The Use of High-Frequency Ultrasound as a Method of Assessing the Severity of a Plaque of Psoriasis

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Background and Design: Ultrasound imaging, while initially developed to visualize internal organs, is now being applied to image the skin. In this preliminary study, we used a high-frequency, 40-MHz ultrasound imaging system to provide high-resolution images in psoriasis and examined the relationship between clinical and ultrasound ratings in plaque-type psoriasis. The ultrasound image of a psoriatic plaque demonstrates a superficial echogenic band (band A), followed by a nonchogenic band (band B), and a deeper echogenic band (band C).

Results: In psoriatic plaques (N=145), the severity of the psoriasis as assessed according to the degree of scaling, erythema, and thickness (SET score) correlated best with the width of band B (P<.001, r=0.86) and less well with the width of bands A (P<.001, r=0.59) and C (P<.001, r=0.44). For the treated psoriatic plaques (n=64), for which paired readings were available before and after therapy, changes in the SET scores correlated best with the change in the width of band B (P<.001, r=0.96) and less well with the change in the width of bands A (P<.001, r=0.61) and C (P<.001, r=0.45). Ultrasound analyses and clinical evaluation were performed by independent raters.

Conclusions: The data suggest that high-frequency ultrasound imaging may prove to be a noninvasive technique that can be used as an adjunct to the clinical evaluation of the lesional severity of psoriatic plaques.

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ULTRASOUND IMAGING is a noninvasive, rapidly developing technology that was initially used to visualize internal organs. In dermatology, ultrasound systems have been used to image cutaneous neoplasms, eg, melanomas and basal cell carcinomas, skin diseases such as psoriasis and scleroderma, and allergic contact, irritant, and atopic dermatitis.1-12 In the beginning, amplitude scans, or A-scans, were developed that provided one-dimensional data. With A-mode scanning, the amplitude of the ultrasound wave is expressed as a function of its distance from the transducer. The subsequent use of B-scans enabled two-dimensional or cross-sectional images of psoriasis to be visualized.24-33 With B-mode scanning, a two-dimensional image is synthesized from a series of A-scans, each corresponding to a different position of the transducer. In this case, the amplitude of the ultrasound signal received from a given location is displayed in gray scale, from low (black) to high (white).

The earlier B-scan imaging systems used lower frequencies, between 2 and 20 MHz, to image psoriasis, and the resolution was limited to approximately 200 μm at best.24-34,35 With advances in high-frequency ultrasound technology, investigators have attempted to perform objective measurements on ultrasound images of psoriatic plaques. They have then tried to relate the results to clinical and histologic findings.30,31,33 Recently, ultrasound imaging systems operating at 40 to 50 MHz have improved visualization of cutaneous lesions, and in this study, we investigated whether imaging in this frequency range can be used to provide data regarding the disease severity of a psoriatic plaque.

Comparison between the ultrasound and the corresponding histologic section, both at the same magnification, showed that the initial echogenic band...
PATIENTS AND METHODS

PATIENTS

Thirty-one patients with stable plaque-type psoriasis (22 men and nine women; mean ± SEM disease duration, 14 ± 2.0 years; mean ± SEM age, 50 ± 3.5 years) were enrolled in this outpatient study. Psoriatic plaques were imaged using 40-MHz ultrasound, and a clinical evaluation of the severity of each plaque was performed. The patients had no concomitant serious illness. Patients who were lactating or pregnant were excluded from the study. All patients gave informed consent after a full discussion of the details and procedures involved in the study. The protocol and consent form were approved by the institutional review board of the Sunnybrook Health Science Center, University of Toronto, Toronto, Ontario.

CLINICAL EVALUATION

The clinical severity of a psoriatic plaque was assessed according to the degree of scaling (desquamation), erythema, and thickness (infiltration) (SET). In this study, the severity of each individual psoriatic plaque was graded according to the degree of SET, each component of which was graded on a 7-point scale (0 indicates that the parameter was absent or clear; 0.5, very mild in severity; 1, mild; 1.5, between mild and moderate; 2, moderate; 2.5, between moderate and severe; and 3, severe). The individual scores for each of the three SET components were added to obtain the SET score (each component having a score ranging from 0 to 3). The SET score ranged from a minimum of 0 (clinically normal or uninvolved skin) to a maximum of 9 (psoriasis with severe scaling, severe erythema, and severe thickness).

To determine interrater agreement when different investigators assessed the same plaque of psoriasis, one physician (A.K.G.) and two nurses evaluated 50 different plaques of psoriasis. For each plaque, the three evaluators assigned a SET score independently, and the agreement between the three scores was then calculated.

ULTRASOUND IMAGING

In this study, a real-time B-scan ultrasound backscatter microscope operating at 40 MHz was used.31 It provided axial (depth) resolution of 30 μm and lateral (horizontal) resolution of 94 μm. The depth of penetration was 3 to 4 mm. The scanner used a focused transducer made of a copolymer of polyvinylidene difluoride and trifluoroethylene. The ultrasound signal received from the cutaneous tissues was logarithmically amplified, demodulated, and passed through a custom scan converter that output the video images. Each image was produced by the transducer scanning over an 8-mm linear path at a frame rate of five images per second.

Coupling to the skin was provided by a 30-mm-diameter acrylic cup filled with distilled water that was pressed gently against the skin over the area to be imaged. The individual who imaged a psoriatic plaque and an adjacent area of normal-appearing skin 6 cm away was blinded to the results of the clinical evaluation. When imaging, the transducer was positioned perpendicular to the skin to avoid obliquity and to prevent errors during determination of skin thickness. Echogenic bands generally comprised three layers, which we have labeled A, B, and C, as illustrated schematically in Figure 1. When indicated, the width of a band was measured at several places and an average value was obtained. Electronic calipers enabled the width of the bands to be measured accurately to the nearest 0.01 mm.

HISTOLOGIC EVALUATION

Punch biopsies (4 mm) were performed at the site of ultrasound imaging in 12 patients. The specimens were fixed in buffered formalin, and the sections were stained with hematoxylin-eosin. The ultrasound image was then compared with the corresponding histologic section.

STATISTICAL ANALYSIS

Nonparametric Spearman's rank correlation was used to examine the relationship between the SET scores and the width of bands A, B, and C (Figure 1). Student's paired t test was used to test the hypothesis that the mean difference between the width of band C in a psoriatic plaque (Cp) and in normal-appearing skin (Cn) is equal to zero, i.e., mean (Cp−Cn)=0.
High-frequency ultrasound

Figure 1. Line diagram depicting location of bands A, B, and C in a high-frequency ultrasound image of a plaque of psoriasis.

Figure 2. Comparison between histologic section and high-frequency ultrasound image of a plaque of psoriasis showing bands A, B, and C (both views are at the same magnification). Bar indicates 200 μm.

site in a particular plaque was imaged by independent investigators. Once the equipment had been set up, it took approximately 5 to 10 minutes to image a psoriatic plaque.

The dermatologic evaluations were performed by the same investigator who graded the psoriatic plaques according to severity of SET (each component of SET was rated from 0 to 3 on a 7-point scale). For each plaque, the SET scores were added, resulting in a score ranging from 0 to 9.

To assess the variability in SET scores when different trained observers evaluate a given psoriatic plaque, 50 plaques of psoriasis were each rated independently by three evaluators, and the interrerator correlation coefficient was found to be 0.8.

Ultrasound images of psoriatic plaques obtained before therapy were compared with the images seen after therapy and with the nearby clinically uninvolved skin. Two examples of psoriatic plaques that showed different responses to treatment will be discussed in detail. In the first patient, the SET score of the psoriatic plaque before therapy was 7. Four weeks later, there was moderate to marked improvement, and the SET score had decreased to 2, with the plaque still demonstrating some scaling, erythema, and thickness. After treatment, both band B and band A had decreased in thickness, although band B was still visible (Figure 3, top and center). In clinically uninvolved skin, band B was not seen (Figure 3, bottom). In another patient, there was marked improvement of a psoriatic plaque, with a change in the SET score from 7.5 before therapy to 0.5 after 4 weeks of treatment. In this patient, the ultrasound image showed that the band B seen before therapy was not visible when the psoriasis had practically cleared.

In some instances, the lower edge of band C was diffuse, making it difficult to precisely determine the lower border of this band, particularly in psoriatic plaques imaged before the initiation of treatment. In such cases, the lower edge of band C corresponded to the point at which there was a change from an echogenic to a less echogenic pattern. In untreated psoriatic plaques, the echogenic pattern of band C and the layer beneath this might be explained by the attenuation of signal that occurs as the high-frequency ultrasound beam traverses the thickened stratum corneum and epidermis. In contrast, both in treated psoriatic plaques, which have a thinner stra-
In this study, we used high-frequency, B-mode, 40-MHz ultrasound scanning to image plaques of psoriasis. In early studies, 15-MHz ultrasound A-scans or amplitude-mode scans demonstrated that the thickness of psoriatic plaques is increased compared with normal skin. When plaques of psoriasis are viewed using ultrasound imaging, bands of varying echogenicity have been observed. At 40 MHz, ultrasound images of psoriasis exhibit a three-layer structure similar to that reported by el-Gammal et al. We found that (1) band A corresponds to the scaly parakeratotic cell layers and the suprapapillary epidermis; (2) band B represents the edematous and congested papillary dermis in the elongated epidermal rete ridges; and (3) band C is associated with the underlying reticular dermis (Figures 1 and 2).

It has been suggested that the data from ultrasound images may reflect the severity of the psoriasis. Sono-grams obtained at the lower ultrasound frequencies may not be of high enough quality to accurately assess the thickness of the echogenic bands. It is only recently that the development of higher-frequency systems has produced pictures with improved resolution, thereby enabling us to image skin in greater detail. The 40-MHz high-frequency ultrasound machine, with its higher resolution, has enabled us to determine the size of the bands in a psoriatic plaque more precisely than we were previously able to do with the lower-frequency systems. Our data indicate that the width of band B correlates best with the severity of psoriasis of a plaque as measured by the SET score. Also, the change in disease activity of a psoriatic plaque as measured by ΔSET correlates best with the change in the thickness of the nonechogenic band B (Figure 4). To our knowledge, this is the first study in which the widths of the various bands visible in a plaque of psoriasis were measured by means of high-frequency 40-MHz ultrasound imaging and in which these findings were correlated with the clinical severity of that psoriatic plaque, as rated by the degree of SET. These non-invasive data, which are not subject to clinical bias or experience, could provide a useful adjunct to clinical evaluation of the severity of the psoriatic activity and the efficacy of therapy for a given plaque.

The observation that band B corresponds to the major portion of the acanthotic epidermis and the superficial dermis is in agreement with the findings of el-Gammal et al. The width of band B is not a direct measure of thickness of a plaque of psoriasis; however, it reflects the thickness of the papillary dermis, which varies with the degree of vascularity, edema, and inflammation. The thickness of band B correlates with the clinical severity of a psoriatic plaque as assessed by the degree of SET. The normalisation of the epidermis and dermis that occurs with clinical improvement of a plaque of psoriasis may be responsible for the corresponding decrease in the width of the nonechogenic band B (Figure 3).

The use of high-frequency, real-time ultrasound scanning has enabled the generation of high-resolution images of psoriatic plaques. Ultrasound imaging has the advantage of being a noninvasive, relatively inexpensive technology that is quick and quite easy to perform. We
obtained reproducible images when different investigators used this method. Our findings suggest that further research is needed to evaluate the usefulness of high-frequency ultrasound imaging in rating disease activity in psoriasis. The ultrasound machine used in this study is the initial prototype, and it is hoped that in the future the system will be more automated, enabling several psoriatic plaques to be imaged fairly rapidly.

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REFERENCES