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Diagnostic Value of Elastography in the Diagnosis of Intermetatarsal Neuroma

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ABSTRACT

The objective of the present study was to characterize the ultrasound and elastographic properties of intermetatarsal neuroma (interdigital neuroma) and their contribution to diagnosis. Eighteen patients with metatarsalgia, who had presented to an orthopedic clinic from April 2013 to February 2015, were diagnosed with 25 intermetatarsal neuromas (11 unilateral [61.11%], 7 bilateral [38.89%]). These patients underwent evaluation with ultrasonography and simultaneous ultrasound strain elastography to assess the elastographic properties of the tissues in the intermetatarsal space. The intermetatarsal neuroma diagnosis was confirmed by histopathologic inspection. The lesion contours, localization, dimensions, and vascularization were evaluated before surgical excision. The elasticity and strain ratio values were compared between the neuroma and adjacent healthy intermetatarsal space. Of the 25 intermetatarsal neuromas, 1 (4%) was not detected by ultrasonography (incidence of detection of 96%). The mean neuroma width was 6.35 (range 3.7 to 13) mm in the coronal plane, and the mean elasticity and strain ratio values were 3.44 (range 1.1 to 5.1) and 9.47 (range 2.3 to 19.3), respectively. The elasticity and strain ratio values were significantly greater in the presence of an interdigital neuroma than in the adjacent healthy intermetatarsal spaces ($Z = -3.964$, $p = .0001$ and $Z = -3.927$, $p = .0001$, respectively). The diagnostic cutoff values were calculated as 2.52 for elasticity and 6.1 for the strain ratio. Four neuromas (16%) were not demarcated, and the elasticity and strain ratio values for these were lower than those for neuromas with demarcated contours but were greater than those for healthy intermetatarsal spaces ($p < .006$ and $p < .005$, respectively). Patients with clinically suspected intermetatarsal neuromas that do not show demarcation and with smaller lesions might benefit from the use of ultrasound elastography for diagnosis.

Intermetatarsal (Morton's) neuroma is a mechanically triggered entrapment neuropathy of interdigital nerves. Although its exact pathophysiology is still unknown (1,2), it is commonly seen in middle-age females and diagnosed mainly in the third, followed by the second, intermetatarsal space (1–6).

Intermetatarsal neuroma can be diagnosed by careful clinical examination and patient history review (3,7,8). Patients will frequently have a habit of wearing shoes with narrow toe boxes and high heels (1,2,9). Clinical symptoms can vary from pain, numbness, and tingling to burning sensations. In the published data, the tests used for the clinical diagnosis of intermetatarsal neuroma, such as web-space tenderness, foot squeeze, plantar percussion, and toe-tip sensation, have high sensitivities (5,8). The basic principle of those tests is to compress the lesion between the metatarsals, causing pain and sensitivity. Imaging studies have also played an important role (10,11). Imaging studies aid in confirming the diagnosis and detecting asymptomatic and multiple neuromas, as well as possible coexisting pathologies. Ultrasonography (US) is also important in neuroma management (e.g., ultrasound-guided injections). Multiple neuromas will be present in 65% of cases, according to a previous study (5).

Magnetic resonance imaging (MRI) and US are the imaging methods most commonly used in the diagnosis. US has been widely demonstrated as sensitive in detecting interdigital neuroma; however, sometimes, its diagnostic sensitivity has been low, especially for smaller and poorly demarcated lesions (3,12). Moreover, they can be

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misdiagnosed as other lesions with similar ultrasound properties. In the study by Saragas (13), the accuracy rate was 97.67%, with 1 lesion misdiagnosed as a ganglion. In such cases, additional methods to increase the sensitivity of US might be necessary.

Elastography is a relatively new technique developed in the 1990s that quantifies the stiffness of a lesion, which has otherwise been evaluated subjectively by physical examination (14). It has since been used to assess various types of tissues, including prostate, breast, liver, thyroid, and musculoskeletal structures (15). Many forms of US elastography are available (e.g., shear-wave and strain). One of the most commonly used forms is strain elastography, also known as compression elastography, real-time elastography, and sonoelastography (16,17). The main principle is that soft tissues will be recompressed or displaced more with application of pressure than will be hard tissues. Patient factors (e.g., size and density in breast tissue), lesion factors (e.g., size, localization, and depth), the properties and capabilities of the US machine, the tissue compression amount and technician-related factors can all have an effect on the elastographic images (18,19). This method involves a comparison of echoes from a particular tissue before and after displacement (14). The lesion elasticity and the elasticity of the surrounding normal tissues are compared (20). Depending on the machine used, different color codes are superimposed over the 2-dimensional images. Stiff areas are marked with blue and soft or elastic tissues with red or green (20). Sonoelastography can provide information on the mechanical properties of the tissues, such as the elasticity and strain ratio, in addition to color mapping of the tissue. Elasticity is the tendency to preserve the tissue's original shape and dimensions. The strain ratio is the degree of the size and shape change occurring with external compression (21). Thus, the strain ratio is a postacquisition assessment that compares lesion deformability with the reference values of the surrounding uninvolved tissue's response to external compression (22).

Elastography has become increasingly common in the evaluation of musculoskeletal systems to determine the presence of Achilles tendinopathy (16), rotator cuff tendinopathy (23), lateral epicondylitis (17), various traumatic and degenerative diseases of the muscles and tendons (24), inflammatory myositis (25), and patellar tendinopathy (26). However, we are aware of only 1 report of elastography for the diagnosis interdigital neuroma. Mossa et al (27) reported that elastography can be used in the diagnosis of intermetatarsal neuroma, but they did not discuss the method in detail. In the present study, we tried to characterize the US and elastographic properties of interdigital neuroma and their contribution to its diagnosis.

Patients and Methods

Study Group Formation

The university ethics board provided ethical approval for the present study. Consecutive patients who had presented to the orthopedics and traumatology departments from April 2013 to February 2015 with pain in the metatarsal region were eligible for inclusion in the present study. Patients with a history of surgery, trauma, or fractures, osteomyelitis seen on radiographs, lesions that might cause foot pain, such as calluses or fungal infections, and/or systemic diseases with joint involvement, such as rheumatoid arthritis, were excluded. Patients without any of the exclusion criteria were included in the present study. These patients underwent surgery after clinical examination and radiologic assessment, and the diagnosis was confirmed by the histopathologic results. Patients who met the inclusion criteria were asked for a detailed history of their disease, and the disease period (period between the onset of symptoms and arrival at the clinic with a complaint) was recorded for each patient. Initially, treatment was planned from the assessment of the patient's history, physical examination results, and radiographic findings. Patients with an unclear diagnosis were referred for advanced imaging studies (US and contrast MRI) to determine a definite diagnosis. The patients with a diagnosis of interdigital neuroma during US examination also underwent simultaneous elastographic evaluations by a radiologist experienced in the musculoskeletal system. The same radiologist also reviewed the MRI scans of the patients in a blinded fashion. Of those patients with a diagnosis of neuroma, those who agreed underwent surgery to allow for histopathologic confirmation.

Radiologic Evaluation

The initial radiologic evaluation included US and strain elastography, followed by MRI to confirm the diagnosis and eliminate other causes of metatarsalgia. All cases were evaluated by a radiologist with 10 years of experience in the musculoskeletal system. US and elastography used a LOGIQ E9 (GE Healthcare GmbH, Munich, Germany) with a linear 9-MHz probe. The examination was performed in the superficial musculoskeletal examination mode, with the appropriate magnification factors. The patients underwent both US and MRI on the same day. US examinations of the foot from the plantar side to the level of the metatarsal head, in the axial and sagittal planes, were performed with the patients in the prone position. In 3 cases with lesions <5 mm, manual pressure was applied only during US imaging (not during elastography) from the dorsal side into the intermetatarsal space to make the lesion more noticeable. Generally, ovoid, hypoechoic (relative to adjacent muscle tissue), noncystic masses with regular contours, oriented parallel to the long axis of the metatarsals at the level of the metatarsal head, were diagnosed as interdigital neuroma (28) (Fig. 1).

The lesion contours, localization, dimensions, and vascularization were evaluated on the US images. Transverse dimensions were measured on the coronal plane image with optimal view of the lesion. The depth could not be measured because of prominent acoustic shadowing caused by the metatarsals.

The standard US analysis was followed by strain elastography, in which the lesion was located on a gray-scale image. The stiffness of a corresponding region of interest (ROI) was assessed on a color map image. In elastography, hard tissues are pseudocolored blue, soft tissues red, and semi-hard tissues green-blue. The stiffness of relatively homogenous fatty tissue without significant plantar fat pad pathology on the same image was used as a reference point. Two ROIs of similar size to the reference ROI were placed on the involved intermetatarsal space, avoiding the metatarsal bones. The reference ROI placed on the fatty tissues could not be placed at the same level as the neuroma because of shadowing from the metatarsal bones. After confirming adequate pressure and that the color scale was homogenous, the elasticity and strain ratio values were measured twice in the lesion and a healthy intermetatarsal space for comparison. For each intermetatarsal space, the elasticity and strain ratio values were calculated by taking the mean of 2 measurements. The intermetatarsal bursal fluid, presence of bursitis, and nonspecific edema or inflammation of the soft tissue on the plantar side of the foot, which can accompany interdigital neuromas, were also evaluated.

Surgical Procedure

Of the 45 patients diagnosed with interdigital neuroma after a review of the patient's history and clinical examination, MRI, US, and elastographic evaluation results, 18 patients (25 interdigital neuromas; 40% of 45 patients) agreed to surgery and underwent dissection of the intermetatarsal space and excision of a plantar intermetatarsal neuroma. All the patients were treated with oral anti-inflammatory drugs, injection of local anesthetic and corticosteroids in the symptomatic intermetatarsal space, physical therapy, foot orthoses and insole modification, alteration of weight-bearing activities, and immobilization. Only those patients without a satisfactory response after $\geq$12 weeks of nonsurgical therapy subsequently underwent neuroma excision. Those patients with failure of nonoperative therapy underwent surgery from a dorsal approach, with the patients under general anesthesia and using limb exsanguination and a pneumatic tourniquet. The deep transverse intermetatarsal ligament was cut to free the entrapped, plantar common digital nerve. Operatively, a neuroma was identified by the presence of perineural and intraneural fibrosis and enlargement of the entrapped nerve trunk. The abnormal nerve was excised proximal to the proximal margin of the deep transverse intermetatarsal ligament, and the transected proximal nerve stump was allowed to retract proximally into the intact intrinsic

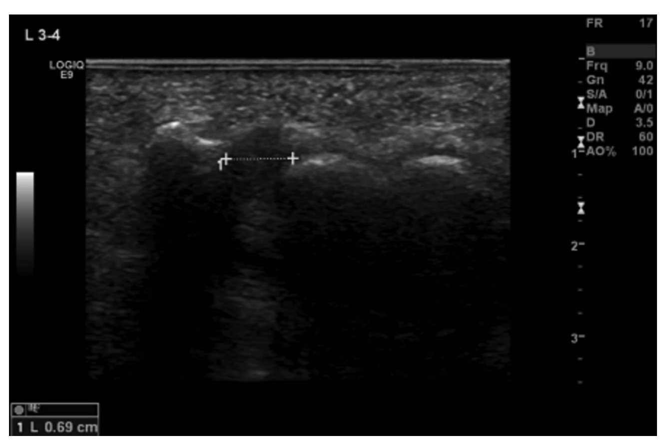

Fig. 1. Coronal ultrasound image showing a well-circumscribed, ovoid, and hypoechoic (relative to adjacent muscle) mass in the third intermetatarsal space of the left foot, consistent with Morton's neuroma.