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Psoriasis Vulgaris in 50 MHz B-scan Ultrasound – Characteristic Features of Stratum Corneum, Epidermis and Dermis*

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One hundred and forty fully developed, non-treated plaques of psoriasis vulgaris from the arms and legs of 22 patients were examined using 50 MHz B-scan ultrasound and compared with the images from adjacent, clinically normal skin. To visualize the dermis, high pre-amplification (digitization range 200 mV) was used, determined according to A-scan images. For evaluation of epidermal phenomena, low pre-amplification (digitization range 380 mV) was chosen in order to avoid overmodulation of the skin entry echo. In 10 patients, sonographic images were compared with histological sections from the exact same planes at the same magnification. At low pre-amplification, the skin entry echo is displayed as a markedly widened, frequently interrupted band composed of spots varying in thickness, height and echo density. Within these spots, several lamellae can be observed, represented as fine, echo-rich lines stacked one upon another. These phenomena correspond histologically to focal hyperparakeratosis, scaling and cracking of the stratum corneum. Due to the low amplification of the echo-signal the dermis is not visible. High pre-amplification allows evaluation of dermal changes. Below the entry echo there is an echopoor band (EPB) corresponding to the sum of acanthosis and infiltrate in the upper dermis. Underneath the EPB the dermis is represented as a zone with scattered internal echoes which are less intense than in normal skin. Dorsal shadows are typically present. They are artifacts emanating from epidermal regions with marked hyperkeratosis and disappear when the sonographic characteristics of the epidermis are changed, for instance by application of ointments prior to sonographic examination. Up to a thickness of the EPB of 800 μm, the total dermal thickness remains constant, not differing from the one in normal skin. With further increase in EPB-thickness, the total dermal thickness increases proportionally. Evaluation of psoriatic plaques with 50 MHz ultrasound at different pre-amplification levels of the echo signal allows to exactly visualize stratum corneum changes, to determine the thickness of acanthosis plus infiltrate and to quantify the thickness and echo-density of the dermis. ***Key words: 50 MHz-sonography; psoriasis vulgaris; follow-up; stratum corneum.***

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Ultrasound has been proposed as a non-invasive method to quantify the activity of psoriatic plaques and to study the effects of different treatment regimens (8). So far, B-scan sonography up to 25 MHz was used (1, 5, 8); evaluations focused on the so-called echopoor band which histologically correlates to the sum of acanthosis and infiltrate in the upper dermis. By raising the centre frequency and bandwidth of the ultrasound transducer, higher resolution can be obtained. It is thus possible to assess characteristics of the stratum corneum and the epidermis as well. We studied the epidermal and dermal sonographic features and their histological correlate in chronic psoriasis plaques using 50 MHz ultrasound.

PATIENTS AND METHODS

22 patients (13 men, 9 women, age range 25–55 years) with a more than 10-year history of chronic psoriasis vulgaris were studied. In each patient, several non-treated psoriatic plaques on the arms and legs were examined. All lesions were fully developed, showing the following criteria of psoriasis: silvery scales, marked infiltration and erythema. A total of 140 sonographic images were obtained. Moreover, in each patient, healthy skin adjacent to each plaque was assessed sonographically.

To correlate the ultrasound image with histology, an excision was performed in 10 patients as follows: a 10 mm long line was drawn on the lesion with a waterproof pen to define the plane of the B-scan. After sonography, the area was anesthetized. In a first step, the skin was cut

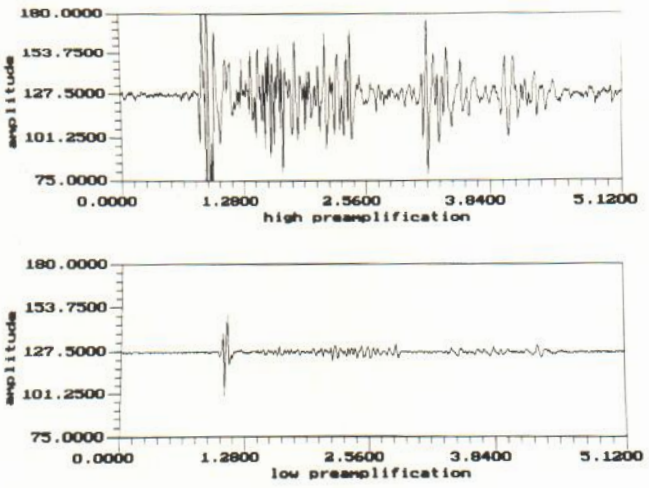

Fig. 1. A-scan of normal skin at high (upper curve) and low (lower curve) pre-amplification. Upper curve: First peak = entry echo, following peaks = dermis, following oscillations with low amplitude = subcutis, last peaks with higher amplitude = trabeculae and muscle fascia.

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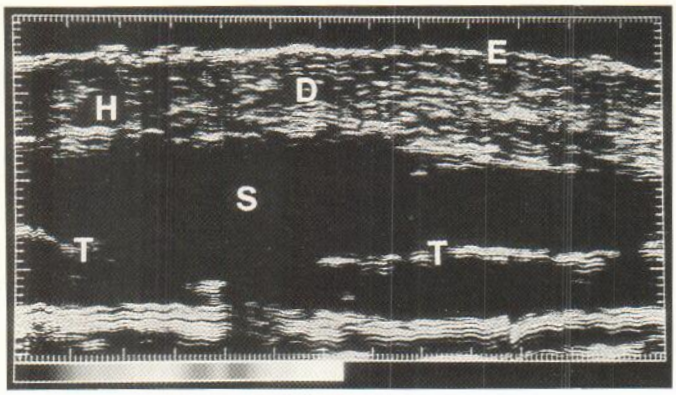

Fig. 2. B-scan of normal skin at high pre-amplification. The distance between the smaller scaling-marks at the border of the ultrasound images is 0.1 mm, between the larger ones, 1 mm. E = skin entry echo, D = dermis, S = subcutis, H = hair follicle, T = connective tissue trabeculae.

along this line down to the subcutis. Then a spindle-shaped excision was performed with this cut in the centre. The two halves of the tissue spindle were separated and their central cutting planes were placed on cardboard. This prevents warping of the tissue during fixation in 10% formalin. Biopsies were processed for light microscopy and stained with H&E.

Sonography was performed using a 50 MHz experimental system. We used a point-focused ultrasound transducer on polymer base (PVDF, polyvinylendifluoride) with a centre frequency of 40 MHz and a bandwidth of 30 MHz. Within the focal area, the transducer has an axial resolution of 37.5 μm and a lateral resolution of 125 μm (6). The inverted plexiglass pyramid socket in the lower part of the applicator has a slit, which is pressed lightly on the skin surface. Water is used as coupling medium between the transducer and the skin.

A-scan oscillations were registered using different echo-signal pre-amplifications prior to digitization of the high-frequency signal (Fig. 1).

High pre-amplification (digitization range 200 mV) was chosen in order to visualize the dermis (Fig. 1, upper curve): after a short time lapse (coupling water path) a large echo signal oscillation is seen (skin entry echo). When its amplitude exceeds a certain height, its peaks are cut off during analog-to-digital conversion. Cutting off of the signal is accompanied by an audible sound. The entry echo is followed by multiple irregular oscillations at lower amplitude (dermis). There is an abrupt transition of these oscillations to very low amplitudes, originating from the fatty tissue of the subcutis. Connective tissue trabeculae and fasciae are represented as echoes with high amplitude.

Low pre-amplification (digitization range 380 mV) was used to evaluate epidermal ultrasound characteristics: the oscillation curve has a markedly lower amplitude and the skin entry echo is located within the digitization range; hardly any signals follow the entry echo.

B-scans were registered with these pre-amplifications; the transducer was moved laterally in the applicator on the skin. Details of the technical setup have been described elsewhere (6). The original A-scans and their demodulated counterparts provide information about the distortion due to cutting off of the signal within the quantitization range of the analog-to-digital converter.

In 34 lesions, the thickness of the echopoor band and the thickness between the entry echo and the border dermis/subcutis were measured using an image analysis program (AnalySIS, SIS, Münster, Germany). Clinically normal skin adjacent to the psoriatic plaque served as a control; there the thickness between the entry echo and the dermis/subcutis interface was determined as well.

RESULTS

Healthy skin

High pre-amplification (Fig. 2):

In the B-scan image there is a rather linear, regular skin entry

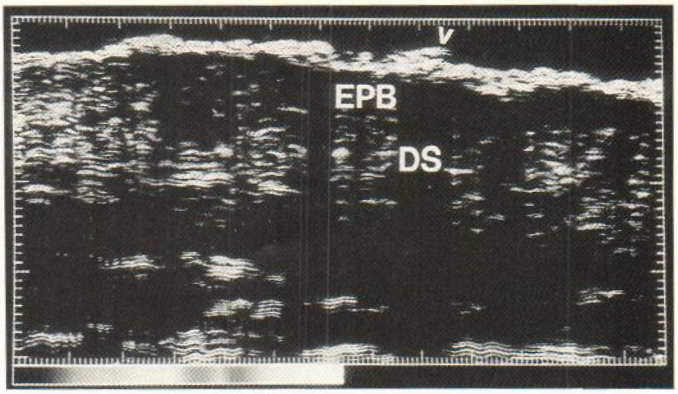

Fig. 3. B-scan of a psoriatic plaque at high pre-amplification. EPB = echopoor band, DS = dorsal shadow. Arrow head = scale.

echo with a fine echo-lucent line beneath. Below this line, a wide zone with multiple, scattered echo-reflexes is seen. Often from this zone, several obliquely oriented, partly interrupted, linear, echo-rich stripes project into a wide, echo-lucent region.

Low pre-amplification:

The skin entry echo is represented as a white, homogeneous line, which is less wide than at high pre-amplification; no reflexes are visible beneath the entry echo.

Psoriatic plaques

All lesions show similar sonographic characteristics.

High pre-amplification (Fig. 3):

In the B-scan images, we see an irregularly thickened skin entry echo.

Beneath, an echo-poor band (EPB) of variable thickness separates the skin entry echo from a zone with numerous scattered echoes. The reflexes within this zone are less intense than in healthy skin. In regions with marked irregularity and thickening

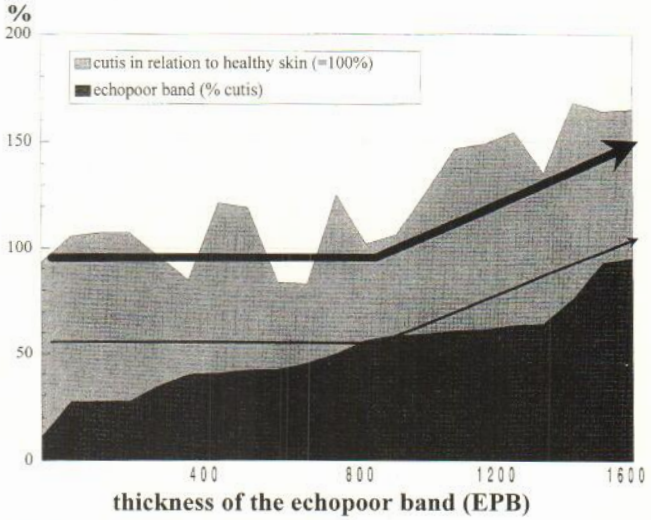

Fig. 4. Thickness of the echopoor band and the cutis (= distance between entry-echo and dermis/subcutis interface). Thickness values (y-axis) are expressed as percentage differences to the values obtained from normal skin adjacent to the plaques (= 100%).

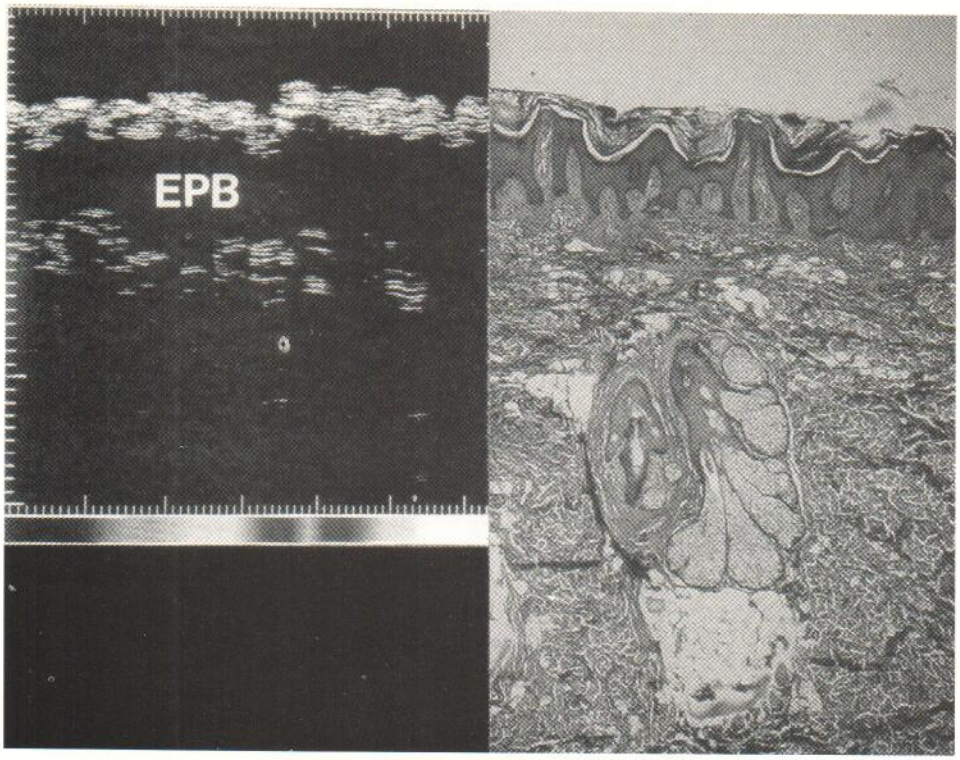

Fig. 5.
(*a*): B-scan of a psoriatic plaque at low pre-amplification. EPB = echopoor band.
(*b*): Histological section at same magnification.

of the entry echo, dorsal shadows (echo-free stripes oriented in the direction of the ultrasound beam) are observed.

Comparison with the histological sections at exactly the same magnification demonstrates that the skin entry echo corresponds to the irregularly thickened stratum corneum. The EPB corresponds to the sum of the acanthotic epidermis and the inflammatory infiltrate in the upper dermis. The dermis underneath the infiltrate is represented as the zone of scattered reflexes in the sonographic image.

The subcutaneous fat is visualized as an echo-lucent region.

Fig. 4 shows the results of the thickness measurements. Thickness values (*y*-axis) are expressed as percent differences vs. the values obtained from normal skin adjacent to the plaques (100%). With a thickness-increase of the EPB (*x*-axis) up to 800 μm, the total cutis-thickness (distance between entry-echo and dermis/subcutis interface) remains constant and does not differ from normal skin. With a further increase in EPB-width (from 800 to 1300 μm) there is a corresponding linear increase in the total cutis thickness as well. In other words, the EPB first expands at the cost of the cutis, until reaching 50% of the total cutis thickness. From that point on, both EPB and cutis increase proportionately in thickness.

Low pre-amplification (Fig. 5):
The skin entry echo differs significantly from the one in normal skin: it is a markedly widened, frequently interrupted band composed of spots varying in thickness, height and echo density. Within these spots several lamellae (up to 5) can be observed. These are represented as fine, echo-rich lines stacked one upon another. Generally, the uppermost of these lamellae shows the most intense reflex (see Fig. 5*a*).

Comparison with the histology (Fig. 5*b*) shows the pathological changes in the psoriatic plaques responsible for these ultrasound characteristics: there is focal hyperparakeratosis with irregular thickening of the stratum corneum, scaling and cracking of the stratum corneum and the upper epidermis.

DISCUSSION

Combining ultrasound at high resolution (50 MHz) with low pre-amplification of the echo-signal, we were able to visualize the specific characteristics of the stratum corneum in psoriasis vulgaris. The entry echo is widened and fragmented and shows a lamellar structure with spots of varying echo-density. The upper border of the entry echo is irregular and shows level jumps.

Visualization of these changes is possible only when the pre-amplification of the echo-signal is reduced so that the oscillation peak in the A-scan curve is located within the digitization range of the transient recorder. This avoids cutting off the oscillation peaks and subsequent distortion during demodulation. At this low pre-amplification however, the dermis is no longer visible. During normal sonographic skin examination, the pre-amplification is usually chosen to particularly judge the dermis (1, 5, 7). This leads to an overmodulation of the entry echo; the B-scan image shows a wide, echo-rich band (4) from which information about structural details cannot be obtained. Reduction of the overmodulated amplification parallels a narrowing of the entry echo. When the entry echo no longer narrows and only fades, the optimal preamplification for its evaluation is reached.

To observe the sonographic characteristics of the horny layer in normal skin, we previously examined the palms and soles at low pre-amplification (3, 4). The orthohyperkeratotic stratum corneum is represented as an echopoor structure, bordered by echo-rich lines at the water/stratum corneum interface (entry echo) and stratum corneum/stratum Malpighii interface. In

healthy skin of other body regions the horny layer is too thin to be resolved into sonographic images at 50 MHz, as confirmed by our study. As opposed to normal skin the hyperparakeratotic stratum corneum of psoriasis vulgaris is echorich, no matter how low the pre-amplification chosen. We believe that this is due to air trapped in the scales of the upper stratum corneum and to the higher reflectivity of the parakeratotic and thus inhomogeneous horny material. The irregular, scaly surface of the lesions leads to jumps of the entry echo. Hyperparakeratosis is represented as widening, fragmentation and lamellar structure of the entry echo and spots of varying echo-density. In fully developed psoriatic plaques, the width of the entry echo therefore represents the thickness of the stratum corneum.

Underneath the entry echo, psoriatic plaques exhibit an echopoor band. This corresponds histologically to the acanthosis and infiltrate in the upper dermis. This band is by no means specific for psoriasis, but can be demonstrated in all skin diseases which are accompanied by acanthosis and/or infiltrate in the upper dermis (3–5, 7). In psoriasis, it corresponds to the clinically palpable papule as assessed in the PASI index. Sonometry of the thickness of this band has been used to quantify the activity of psoriatic lesions (5, 7).

In chronic psoriatic plaques the dermis below the entry echo shows decreased echo-density compared with normal skin. Numerous echo shadows are visible. This is due to intense signal absorption and reflection in the hyperkeratotic stratum corneum, as discussed above. Shadows and decreased echogenicity are therefore artifacts emanating from the horny layer. Topical application of ointments for 30 minutes causes swelling and moisturization of the stratum corneum and removes air inclusion in the scales. This significantly reduces the shadows (3) and the decreased echogenicity of the dermis is no longer obvious.

Our measurements showed that the total cutis thickness remains constant as long as the thickness of the echopoor band does not exceed 50% of the total cutis thickness, respectively 800 μm. The echopoor band thus expands at the cost of the cutis. Bacharach-Buhles et al. (2) analysed the architecture of the elongated rete pegs and their spatial relation to the dermal vascular plexuses in psoriasis by means of image analysis of serial histological sections. They could demonstrate that the vascular architecture remains unchanged while the epidermal rete pegs grow down and include the vessels of the first horizontal dermal vascular plexus into the dermal papillae. This is entirely consistent with our finding that the total cutis thickness remains constant.

Further acanthosis, however, leads to an exophytic growth and thus to a thickening of the total cutis thickness, as demonstrated histologically (2). Sonographically, this finding is supported by the fact that further widening of the echopoor band results in a linearly proportional increase in cutis thickness.

Using 50 MHz sonography, stratum corneum, epidermal and dermal characteristics of psoriatic plaques can be quantified in vivo. This method is particularly valuable for follow-up studies evaluating different therapeutic regimens.

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