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Beyond Clinical Scoring: Can High-Frequency Ultrasound and Power Doppler Detect Subclinical Activity in Psoriasis

Maha Mohammed Mahmoud[1]
[1]*Department of Diagnostic Radiology, College of Medicine, Tikrit University, Tikrit, Salah al-Din Governorate, Iraq*
E-mail: maha.m.mahmoud@tu.edu.iq

Suroor Rafea Alkumait[2]
[2]*Department of Dermatology, College of Medicine, Tikrit University, Tikrit, Salah al-Din Governorate, Iraq*

Abstract:
Psoriasis is a chronic inflammatory skin disease and that clinical severity scores may not be a good indicator of the inflammatory activity. High-frequency ultrasound (HFUS) and Power Doppler (PD) offer non-invasive imaging of structural and vascular variations of psoriatic plaques. The purpose of this study was to assess whether HFUS and PD can detect subclinical inflammatory activity that is not detected by conventional clinical assessment. The prospective observational cross-sectional study took place from March 2025-May 2026 in private dermatology and radiology/ultrasound clinics. The patients were 50 adults' patients with psoriasis vulgaris from 18-60 years old, both male and female were enrolled. All participants were assessed dermatologically according to the Psoriasis Area and Severity Index (PASI) and then by HFUS and PD of a representative psoriatic plaque and adjacent clinically normal skin. The epidermal thickness, dermal thickness, subepidermal low-echogenic band (SLEB) thickness, total skin thickness, and Power Doppler vascularity were measured. Psoriatic plaques demonstrated significantly greater epidermal thickness (0.38 ± 0.09 vs. 0.21 ± 0.05 mm), dermal thickness (1.72 ± 0.31 vs. 1.24 ± 0.22 mm), SLEB thickness (0.42 ± 0.15 vs. 0.09 ± 0.05 mm), and total skin thickness (2.10 ± 0.34 vs. 1.45 ± 0.24 mm) compared with clinically normal skin (all $P < 0.001$). Vascularity was detected in 86.0% of plaques and moderate to marked vascularity was found in 62.0%. The 72.2% of patients who had mild psoriasis (PASI <5) had at least one significant ultrasound abnormality. PASI was significantly correlated with SLEB thickness (r 0.68; $P < 0.001$) and Power Doppler vascularity (r 0.72; $P < 0.001$). The ROC analysis showed that all three parameters (Power Doppler vascularity, SLEB thickness, or their combination) performed well, with the combination of Power Doppler vascularity and SLEB thickness showing an AUC of 0.96. HFUS and Power Doppler are able to demonstrate structural and vascular inflammatory abnormalities which may be underdiagnosed with traditional clinical score, especially in patients with mild psoriasis. SLEB and Power Doppler vascularity exhibited excellent diagnostic performance, and may be useful as a non-invasive tool in the detection of sub clinical activity. The combination of ultrasound biomarkers with clinical evaluation may help to better characterize the disease objectively and help to monitor inflammatory activity in the disease more accurately.

Keywords: *Psoriasis; High-frequency ultrasound; Power Doppler; Subepidermal low-echogenic band; SLEB; PASI; Subclinical inflammation; Skin ultrasonography.*

Introduction

Psoriasis is a chronic immune-mediated inflammatory disorder in which there is an abnormal proliferation of keratinocytes, changes to the differentiation of keratinocytes, infiltrations of inflammatory cells, and remodeling of the vascular system of the skin. Psoriasis, although most obviously physical, is now known to be a systemic inflammatory condition with significant physical and psychosocial implications. Chronic and fluctuating activity of the disease makes it especially important

to assess the inflammatory activity accurately, as the apparent severity of a lesion doesn't always match the inflammatory activity of the underlying disease [1].

Routine assessment or clinical research of psoriasis has been traditionally based on clinical tools, including the Psoriasis Area and Severity Index (PASI), body surface area, and Physician Global Assessment. PASI is the most frequently used clinical severity scale, but a number of studies have pointed to some limitations, such as poor interobserver agreement, poor responsiveness in mild disease and problems relating the numerical score to the biological activity of individual plaques [2,3]. In addition, clinical exam is limited to superficial features like erythema, scaling and induration and does not give any information about changes that happen at the microscopic level in the epidermis or dermis. These studies have therefore highlighted the importance of more objective, reproducible and standardized assessment methods [4].

Clinical scoring is a challenge in patients with low disease burden. It is possible that the clinical severity of psoriasis does not reflect the disease burden or underlying activity of the disease in patients with relatively low PASI scores [5]. This mismatch suggests that subtle plaques may still have vascular and/or structural inflammatory changes that cannot be safely identified by visual inspection. Thus, there is a need for non-invasive imaging techniques that could provide objective tissue level information that complements existing clinical scoring.

High-frequency ultrasonography (HFUS) is a promising non-invasive imaging technique for superficial skin structures evaluation. Ultrasound, with the help of high-frequency transducers, can bring more details of the epidermis, dermis, and superficial tissues of the subcutaneous tissue into view and can be used to quantitatively measure the thickness of the skin. Preliminary ultrasound studies showed that psoriatic plaques were much thicker than apparently normal skin in their epidermis and in the total thickness of the skin and that the measurements were reasonably correlated with the histology findings [6]. Importantly, ultrasound can be used to generate information that cannot be gained from a routine inspection and a clear indication of the differences in the structure.

Subepidermal low-echogenic band (SLEB), one of the typical sonographic features of psoriasis, is found just below the epidermis. A hypoechoic zone has been described which is correlated with inflammatory and edematous changes in the superficial dermis and can be seen with the use of high-frequency probes [7]. In a pilot study, lesional and non-lesional skin was assessed, with the skin thickness and clearly discernible hypoechoic band being significantly greater in psoriatic plaques than in non-lesional skin, suggesting potential use for HFUS as a quantitative measure of inflammation[8]. These results are especially relevant as structural changes could be an objective measure of inflammation, even when clinical changes are not that prominent.

Psoriasis is accompanied by conspicuous changes in the superficial microcirculation of the skin besides structural changes. Histopathological examination has shown that psoriatic plaques have dilated and tortuous capillaries in the dermal papillae, leading to the characteristic "red" appearance of the lesions [9]. Therefore, techniques that can measure blood flow in the skin might yield complementary data related to inflammatory activity. Doppler based imaging has great appeal as it allows one to measure the vascular signal without the need for invasive procedures. In the past, objective blood-flow imaging studies showed that the blood-flow flux in psoriatic plaques was significantly higher than in normal skin and that it could be higher than the clinically visible plaque border [10].

Power Doppler ultrasonography has then broadened the capabilities of ultrasound to evaluate superficial vascularity. With the combination of high frequency probes and sensitive Power Doppler technology, low velocity blood flow can be detected in the dermis and a semi-quantitative vascular

activity assessment can be made [11]. This is clinically relevant as vascular changes are a fundamental part of psoriatic inflammation, and may even persist even after the skin changes are no longer as noticeable. Therefore, when using B-mode assessment with Power Doppler vascular assessment, it may be used to give a more complete picture of how inflamed a psoriatic plaque is.

Longitudinal studies of the evaluation of psoriasis further support the potential value of ultrasound. High-frequency ultrasonography has been demonstrated to be useful for measuring epidermal and dermal thickness changes during therapy, and may offer objective data regarding therapeutic responses [12]. Other studies that have integrated ultrasound and vascular imaging have shown that it is not always the case that normalization of the structural parameter is concurrent with the vascular parameter, indicating that different imaging biomarkers might be a reflection of different aspects of the inflammatory process [13]. Therefore, the diagnosis made by the one clinical parameter may miss underlying abnormalities that can be detected by imaging.

Further research has concentrated on the use of non-invasive imaging in psoriasis in more recent studies. The study of whole skin in patients with psoriasis yielded similar results, finding a difference in the thickness of lesional versus non-lesional skin, and showing that HFUS is an objective technique for assessing inflammation [8]. Moreover, modern methods that involve dermoscopy and high frequency ultrasound are focused on the fact that, although a clinical improvement may be achieved, vascular and structural changes can still be present, thus indicating that visible clinical clearance does not necessarily mean complete resolution of the tissue level disease activity [14]. Moreover, modern methods that involve dermoscopy and high frequency ultrasound are focused on the fact that, although a clinical improvement may be achieved, vascular and structural changes can still be present, thus indicating that visible clinical clearance does not necessarily mean complete resolution of the tissue level disease activity [15].

This study aimed to determine the value of high frequency ultrasound and Power Doppler in patients with psoriasis vulgaris for assessment of both structural and vascular markers of subclinical inflammatory activity. The purpose of the study was also to explore whether these sonographic parameters were correlated with the traditional clinical severity determined by Psoriasis Area and Severity Index (PASI).

Materials and Methods

Study Design and Setting

To assess the role of high-frequency ultrasound (HFUS) and Power Doppler (PD) ultrasonography in the detection of subclinical inflammatory activity in psoriasis beyond conventional clinical assessment, a prospective observational cross-sectional study was carried out. The study was carried out between March 2025 and May 2026 in private dermatology and radiology/ultrasound clinics. All patients were clinically examined by a dermatologist and the ultrasound examination was carried out by a physician specialized in diagnostic radiology and ultrasonography. The study was based on comparing the conventional clinical severity of the psoriatic plaques with the objective sonographic changes.

Study Population

The study was conducted on 50 adult patients (aged between 18-60 years) with clinically diagnosed psoriasis vulgaris (both male and female). The study patients were selected in consecutive order from the patients attending the participating private clinics during the study period. The age range selected was designed to provide a meaningful sample of adult patients with varying duration and severity of psoriasis, and at the same time to have a fairly uniform adult patient population. One

representative psoriatic plaque suitable for ultrasound examination was selected for each patient as the target lesion. Adjoining clinically normal skin, if technically and anatomically feasible, was used as an internal reference.

Clinical Assessment

All patients had a uniform dermological evaluation prior to ultrasound evaluation. Detailed demographic and clinical data were collected such as age, sex, treatment and clinical history, presence or absence of scalp, nail and joint involvement, and duration of psoriasis. Psoriasis Area and Severity Index (PASI) was used to measure the severity of psoriasis. The plaque chosen was also examined clinically for its degree of erythema, scaling and infiltration or thickness. The clinical findings were then compared with the structural and vascular abnormalities found by the use of the HFUS and Power Doppler.

High-Frequency Ultrasound Examination

High-frequency ultrasound examination was carried out by a high frequency linear transducer appropriate to superficial examination of skin. A frequency of 15–22 MHz (the highest frequency able to give optimum visualization of the epidermis and dermis) was used. Patients were examined in a comfortable position depending on the anatomic location of the plaque chosen. The amount of ultrasound gel was generous and the transducer was laid on the skin gently without compressing the superficial tissues and small blood vessels. This lesion was viewed longitudinally and transversely and special attention was paid to the central part of the plaque and the edges.

B-mode ultrasonography was used to evaluate the morphological characteristics of the skin. The thickness of the epidermis, dermis, subepidermal low-echogenic layer (SLEB) and total skin thickness were measured in millimeters. The thickness of the epidermis was measured from the skin surface to the dermoepidermal interface and the thickness of the dermis was measured from the dermoepidermal interface to the dermal-subcutaneous tissue boundary. SLEB was evaluated as a hypoechoic band just under the epidermis, and the thickness was measured when it was clearly seen. The epidermal and dermal measurements were added together to get the total skin thickness. Three measurements were taken in representative areas of the lesion and used the mean values for statistical analysis.

Also the echogenicity and structural appearance of the dermis was assessed. Decreased echogenicity of the dermis was areas of special interest because it could be a sign of inflammatory edema or cellular infiltration. Associated subcutaneous tissue changes, such as edema, fluid collection, and other changes of interest which may affect interpretation of the skin changes were examined.

Power Doppler Assessment

Power Doppler ultrasonography was then undertaken to evaluate the microvascular activity in the psoriatic plaque. The Doppler parameters used were optimized for detection of low velocities superficial blood flow, using a low pulse repetition frequency, low wall filter and appropriate Doppler gain. Doppler setting was kept as similar as possible for the psoriatic plaque and the normal clinically adjacent skin to increase the degree of comparability.

Vascularity was graded on a semi-quantitative scale. Grade 0 = absence of detectable vascular signals, Grade 1 = minimal or isolated vascular signals, Grade 2 = moderate vascularity, Grade 3 = marked or intense vascularity within the dermis. The presence of dermal vascular signals and the vascularity grade were recorded for each lesion. If ultrasound allowed for quantitative assessment, a standardized ROI was positioned in the dermal part of the plaque and the percentage of vascularized area was noted. The results of the Power Doppler were correlated with clinically normal adjacent skin.

Assessment of Subclinical Activity

Subclinical inflammatory activity was considered to be lesions with limited or relatively mild clinical activity, but with objective sonographic abnormalities suggestive of inflammatory activity. These abnormalities were thicker dermis (increased) or thicker epidermal (increased) and/or the presence or increase of dermal SLEB, decrease of dermal echogenicity and increase of dermal vascularity on Power Doppler examination. Special focus was given to cases in which Power Doppler showed "increased" vascularity with relatively low clinical activity, suggesting a persistent inflammatory activity which was not captured well by the traditional clinical examination.

Comparison With Clinically Normal Skin

The selected psoriatic plaque, in as far as possible, was compared with an adjacent region of clinically normal skin from the same anatomical area. For both areas, the same ultrasound method, transducer frequency, and Doppler settings were utilized. The thickness of the epidermidis, dermis, SLEB, total skin, and vascularity were recorded. This within-patient comparison was employed to minimize the impact of normal differences in skin thickness and vascularity due to patient and anatomical variations.

Image Acquisition and Quality Control

Representative b-mode and power Doppler images were acquired and saved for every participant. Images capturing the epidermal and dermal thickness, and dermal vascularity, were kept for future documentation and analysis. Measurement variations were minimized by conducting three quantitative measurements and calculating the average. The ultrasound examinations were carried out using a standardized protocol and with special care taken to minimize transducer pressure and the consistency of Doppler settings during the study.

Statistical Analysis

SPSS 27 software was used to analyze the data. Data were presented as mean ± standard deviation values for continuous variables and frequencies (and percentages) for categorical variables. Appropriate paired statistical tests were used to compare psoriatic plaques to clinically normal skin. Pearson or Spearman correlation was used to evaluate correlations between PASI scores and ultrasound parameter as a function of the distribution of the data. Selected ultrasound parameters, including the thickness of SLEB and the Power Doppler vascularity, were assessed for their capacity to detect active inflammatory changes, by employing ROC curve analysis (where applicable). A p-value of < 0.05 was deemed to be statistically significant.

Results

The study participants were 50 patients of psoriasis vulgaris, 28 (56%) were male patients and 22 (44%) were female patients. The ages of participants ranged from 18 to 60 years with mean age of 38.6 ± 10.7 years. The mean time of psoriasis was 8.1 ± 5.6 years. Plaque psoriasis was seen in most patients, and nail and joint involvement were noted in a smaller number of patients.

Table 1. Demographic and Clinical Characteristics of the Study Participants.

Characteristic	Patients (n=50)
Age, years, mean ± SD	38.6 ± 10.7
Age range	18–60
Male, n (%)	28 (56.0)
Female, n (%)	22 (44.0)
Disease duration, years	8.1 ± 5.6
Family history, n (%)	19 (38.0)

Scalp involvement, n (%)	21 (42.0)
Nail involvement, n (%)	13 (26.0)
Joint symptoms, n (%)	9 (18.0)
Current topical treatment, n (%)	24 (48.0)
Current systemic treatment, n (%)	11 (22.0)
No current treatment, n (%)	15 (30.0)
PASI score, mean ± SD	8.4 ± 5.1

The 18 patients (36.0%) had mild disease, 22 had moderate disease (44.0%) and 10 had severe disease (20.0%) according to PASI classification. The study population was therefore large enough to cover a wide range of clinical severity, and the correlations between the conventional clinical scoring and ultrasound based inflammatory markers were assessed.

Table 2. Distribution of Psoriasis Lesions According to Anatomical Site.

PASI category	PASI range	n	%
Mild	<5	18	36.0
Moderate	5–10	22	44.0
Severe	>10	10	20.0
Total	—	**50**	**100.0**

Using high-frequency ultrasonography, significant differences in the structure of psoriatic plaques and clinically normal skin was found. The thickness of the epidermis, dermis, SLEB and total skin thickness was significantly higher in psoriatic plaques. The most obvious difference, however, was encountered in the thickness of the SLEB, which was almost nonexistent or very thin in clinically normal skin, but always evident in most, if not all, psoriatic plaques.

Table 3. High-Frequency Ultrasound Findings in Psoriatic Plaques Compared With Clinically Normal Skin.

Ultrasound parameter	Psoriatic plaque	Normal adjacent skin	P-value
Epidermal thickness (mm)	0.38 ± 0.09	0.21 ± 0.05	<0.001
Dermal thickness (mm)	1.72 ± 0.31	1.24 ± 0.22	<0.001
SLEB thickness (mm)	0.42 ± 0.15	0.09 ± 0.05	<0.001
Total skin thickness (mm)	2.10 ± 0.34	1.45 ± 0.24	<0.001

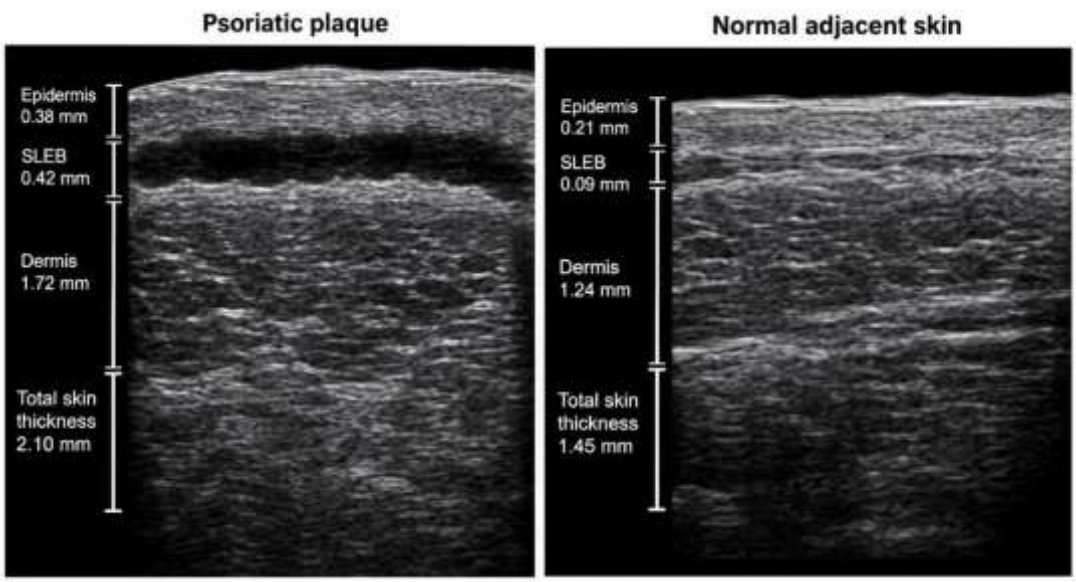

Figure 1. High-frequency B-mode ultrasonography demonstrating increased epidermal and dermal thickness and a prominent subepidermal low-echogenic band in a psoriatic plaque compared with adjacent normal skin.

HFUS was often able to identify structural abnormalities. The thickness of the epidermis had increased in 44 patients (88.0%) and the thickness of the dermis had increased in 42 patients (84.0%). One of the most common sonographic abnormalities, SLEB was seen in 43 patients (86.0%). Of the 39 patients, 78.0% had reduced dermal echogenicity.

Table 4. Frequency of Structural Ultrasound Abnormalities in Psoriatic Plaques.

Ultrasound finding	**n**	**%**
Increased epidermal thickness	44	88.0
Increased dermal thickness	42	84.0
Presence of SLEB	43	86.0
Reduced dermal echogenicity	39	78.0
Increased total skin thickness	45	90.0
Subcutaneous edema	8	16.0

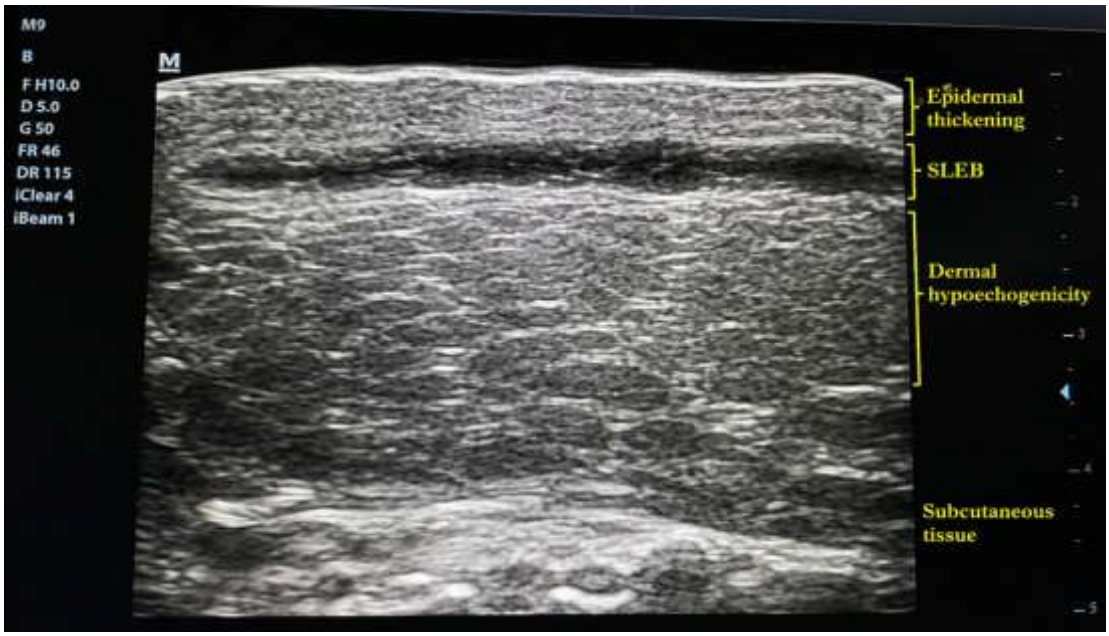

Figure 2. Representative B-mode ultrasound image showing marked epidermal thickening, dermal hypoechogenicity, and SLEB in an active psoriatic plaque.

Detectable dermal vascularity was detected in 43 of 50 patients (86.0%) with power Doppler. The vascularity was moderate to marked in 31 patients (62.0%), representing good microvascular activity in the plaques studied. Adjacent clinically normal skin on the majority of patients was found to have no Doppler activity or low Doppler activity, respectively.

Table 5. Power Doppler Findings in Psoriatic Plaques.

Power Doppler grade	Psoriatic plaque n (%)	Normal skin n (%)
Grade 0	7 (14.0)	39 (78.0)
Grade 1	12 (24.0)	9 (18.0)
Grade 2	19 (38.0)	2 (4.0)
Grade 3	12 (24.0)	0 (0.0)
Grades 2–3 combined	**31 (62.0)**	**2 (4.0)**

The difference in vascularity distribution between psoriatic plaques and clinically normal skin was statistically significant ($P < 0.001$).

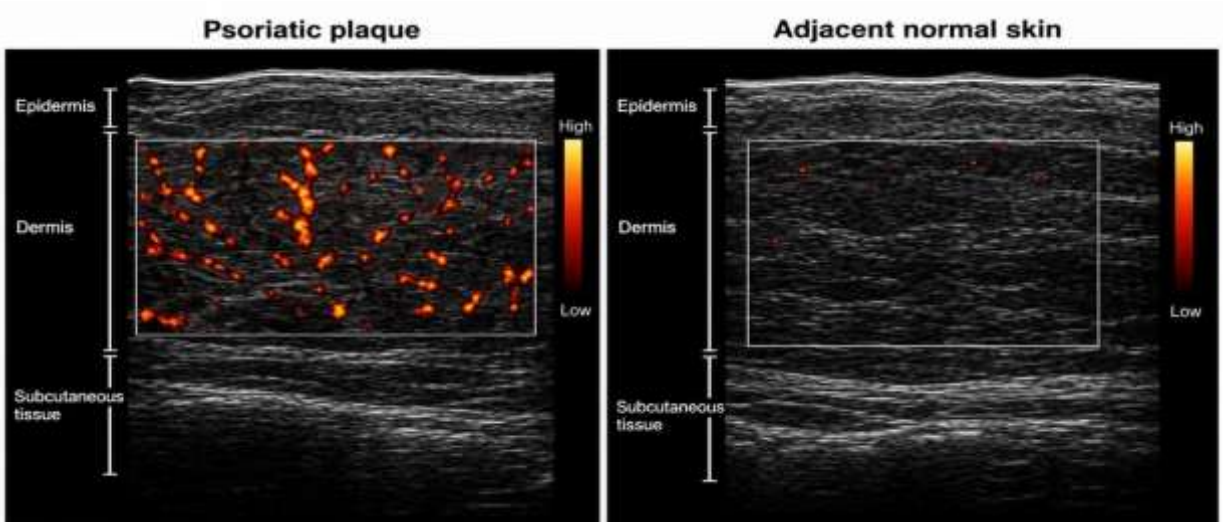

Figure 3. Power Doppler ultrasound demonstrating prominent dermal microvascular signals within a psoriatic plaque, with minimal vascularity in adjacent clinically normal skin.

There was a significant positive correlation between PASI scores and some sonographic parameters. PASI had the highest correlation with Power Doppler vascularity (r = 0.72), and the second highest correlation with SLEB thickness (r = 0.68). There were also significant positive correlations with PASI and the epidermal, dermal, and overall skin thickness. The results show that there is a correlation between ultrasound abnormalities and clinically determined disease severity, but they also show that ultrasound abnormalities are present at relatively low PASI scores.

Table 6. Relationship Between PASI Score and Ultrasound Parameters.

Ultrasound parameter	Correlation with PASI (r)	P-value
Epidermal thickness	0.59	<0.001
Dermal thickness	0.61	<0.001
SLEB thickness	0.68	<0.001
Total skin thickness	0.63	<0.001
Power Doppler vascularity	0.72	<0.001

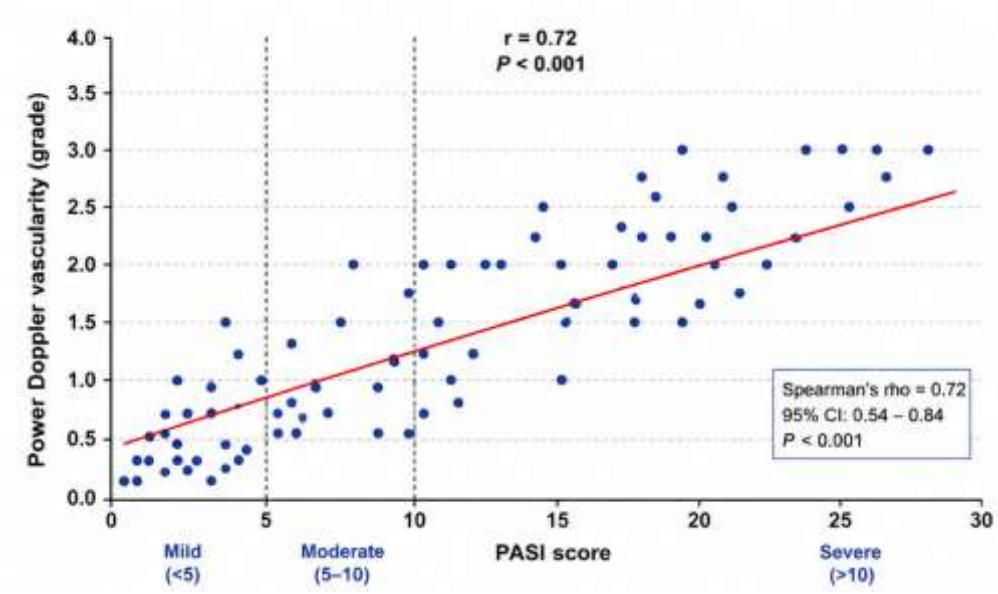

Figure 4. Scatter plot demonstrating the positive correlation between PASI score and Power Doppler vascularity in patients with psoriasis.

The sonographic inflammatory markers showed a progressive increase as well as the clinical severity categories. The most severe psoriasis patients had the thickest epidermal and dermal thickness, the thickest SLEB and the highest Power Doppler vascularity. However, there was a significant number of patients in whom the diagnosis was mild psoriasis who had measurable SLEB and increased dermal vascularity.

Table 7. Ultrasound Findings According to Clinical Disease Severity.

Parameter	Mild PASI <5 (n=18)	Moderate PASI 5–10 (n=22)	Severe PASI >10 (n=10)	P-value
Epidermal thickness (mm)	0.32 ± 0.06	0.39 ± 0.07	0.46 ± 0.09	<0.001
Dermal thickness (mm)	1.53 ± 0.21	1.75 ± 0.25	1.98 ± 0.28	<0.001
SLEB thickness (mm)	0.32 ± 0.10	0.44 ± 0.12	0.54 ± 0.14	<0.001
PD grade, mean	1.44 ± 0.78	2.09 ± 0.75	2.70 ± 0.48	<0.001
PD grades 2–3, n (%)	7 (38.9)	16 (72.7)	8 (80.0)	0.018

The most significant finding of the study was that a significant number of patients with clinically mild psoriasis had inflammatory activity detected by ultrasound. In the 18 patients who had PASI <5, 13 (72.2%) had at least one objective ultrasound marker of inflammation and 7 (38.9%) had moderate to marked Power Doppler vascularity. Fifteen patients (77.8%) had SLEB. The results suggest that there is no clear correlation between a relatively low clinical score and total lack of inflammatory activity.

Table 8. Detection of Subclinical Activity in Patients With Mild Clinical Disease.

Ultrasound marker in mild psoriasis	n (18)	%
SLEB present	14	77.8
Increased epidermal thickness	15	83.3
Increased dermal thickness	14	77.8
Reduced dermal echogenicity	12	66.7
Detectable PD vascularity	13	72.2
PD grade 2–3	7	38.9
At least one significant ultrasound abnormality	13	72.2
≥2 ultrasound abnormalities	11	61.1

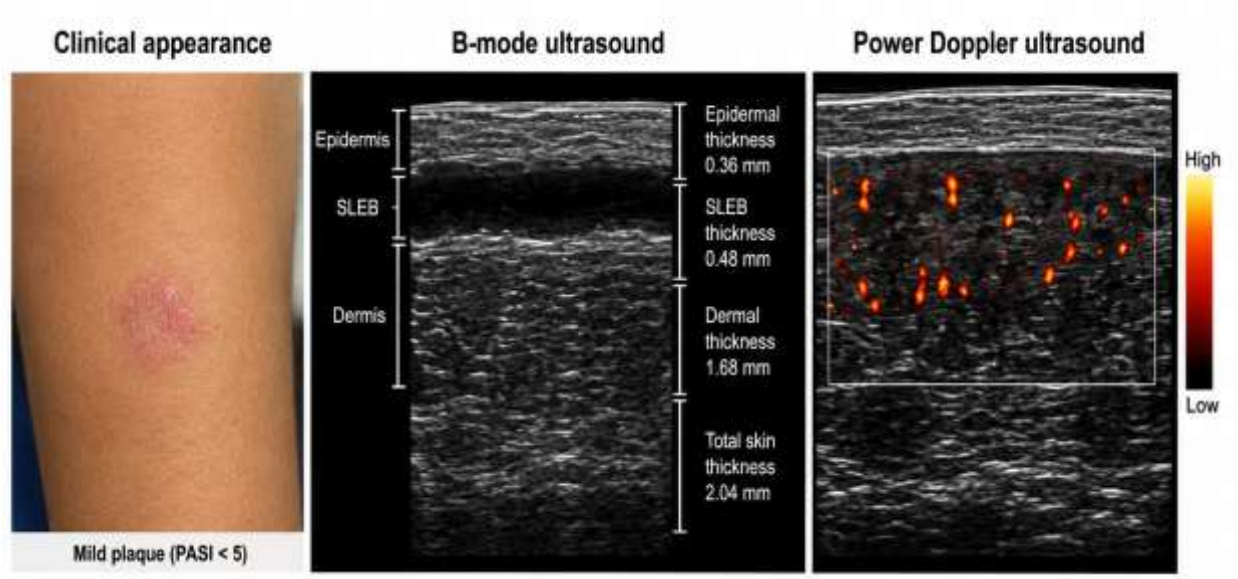

Figure 5. Representative case of clinically mild psoriasis demonstrating prominent SLEB and dermal Power Doppler vascularity despite limited visible clinical inflammation.

Several ultrasound parameters showed excellent discriminatory performance using ROC curve analysis. The best diagnostic value was obtained with power Doppler vascularity (AUC = 0.93). Similarly, thickness in SLEB showed a very good discrimination (AUC 0.91). The thickness of SLEB was combined with Power Doppler vascularity, further enhancing the diagnostic performance (AUC = 0.96).

Table 9. Diagnostic Performance of Selected Ultrasound Parameters for Detecting Active Psoriatic Inflammation.

Ultrasound parameter	Optimal cutoff	Sensitivity (%)	Specificity (%)	AUC	P-value
Epidermal thickness	>0.29 mm	84.0	80.0	0.88	<0.001
Dermal thickness	>1.48 mm	86.0	82.0	0.89	<0.001
SLEB thickness	>0.20 mm	90.0	86.0	0.91	<0.001
PD vascularity	≥Grade 1	92.0	84.0	0.93	<0.001
SLEB + PD	Combined assessment	94.0	90.0	**0.96**	<0.001

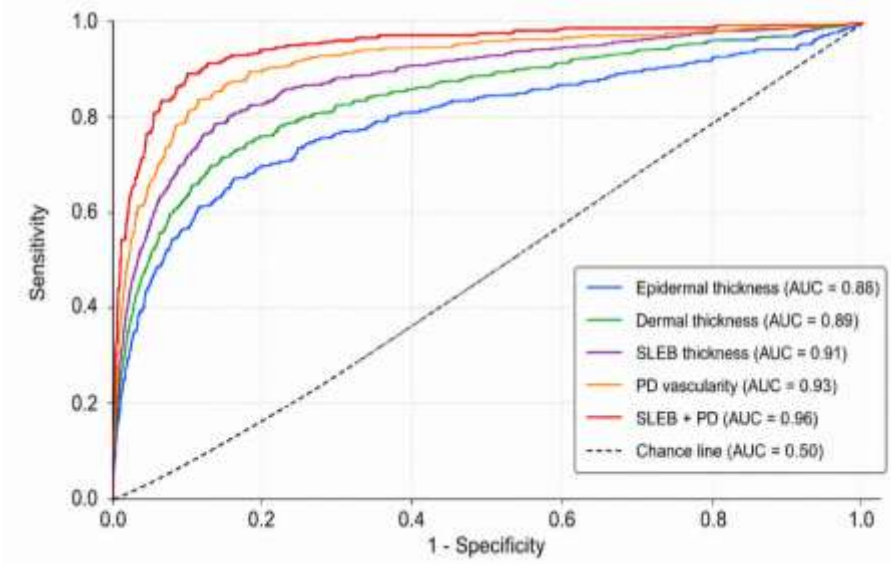

Figure 6. Receiver operating characteristic curves demonstrating the diagnostic performance of epidermal thickness, dermal thickness, SLEB, Power Doppler vascularity, and combined SLEB plus Power Doppler assessment.

In patients with mild psoriasis, the patients with moderate to marked Power Doppler activity had significantly higher SLEB thickness and dermal thickness than the patients with absent or minimal Doppler activity. Importantly, the clinical PASI scores in this mild subset were not significantly different while ultrasound showed significant variation in inflammatory activity. Importantly, there were significant differences in inflammatory activity as seen by ultrasound, but not in clinical PASI scores in this mild subset.

Table 10. Comparison Between Clinically Mild Lesions With and Without Significant Power Doppler Activity.

Parameter	PD Grade 0–1 (n=11)	PD Grade 2–3 (n=7)	P-value
PASI score	3.1 ± 0.9	3.5 ± 0.8	0.342
Epidermal thickness (mm)	0.29 ± 0.05	0.37 ± 0.06	0.008
Dermal thickness (mm)	1.41 ± 0.18	1.71 ± 0.20	0.004
SLEB thickness (mm)	0.24 ± 0.08	0.44 ± 0.10	<0.001
Total skin thickness (mm)	1.70 ± 0.21	2.08 ± 0.23	0.002

Multivariable logistic regression showed that the most powerful independent ultrasound predictors of subclinical inflammatory activity were the thickness of the SLEB and Power Doppler vascularity. Both SLEB thickness and Power Doppler vascularity were independently associated with subclinical activity, even after adjusting for age, sex, disease duration and PASI score.

Table 11. Multivariable Analysis of Ultrasound Predictors of Subclinical Activity.

Predictor	Adjusted OR	95% CI	P-value
SLEB thickness >0.20 mm	5.84	1.72–19.82	0.005
PD grade ≥2	7.31	2.02–26.44	0.003
PASI score	1.21	1.02–1.43	0.028
Disease duration	1.06	0.98–1.15	0.141
Age	1.01	0.97–1.06	0.562
Male sex	1.18	0.42–3.29	0.749

Discussion

Epidermal thickness, dermal thickness, SLEB thickness and total skin thickness were significantly increased in psoriatic plaques, compared to clinically normal skin in the present study. These results are similar to those of Vaillant et al. who showed that the plaques of psoriasis had an increased thickness of both the epidermis and dermis using high resolution ultrasound and that this difference was especially prominent in the epidermis compared to normal skin [16]. Likewise, Olsen and Serup reported that they saw a characteristic echolucent dermoepidermal junction band in psoriatic lesions and that this could be due to both an acanthosis of the epidermis and inflammatory changes [17]. Therefore, our results suggest that objective proof of structural changes characteristic of psoriatic lesions can be provided by HFUS, which can also supply quantitative data in addition to that derived from clinical visual check-up.

The SLEB was one of the most notable locations we found in our study, as it was seen in 86% of patients, and the mean thickness of the SLEB was significantly different in psoriatic plaques compared with normal adjacent skin. This discovery is noteworthy as the SLEB has been consistently identified as a sonographic marker related to psoriatic inflammation. Gupta et al. measured the width of the hypoechoic subepidermal band in 145 psoriatic plaques and found a strong correlation between the width of the hypoechoic band and the clinical severity of the psoriasis (correlation coefficient 0.86) [18]. It is encouraging that a significant correlation was found in this study, which corroborates our finding that SLEB is a significant objective parameter of disease activity. More recently, Wang et al. showed that SLEB thickness was significantly reduced in patients during biologic therapy and was associated with clinical and dermoscopic improvement, thus reinforcing the relevance of this imaging biomarker [19].

The other significant result of our study was the high vascularity rate of Power Doppler in psoriatic plaques. Dermal vascularity was detectable in 86% of patients and the moderate to marked vascularity was seen in 62% of the patients. This finding is biologically relevant as the inflammatory vascular remodeling, dilatation of superficial vessels and increased dermal perfusion are hallmarks of psoriasis. According to Marina et al., Doppler ultrasonography with high frequency probes could help identify and semi-quantitatively evaluate dermal blood flow in psoriasis, especially to assess the inflammatory activity [20]. Likewise, Gutierrez et al. showed that there was a significant correlation between the Power Doppler and clinical and histological vascular changes in psoriatic plaques treated with etanercept. A correlation was observed between reduction in Doppler activity and improvement in PASI and histological vascular markers (such as VEGF) [21]. This agreement with previous data fortifies our interpretation that increased Power Doppler vascularity can be used as an imaging feature of active cutaneous inflammation.

One of the most relevant findings in the present work was the strong correlation of PASI with all the major ultrasonic parameters. The best correlation was seen between PASI and the Power Doppler

vascularity (r = 0.72), followed by SLEB thickness (r = 0.68). The results show that there are ultrasound abnormalities that are correlated with the clinical disease severity. But this wasn't unconditional, as significant amounts of ultrasound activity were seen even in patients with low PASI scores. To date, PASI is still a primarily macroscopic evaluation tool and may not accurately reflect the microscopic inflammatory activity or inflammation at the tissue level. In previous reviews, the potential importance of imaging as a complementary tool to evaluate structural and vascular changes in psoriatic skin has been highlighted [22,23] and the use of HFUS and Doppler techniques for these purposes has been described.

The most clinically relevant finding was that sonographic abnormalities were detected in patients who had mild psoriasis. In our study, 72.2% of patients had at least one significant ultrasound abnormality, 77.8% had SLEB and 72.2% had Power Doppler vascularity detected. In addition, 38.9% of patients with mild disease exhibited moderate to marked Doppler activity. The results of the present study indicate that a low clinical score does not necessarily indicate a lack of inflammatory activity. This idea is supported by previous imaging studies that have shown that despite good clinical outcomes, there can be vascular and structural abnormalities present. A recent study comparing dermoscopy with HFUS in psoriasis highlighted that although clinical improvement may still have objective imaging abnormalities, such as vascular changes and SLEB, indicating continued tissue activity [24].

A comparison of clinically mild lesions with varying Power Doppler activity was a significant observation. Despite relatively similar PASI scores, patients with moderate-to-marked Doppler activity showed significantly more dermal thickness and SLEB thickness compared to patients with absent or small Doppler activity. This discovery indicates that Power Doppler and the B-mode may yield complementary information, with the Power Doppler reflecting vascular inflammatory activity, and SLEB and dermal thickness reflecting the structural information related to inflammatory activity and tissue remodeling. A combination of the assessment then seems to be more informative than depending on a single parameter.

This idea was further substantiated by our ROC analysis. The AUC value of the Power Doppler vascularity was 0.93, and the AUC value of the SLEB thickness was 0.91. The greatest of all was the AUC of 0.96, with 94% sensitivity and 90% specificity in the proposed analysis for the combination of SLEB and Power Doppler. These values need confirmation in larger numbers of subjects but indicate that combining the structural and vascular sonographic parameters can be helpful in better discriminating active inflammatory lesions than the individual parameters. Earlier studies using ultra-high-frequency ultrasound have also shown that the vascularity of TMAs may vary significantly as effective treatment progresses and may be a useful indicator of inflammatory activity [25].

The results of the present study also corroborate the general idea of ultrasound assessment in psoriatic disease. Gutierrez et al. emphasized that ultrasound may not only detect structural changes but also the smallest changes in blood flow in superficial tissues, thus suggesting its usefulness as an assessment of disease activity [11]. More importantly, our study brings this idea one step closer to the clinically subtle spectrum of psoriasis by focusing on lesions with low clinical severity, and showing measurable inflammation in the sonographic scale remains despite relatively low PASI scores.

In practice, there are a number of advantages of HFUS and Power Doppler in dermatology practice. They are painless, non-invasive, non-ionizing, can be done as part of routine outpatient assessment and can give quantitative data which can be documented and monitored over time. Unlike simply visual clinical assessment, ultrasound allows for direct measurement of tissue thickness and for

visualization of the vascular activity. The use of HFUS as a tool to record treatment responsiveness and treatment independent changes therefore have been suggested in previous studies [26,27].

However, there are some restrictions that need to be taken into account. The number of subjects analysed (50 patients) was relatively small, and the cross-sectional study design precludes the assessment of whether subclinical sonographic activity can predict clinical relapse. Furthermore, the measurements from ultrasound can vary depending on the location and pressure applied by the transducer, characteristics of the ultrasound devices and the operators' experience. The lack of histopathological confirmation in the present study also should be taken into account when interpreting the sonographic findings as imaging biomarkers instead of direct histopathological measurements. To confirm the proposed cut-off values and to establish if ultrasound-defined sub-clinical activity is of prognostic value, larger, longer-term studies with follow-up on treatment and, if ethically feasible, histopathological correlation are needed.

Conclusion

The findings of this study show that high-frequency ultrasound (HFUS) with Power Doppler is a useful objective tool for obtaining more information than just standard clinical evaluation for psoriasis. Epidermal and dermal thickness, presence of subepidermal low-echogenic band (SLEB) and dermal vascularity were significantly higher in psoriatic plaques than in clinically normal skin. Importantly, a significant proportion of patients with mild psoriasis and relatively low PASIP scores had significant sonographic abnormalities, suggesting that there is inflammatory activity that could be clinically underestimated. The power Doppler vascularity and SLEB thickness were strongly correlated with PASI and exhibited excellent discriminatory power with highest diagnostic accuracy when combined. These results indicate that the combination of clinical scoring and HFUS and Power Doppler may provide a non-invasive tissue level assessment of structural and vascular inflammation. These methods could be part of routine dermatological assessment to enhance the ability to identify subclinical disease activity, to allow more objective monitoring, and to possibly aid in earlier identification of persistent inflammation and treatment response in patients with psoriasis.

References

[1] N. M. Golbari, J. M. van der Walt, A. Blauvelt, C. Ryan, P. van de Kerkhof, and A. B. Kimball, "Psoriasis severity: Commonly used clinical thresholds may not adequately convey patient impact," *Journal of the European Academy of Dermatology and Venereology*, vol. 35, no. 2, pp. 417–421, 2021.

[2] D. M. Ashcroft, A. L. Wan Po, H. C. Williams, and C. E. Griffiths, "Clinical measures of disease severity and outcome in psoriasis: A critical appraisal of their quality," *British Journal of Dermatology*, vol. 141, no. 2, pp. 185–191, 1999.

[3] P. I. Spuls, L. L. Lecluse, M. L. Poulsen, J. D. Bos, R. S. Stern, and T. Nijsten, "How good are clinical severity and outcome measures for psoriasis? Quantitative evaluation in a systematic review," *Journal of Investigative Dermatology*, vol. 130, no. 4, pp. 933–943, 2010.

[4] C. Fink, C. Alt, L. Uhlmann, C. Klose, A. Enk, and H. A. Haenssle, "Precision and reproducibility of automated computer-guided Psoriasis Area and Severity Index measurements in comparison with trained physicians," *British Journal of Dermatology*, vol. 180, no. 2, pp. 390–396, 2019.

[5] R. C. Hermann, C. N. Ellis, D. W. Fitting, V. C. Ho, and J. J. Voorhees, "Measurement of epidermal thickness in normal skin and psoriasis with high-frequency ultrasound," *Skin Pharmacology*, vol. 1, no. 2, pp. 128–136, 1988.

[6] J. Czajkowska, P. Badura, S. Korzekwa, and A. Płatkowska-Szczerek, "Deep learning approach to skin layers segmentation in inflammatory dermatoses," *Ultrasonics*, vol. 114, p. 106412, 2021.

[7] V. S. Lucas, R. S. Burk, S. Creehan, and M. J. Grap, "Utility of high-frequency ultrasound: Moving beyond the surface to detect changes in skin integrity," *Plastic Surgical Nursing*, vol. 34, no. 1, pp. 34–38, 2014.

[8] M. C. Șomlea, A. N. Boca, A. D. Pop, R. F. Ilieș, S. C. Vesa, A. D. Buzoianu, and A. Tătaru, "High-frequency ultrasonography of psoriatic skin: A non-invasive technique in the evaluation of the entire skin of patients with psoriasis: A pilot study," *Experimental and Therapeutic Medicine*, vol. 18, no. 6, pp. 4981–4986, 2019.

[9] M. Murphy, P. Kerr, and J. M. Grant-Kels, "The histopathologic spectrum of psoriasis," *Clinics in Dermatology*, vol. 25, no. 6, pp. 524–528, 2007.

[10] E. L. Speight, T. J. Essex, and P. M. Farr, "The study of plaques of psoriasis using a scanning laser-Doppler velocimeter," *British Journal of Dermatology*, vol. 128, no. 5, pp. 519–524, 1993.

[11] M. Gutierrez, X. Wortsman, E. Filippucci, R. De Angelis, G. Filosa, and W. Grassi, "High-frequency sonography in the evaluation of psoriasis: Nail and skin involvement," *Journal of Ultrasound in Medicine*, vol. 28, no. 11, pp. 1569–1574, 2009.

[12] R. K. Mlosek, B. Migda, and M. Migda, "High-frequency ultrasound in the 21st century," *Journal of Ultrasonography*, vol. 20, no. 83, pp. e233–e241, 2021.

[13] G. Micali, F. Lacarrubba, C. Santagati, C. G. Egan, M. R. Nasca, and M. L. Musumeci, "Clinical, ultrasound, and videodermatoscopy monitoring of psoriatic patients following biological treatment," *Skin Research and Technology*, vol. 22, no. 3, pp. 341–348, 2016.

[14] I. A. Halip, D. Vata, A. I. Patrascu, D. Temelie Olinici, I. A. Popescu, M. Mocanu, D. L. Gugulus, V. T. Popa, D. Gheuca-Solovastru, and L. Gheuca-Solovastru, "The role of dermoscopy and high-frequency ultrasonography in the diagnosis and monitoring of psoriasis vulgaris," *Medicina*, vol. 61, no. 11, Art. no. 1978, 2025.

[15] E. Muralidharan, S. K. Malhotra, and A. Singh, "Can dermoscopy and ultrasonography be considered a prognostic tool in management of psoriasis?" *Indian Journal of Dermatology*, vol. 66, no. 6, p. 704, 2021.

[16] L. Vaillant, M. Berson, L. Machet, A. Callens, L. Pourcelot, and G. Lorette, "Ultrasound imaging of psoriatic skin: A noninvasive technique to evaluate treatment of psoriasis," *International Journal of Dermatology*, vol. 33, no. 11, pp. 786–790, 1994.

[17] L. O. Olsen and J. Serup, "High-frequency ultrasound scan for non-invasive cross-sectional imaging of

psoriasis," *Acta Dermato-Venereologica*, vol. 73, no. 3, pp. 185–187, 1993.

[18] A. K. Gupta, D. H. Turnbull, K. A. Harasiewicz, D. T. Shum, G. N. Watteel, F. S. Foster, and D. N. Sauder, "The use of high-frequency ultrasound as a method of assessing the severity of a plaque of psoriasis," *Archives of Dermatology*, vol. 132, no. 6, pp. 658–662, 1996.

[19] J. Wang, Q. Zhu, F. Li, M. Xiao, and J. Liu, "Clinical, dermoscopic, and ultrasonic monitoring of the response to biologic treatment in patients with moderate-to-severe plaque psoriasis," *Frontiers in Medicine*, vol. 10, p. 1162873, 2023.

[20] M. E. Marina, C. Botar Jid, I. I. Roman, C. M. Mihu, and A. D. Tătaru, "Ultrasonography in psoriatic disease," *Medical Ultrasonography*, vol. 17, no. 3, pp. 377–382, 2015.

[21] M. Gutierrez, R. De Angelis, M. L. Bernardini, E. Filippucci, G. Goteri, G. Brandozzi, G. Lemme, A. Campanati, W. Grassi, and A. Offidani, "Clinical, power Doppler sonography and histological assessment of the psoriatic plaque: Short-term monitoring in patients treated with etanercept," *British Journal of Dermatology*, vol. 164, no. 1, pp. 33–37, 2011.

[22] F. Lacarrubba, G. Pellacani, S. Gurgone, A. E. Verzì, and G. Micali, "Advances in non-invasive techniques as aids to the diagnosis and monitoring of therapeutic response in plaque psoriasis: A review," *International Journal of Dermatology*, vol. 54, no. 6, pp. 626–634, 2015.

[23] M. Gutierrez, G. S. Kaeley, C. Bertolazzi, and C. Pineda, "State of the art of ultrasound in the assessment of psoriasis and psoriatic arthritis," *Expert Review of Clinical Immunology*, vol. 13, no. 5, pp. 439–447, 2017.

[24] V. Dini, A. Janowska, F. Faita, S. Panduri, B. B. Benincasa, R. Izzetti, M. Romanelli, and T. Oranges, "Ultra-high-frequency ultrasound monitoring of plaque psoriasis during ixekizumab treatment," *Skin Research and Technology*, vol. 27, no. 2, pp. 277–282, 2021.

[25] R. Białynicki-Birula, R. Reszke, and J. C. Szepietowski, "High-frequency ultrasonography (HFUS) as a useful tool in differentiating between plaque morphea and extragenital lichen sclerosus lesions," *Postępy Dermatologii i Alergologii*, vol. 34, no. 5, pp. 485–489, 2017.

[26] Y. Miao, W. W. Ren, F. Y. Yang, L. Li, L. Wu, D. D. Shan, Z. T. Chen, L. F. Wang, Q. Wang, and L. H. Guo, "Diagnostic value of high-frequency ultrasound (HFUS) in evaluation of subcutaneous lesions," *Skin Research and Technology*, vol. 29, no. 9, p. e13464, 2023.

[27] Y. Miao, W. W. Ren, F. Y. Yang, L. Li, L. Wu, D. D. Shan, Z. T. Chen, L. F. Wang, Q. Wang, and L. H. Guo, "Diagnostic value of high-frequency ultrasound (HFUS) in evaluation of subcutaneous lesions," *Skin Research and Technology*, vol. 29, no. 9, p. e13464, 2023.