperemia test. The digital plethysmographic studies complement the cutaneous temperature gradients.

TABLE 2 Predictability of Surgical Wound Healing

	Normal	*At Risk*	*Poor*
Digital temperatures	>85°	74–85°	<74°
Segmental pressures			
Ankle: ND[a]	>120 mm Hg	120–70 mm Hg	<70 mm Hg
Ankle: DM[b]	>130 mm Hg	130–85 mm Hg	<85 mm Hg
Digital: ND	>80 mm Hg	80–30 mm Hg	<30 mm Hg
Digital: DM	>100 mm Hg	100–40 mm Hg	<40 mm Hg
Ischemic indices			
Ankle/arm ND	1.00–1.20	0.90–0.50	<0.50
Ankle/arm DM	1.00–1.30	1.00–0.65	<0.65
Toe/arm ND	>0.70	0.70–0.30	<0.30
Toe/arm DM	>0.80	0.80–0.40	<0.40
Toe/ankle ND	>0.60	0.60–0.25	<0.25
Toe/ankle DM	>0.65	0.65–0.30	<0.30
Arterial Doppler			
Phasicity	2–4	1	0
Wave peaks	sharp	rounded	saw-tooth
Plethysmography			
Crest time	<35%	35–50%	>50%
Wave peaks	sharp	rounded	saw-tooth
Dicrotic notch	present	shallow	absent
Amplitude: digital	>2.00 mm	2.00–1.25 mm	<1.25 mm

[a] ND = Nondiabetic
[b] DM = Diabetes mellitus

In evaluating the deep venous system for thrombophlebitis, impedance or pneumoplethysmography is used. Both systems rely on a tourniquet pressure of 70 mm Hg applied to the thigh to arrest venous outflow while the sensor cuff is applied at the calf level. Normally the capacitance is high, and when the thigh cuff is released, the maximum venous outflow should allow all previously entrapped venous blood to egress within 3 seconds. In deep venous thrombosis, the measured increased capacitance is less than normal, and the venous outflow is well beyond 3 seconds.

The results obtained by noninvasive testing can predict the patient's capacity for surgical wound healing. Table 2 summarizes these values and classifies the normal, at risk, and poor surgical candidate.

SUGGESTED READING

Kemczynski RF. Clinical application of noninvasive testing in extremity arterial insufficiency. In: Kemczynski RF, Yas JS, eds. Practical noninvasive vascular diagnosis. Chicago: Yearbook Medical Publishers, 1982:343.

Wagner FW. The dysvascular foot: a system for diagnosis and treatment. Foot Ankle 1981; 2(2):64–122.

Wheeler HB, Anderson FA Jr. Impedance phlebography: the diagnosis of venous thrombosis by occlusive impedance plethysmography. In: Bernstein EF, ed. Noninvasive diagnostic techniques in vascular disease. St. Louis: CV Mosby, 1982:482.

ELECTRODYNAGRAM

HAROLD D. SCHOENHAUS, D.P.M., D.A.B.P.S., F.A.C.F.S.

In the comprehensive treatment and care of foot problems, conservative management as well as surgical intervention have been employed. The signs and symptoms our patient population presents with include pediatric abnormalities such as in-toe, congenital and acquired flatfoot, juvenile bunions, hammer toes, and calcaneal apophysitis. In addition, many signs and symptoms associated with the sports-related injuries are seen, and the more mature population presents with manifestations associated with faulty mechanics, including hallux abducto valgus deformities, hammer toes, and heel spur syndromes. Finally, geriatric patients present with problems associated with poor circulation; this category includes the problems of the diabetic patient such as malperforans ulcers. The role of the podiatric physician in treating disorders such as these includes not only the treating of symptoms when they occur but also preventing certain symptomatology and signs from developing.

In evaluating the patient's chief concern, the podiatric physician evaluates all aspects of the patients lower extremity function deciding on what treatment programs to institute. This requires an in-depth history, which in the case of the pediatric patient, would be obtained from the parents. Often diagnostic tests are essential before any treatment can be started. We are all familiar with diagnostic tests such as x-rays, standard-angle and base-of-gait studies, bone scans, tomography, and computed tomographic (CT) scans. Other diagnostic studies include laboratory as well as electromyographic and nerve conduction velocities. The orthopaedic examination of the lower extremity, which we refer to as a functional orthopaedic evaluation, is probably one of the most important elements of our evaluation process. This is true because the vast majority of the signs and symptoms we treat are secondary to pathomechanical abnormalities, which may be congenital or acquired. It is possible, and even probable, for patients to develop problems secondary to arthridites, trauma, neoplasms, or infections, but we often find biomechanical abnormalities superimposed on the original problem as well. As part of the biomechanical examination and functional orthopaedic survey, we include range of motion studies of the joint and lower extremity, muscle evaluation and strength testing, physical and postural evaluation, which includes evaluation for limb length discrepancies and gait analysis.

Gait analysis used by the podiatric practitioner in the office environment consists primarily of visual interpretation. Many authors and podiatric physicians recognize that visual evaluation of gait has marked limitations, based on the distance of the patient as he or she walks away from, or from a distance toward, the examiner. It is difficult for the human eye to detect motion of less than 5 degrees or even 7 to 10 degrees as the distance increases. Other limiting factors are the comfort level of the patient and the patient's normal foot gear. When a patient is wearing shoes, the ability for the examiner to appreciate the extent of pronation or supination, or the motion of the calcaneus in the frontal plane, is hindered. It is also difficult to isolate when a particular muscle or muscle group is activated and what effect that activation has on the lower extremity.

For this reason, diagnostic tests are employed. In the area of muscle evaluation, electromyographic studies determine when a particular muscle or muscle group is firing during the gait cycle. Gross evaluation of the patient's gait has been studied with the use of photography, first using 16-mm film; with the advent of videotaping, the cost and availability have become practical for the practitioner. Video analysis also has a slow motion feature that permits one to evaluate the gait on a frame-per-frame basis. In our office, the patient runs or walks in a fixed position on the treadmill, and the slow motion videotaping enables us to isolate a particular part of the foot or leg and evaluate it.

Another important element in the evaluation of foot function is the relationship of the plantar aspect of the foot to the ground. This was recognized many years ago and certain modalities were developed to assist in evaluating the forces or pressure distribution from the plantar aspect of the foot. Pressure-sensitive mats, chalk imprints, and pressure-sensitive paper such as shutrak have been employed. On a more sophisticated level, the development of force plates adds a further dimension in the evaluation of foot-to-ground forces. I have used force plate interpretation for approximately 15 years and recognize its ability to assist in evaluating a patient's gait by providing a gross evaluation of the forces of the foot. Unfortunately, the force plate cannot isolate or identify the forces of a particular part of the foot, such as the second metatarsal versus the third. Furthermore, the cost of their use is far beyond the wherewithal of the podiatric physician to have available in the office environment. It is a modality that is best used in a research environment.

We are therefore left with having to evaluate a patient's gait in an office environment with the limitations of visual analysis.

Recognizing the importance of identifying parts to the gait cycle as well as the various phases of gait and how they effect foot function has led to the development of the electrodynagram. Functionally speaking, the majority of signs and symptoms podiatric physicians see and treat are associated with problems secondary to gait disturbances. More specifically, deviation from the normal function of the foot during the stance phase of gait leads to the development of signs and symptoms such as hallux abducto valgus, calcaneal spurs, hammer toes, plantar keratomas, shin splints, and chondromalacia of the patella. Our profession has recognized the importance of biomechanics not only treating a particular sign or symptom, but also in evaluating a patient before an orthotic is constructed or surgical procedures are selected. Managing a patient conservatively is preferable in most cases, and in the evaluation process we must include a modality that enables us to isolate and evaluate a patient's gait. It is even more important to be able to evaluate the way a patient walks within his or her natural environment, wearing shoes. For women who wear elevated heels, the normal gait cycle and timing of gait are significantly different from those of a patient wearing a flat shoe. With the introduction of the electrodynagram, we now have a modality that assists the podiatric physician in scientifically evaluating a patient's gait in the office environment.

The data the electrodynagram provides are both dependable and reproducible. They are similar to the data of an electrocardiogram in that a graphic description of the patient's gait becomes a part of the permanent record of the patient. Seven sensors are applied to the plantar aspect of each foot, in predesignated areas. One sensor is a floating sensor and may be placed on any part of the foot to assist in the evaluation of the forces in that particular area. The sensors are so thin they create no discomfort to the patient and do not alter the patient's normal gait cycle. In addition, the patient is able to wear normal foot gear while the test is being recorded. The test is easily performed by a podiatric assistant or technician, and the data are immediately available for evaluation by the practitioner. The electrodynagram provides information on pressure applied to certain parts of the foot. The parts of the foot evaluated include the lateral heel, the medial heel, the fifth metatarsal head, second metatarsal head, first metatarsal head, and hallux. The seventh sensor, being variable, can be placed on any part of the foot, depending on what information is needed by the practitioner.

The electrodynagram records pressure as it is applied while the patient is walking. It demonstrates when a particular sensor is being activated, how long it is activated, and when the particular sensor reaches its maximum peak of pressure relative to the stance phase of gait. We now have the ability to accumulate reproducible and dependable data on the contact phase, midstance, and the propulsive phase of gait. A baseline of normal gait has been established to compare with the data the electrodynagram provides. Various sections of the electrodynagram graphics enable the practitioner to compare the patient's particular force curves and pressure curves with those of a normal patient. In addition, the practitioner can isolate and evaluate a particular part of the foot, depending on the patient's symptoms.

Recognizing that conservative management is essential in the control and treatment of a patient, I have used the electrodynagram in patients whose symptoms I have attempted to alleviate with orthotics. Monitoring and controlling the patient with the electrodynagram enables me to determine and evaluate whether a patient will respond to conservative management or whether adjustments need to be made to improve the patient's function.

Certain conditions of the foot require surgical intervention. Examples include but are not limited to hallux abducto valgus deformities, plantar keratomas, and hammer toes. I have used the electrodynagram for approximately 3 years to assist my evaluation and selection of surgical procedures to alleviate patient symptoms. In a patient with hallux abducto valgus, a number of symptoms are usually present—pain in the joint of the first metatarsal phalangeal area, pain associated with the enlargement on the medial side of the first metatarsal head, and pain in the lesser metatarsal area associated with excessive weight-bearing in those areas. Development of a plantar lesion under the second metatarsal head that may present only as a callus is often symptomatic. From a functional position and biomechanical interpretation, we realize that hallux abducto valgus is associated with hypermobility of the first ray. With the first ray functioning in a hypermobile position, it frequently develops an elevated relationship to the second metatarsal, often referred to as metatarsus primus elevatus. This condition contributes to excessive weight-bearing under the second metatarsal and an associated lesion formation in that area. Preoperatively, I can now evaluate whether the hypermobility of the first ray can be controlled. The sensor located under the first metatarsal enables me to see clearly how the first ray functions during gait and evaluate whether an orthotic can control the hypermobility or reverse the position of the first metatarsal over a period of time. The preoperative use of functional orthotics in a patient with a bunion deformity and hallux abducto valgus is essential to determine which signs and symptoms will respond to control postoperatively. Correction of the bunion deformity is symptomatic, and it is essential to recognize that the pathomechanics must be controlled postoperatively to ensure an excellent result. If the intermetatarsal angle between the first and second metatarsals increases, the selection process of a closing wedge osteotomy should include whether or not a plantarflexion osteotomy should also be performed. We now must select between performing a biplane osteotomy or a single transverse plane osteotomy, based on the fact that the hypermobility that exists leads to excessive pressure under the second metatarsal which we cannot control postoperatively. It is distressing to correct the hallux abducto valgus and bunion deformity and have the patient complain of constant or chronic metatarsal submet 2 and 3 pain or exacerbation of the lesion under the second metatarsal.

With the electrodynagram I can also evaluate the necessity of performing an osteotomy of the second metatarsal in addition to correcting the hallux abducto valgus and bunion deformity. By observing the excessive pressure and duration of pressure under the second metatarsal, one readily realizes that excessive postoperative pressure leads to other symptomatology. The submet 2 symptomatology is further aggravated by the formation of hammer toe of the second digit, which applies a retrograde force against the metatarsal head, increasing the pressure in this area. Because the female patient is going to return to wearing shoes with elevated heels, postoperative orthotic control is less than optimal. Based on all of our findings, we carefully select the surgical procedures necessary to correct the deformity as it exists today and prevent further symptomatology from developing in the future.

Another example of deformity of the first ray and great toe joint associated with submet 2 pain, is the patient with a hallux limitus or hallux rigidus. Many of these patients require Keller resection procedures and/or joint replacement procedures. The literature points out that excessive pressure following this type of surgical intervention leads to the development of *metatarsalgia.* Based on electrodynagraphic findings, we can now determine whether osteotomies of lesser metatarsals are necessary at the same time as first metatarsal phalangeal resection and/or replacement is performed.

Dealing with plantar lesions and plantar metatarsalgia are also important in the preoperative assessment of the patient electrodynagraphically. A number of patients present with plantar pain associated with keratomas, which eventually require surgical intervention. It is interesting to note that the literature vividly shows a high percentage of transfer lesions when isolated metatarsal osteotomies are performed for plantar keratomas. In evaluating the etiology of plantar keratomas, the most probable cause of plantar lesions is pathomechanical disturbances. In addition, evaluation of metatarsal length patterns and positions is essential. The electrodynagram lets me evaluate not only the metatarsal that is primarily associated with a plantar lesion, but also the adjacent metatarsals and their positions and functions. Often, by simply elevating an isolated metatarsal such as is seen in a submetatarsal 3 lesion, we develop transfer lesions. This also happens in isolated selection of submet 2 keratomas and individual osteotomies of the second metatarsal. We are now able to evaluate the forces under each metatarsal head separately and determine whether either one of the adjacent metatarsals bears excessive weight when one elevates a single metatarsal, thereby leading to the development of a transfer lesion. We have the ability to extend our level of expertise in the selection of procedures that not only alleviate the patient's symptoms now but also prevent the development of additional symptoms in the future.

The electrodynagram also allows me to follow and monitor patients who have had extensive reconstructive surgery, such as hypermobile flatfoot surgery and tendo Achilles lengthenings. I have been able to monitor the patient's gait following these types of surgical procedures to assist in evaluating further orthotic control versus return of a fairly normal gait that no longer necessitates orthotic monitoring in patients who have had sinus tarsi implants to stabilize hypermobile flatfoot or tendo Achilles lengthenings. The electrodynagram enables me to evaluate a return to a normal pattern of gait with a normal contact phase midstance and propulsive period. The time sequences can be easily evaluated, and areas of additional pressure can be monitored if necessary.

In conclusion, I have attempted to relay that the electrodynagram has become an essential clinical modality in the management and treatment of the podiatric patient. It has significantly altered my evaluation of patients as well as my selection of surgical procedures to manage and control their symptomatology. It is clear that clinical electrodynography plays a major role in patient evaluation.

SUGGESTED READING

D'Amico J. Retro-calcaneal bursitis insight with EDG. JAPMA 1986:76.

Danenberg H. Functional hallux limitus. JAPMA 1986; 76:648–652.

Journal of Current Podiatric Medicine. Special EDG issue, November 1987.