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DIAGNOSTIC VALUE OF HIGH-FREQUENCY ULTRASOUND IN ASSESSING ATOPIC DERMATITIS IN CHILDREN

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Abstract: Atopic dermatitis (AD) is a chronic inflammatory skin condition common in children, requiring objective diagnostic tools to assess severity and guide treatment. This study evaluates high-frequency ultrasound as a non-invasive method to characterize skin changes in 60 children aged 4 months to 18 years with AD, treated at the Department of Pediatric Dermatology of Tashkent Pediatric Medical Institute university clinic. Ultrasound parameters, including epidermal and dermal thickness and echogenicity, were analyzed across disease severity (mild, moderate, severe), clinical forms (exudative, erythematous-squamous, erythematous-squamous with lichenification, lichenoid, prurigo), and age groups (infantile, childhood, adolescent-adult). The subepidermal low echogenic band (SLEB) was assessed as an inflammation marker. Results show significant variations in ultrasound characteristics, correlating with SCORAD scores, establishing ultrasound as a valuable tool for AD diagnosis and monitoring.

Introduction

Atopic dermatitis (AD) is a prevalent chronic skin disorder in children, driven by epidermal barrier dysfunction, immune dysregulation, and inflammation [1, 9, 10]. Clinical evaluation using the SCORAD index quantifies severity but lacks objectivity for subclinical changes [2, 3, 4]. High-frequency ultrasound (20–100 MHz) enables in vivo visualization of skin layers, measuring epidermal and dermal thickness, echogenicity, and inflammatory markers like the subepidermal low echogenic band (SLEB) [5, 6, 7, 8]. This study investigates the diagnostic utility of ultrasound in a large pediatric cohort, analyzing skin changes across AD severity, clinical forms, and age groups to enhance diagnostic precision and inform personalized treatment.

Objective

To assess the diagnostic value of high-frequency ultrasound in characterizing skin changes in children with atopic dermatitis, evaluating epidermal and dermal thickness, echogenicity, and SLEB across disease severity, clinical forms, and age groups, and correlating findings with SCORAD scores.

Materials and Methods

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This study included 60 children (32 boys, 28 girls) aged 4 months to 18 years, diagnosed with AD based on clinical criteria, treated at the Department of Pediatric Dermatology, Tashkent Pediatric Medical Institute, from January 2023 to December 2024. Severity was assessed using SCORAD: mild (<40, n=26), moderate (40–70, n=16), severe (>70, n=18). Clinical forms included exudative (n=8), erythematous-squamous (n=25), erythematous-squamous with lichenification (n=17), lichenoid (n=6), and prurigo (n=4). Age groups were infantile (4 months–2 years, n=23), childhood (2–12 years, n=27), and adolescent-adult (12–18 years, n=10). Parents provided informed consent.

Ultrasound was performed using a SkinScanner DUB TPM with a 75 MHz transducer (resolution 21 micrometers, scan depth 4 mm) in B-mode. Parameters measured included:

- Epidermal and dermal thickness (micrometers).

- Echogenicity (arbitrary units, 0–255).

- SLEB thickness and echogenicity, when present.

Scans were conducted in AD lesions and adjacent healthy skin, yielding 1422 measurements (6 per patient). The ratio coefficient (RC) was calculated as the ratio of healthy skin parameter to lesion parameter. RC > 1 indicates reduced lesion parameters, RC < 1 indicates increased lesion parameters, and RC = 1 suggests normalization.

Data were analyzed using RStudio with multivariate analysis of variance (MANOVA) and Student's t-test. Results are presented as mean ± standard deviation (M ± m). Significance was set at $p<0.05$.

Results

Ultrasound parameters varied significantly with AD severity (Table 1). In mild AD (SCORAD 23.5 ± 2.3), epidermal thickness was slightly increased (RC = 0.92), with minimal echogenicity changes. Moderate AD (SCORAD 56.8 ± 3.1) showed increased epidermal and dermal thickness (RC = 0.80, 0.82) and reduced echogenicity (RC = 1.35, 2.05). Severe AD (SCORAD 79.2 ± 7.8) exhibited the greatest thickness increases (RC = 0.70, 0.75) and echogenicity reductions (RC = 1.50, 2.30). SLEB was detected in 60% (mild), 78% (moderate), and 98% (severe) of scans, with thicknesses of 85.0 ± 30.0, 100.5 ± 35.2, and 130.2 ± 40.1 micrometers, respectively.

Table 1. Ultrasound Characteristics by AD Severity (M ± m, RC)

Parameter	Mild (n=26)	Moderate (n=16)	Severe (n=18)
Epidermal thickness (μm)	0.92 ± 0.05	0.80 ± 0.11*	0.70 ± 0.18*
Epidermal Echogenicity (u.e.)	0.85 ± 0.09	1.35 ± 0.50*	1.50 ± 0.35*
Dermal Thickness (μm)	0.85 ± 0.08	0.82 ± 0.10*	0.75 ± 0.14*
Dermal Echogenicity (u.e.)	1.45 ± 0.10	2.05 ± 0.85*	2.30 ± 0.95*

** $p<0.05$ compared to mild AD.*

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The Figure 1 shows a clear trend of increasing SLEB thickness with AD severity, with the Severe bar being the tallest, indicating significant inflammation, while the Mild bar is the shortest, suggesting less inflammatory activity, and the Moderate bar lies in between, reflecting a transitional state. Scientifically, this aligns with SCORAD scores (Mild: 23.5 ± 2.3, Moderate: 56.8 ± 3.1, Severe: 79.2 ± 7.8), confirming SLEB as an objective marker of inflammation.

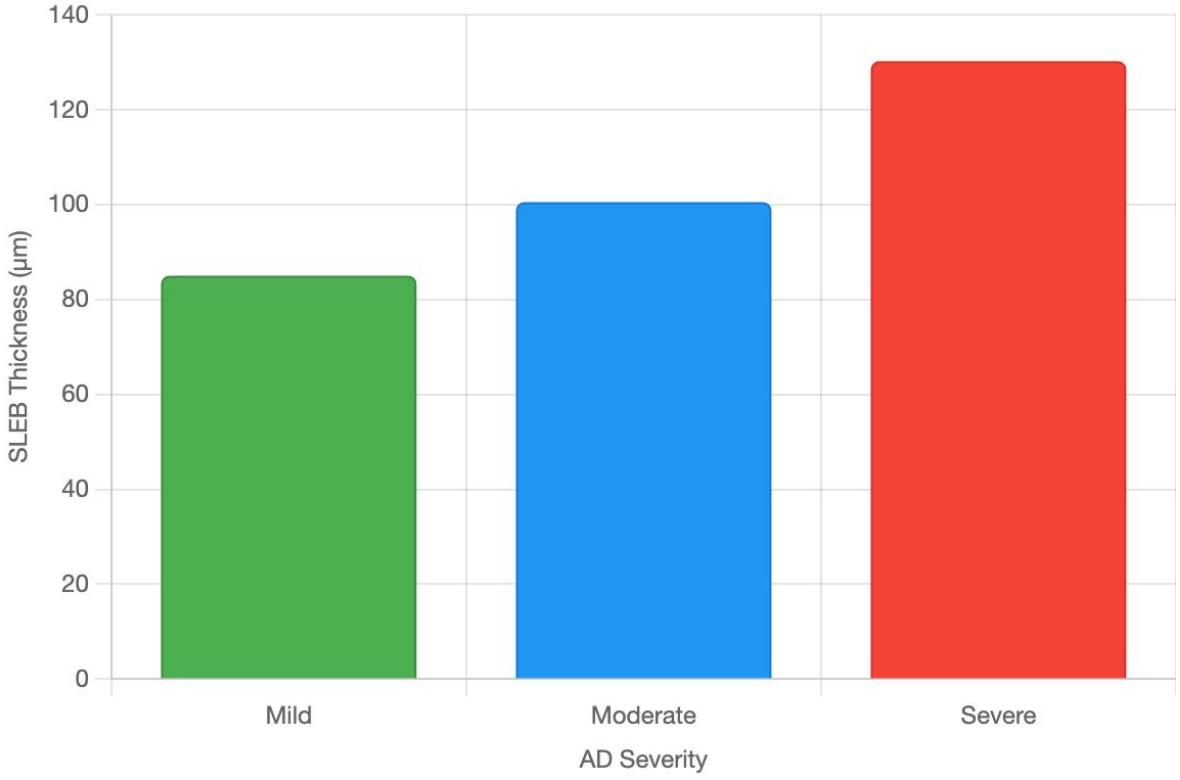

Figure 1. SLEB Thickness by AD Severity

Clinical forms displayed distinct ultrasound profiles (Table 2). Exudative AD showed the highest epidermal and dermal thickness (RC = 0.68, 0.72) and lowest echogenicity (RC = 1.60, 2.40), reflecting edema. Erythematous-squamous AD had moderate changes (RC = 0.80, 0.85). Lichenified forms (erythematous-squamous with lichenification, lichenoid) showed increased dermal thickness (RC = 0.78, 0.75) and higher echogenicity (RC = 1.90, 1.85), indicating fibrosis. Prurigo AD had variable thickness (RC = 0.82) and echogenicity (RC = 2.00). SLEB thickness was highest in exudative (135.0 ± 42.0 micrometers) and lowest in lichenoid (90.0 ± 28.0 micrometers) forms.

Table 2. Ultrasound Characteristics by Clinical Form (M ± m, RC)

Parameter	Exudative	Ery-Squam	Ery-Squam-Lich	Lichenoid	Pruriginous

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Epidermal thickness (µm)	0.68 ± 0.15*	0.80 ± 0.10	0.78 ± 0.12	0.85 ± 0.08	0.82 ± 0.11
Epidermal Echogenicity (u.e.)	1.60 ± 0.40*	1.30 ± 0.45	1.40 ± 0.35	1.20 ± 0.30	1.35 ± 0.38
Dermal Thickness (µm)	0.72 ± 0.13*	0.85 ± 0.09	0.78 ± 0.11	0.75 ± 0.10	0.80 ± 0.12
Dermal Echogenicity (u.e.)	2.40 ± 0.90*	2.00 ± 0.80	1.90 ± 0.75	1.85 ± 0.70	2.00 ± 0.85

** $p<0.05$ compared to erythematous-squamous clinical form.*

Figure 2 illustrates the Exudative bar is the tallest, showing the highest SLEB thickness due to pronounced edema and inflammation, while the Lichenoid bar is the shortest, indicating less inflammatory activity, likely due to chronic fibrosis. Erythematous-squamous, Erythematous-squamous with lichenification, and Prurigo bars are intermediate, with Erythematous-squamous with lichenification slightly taller, suggesting additional chronic changes. This variation reflects clinical presentations, with exudative AD showing acute inflammation and lichenoid forms indicating chronicity.

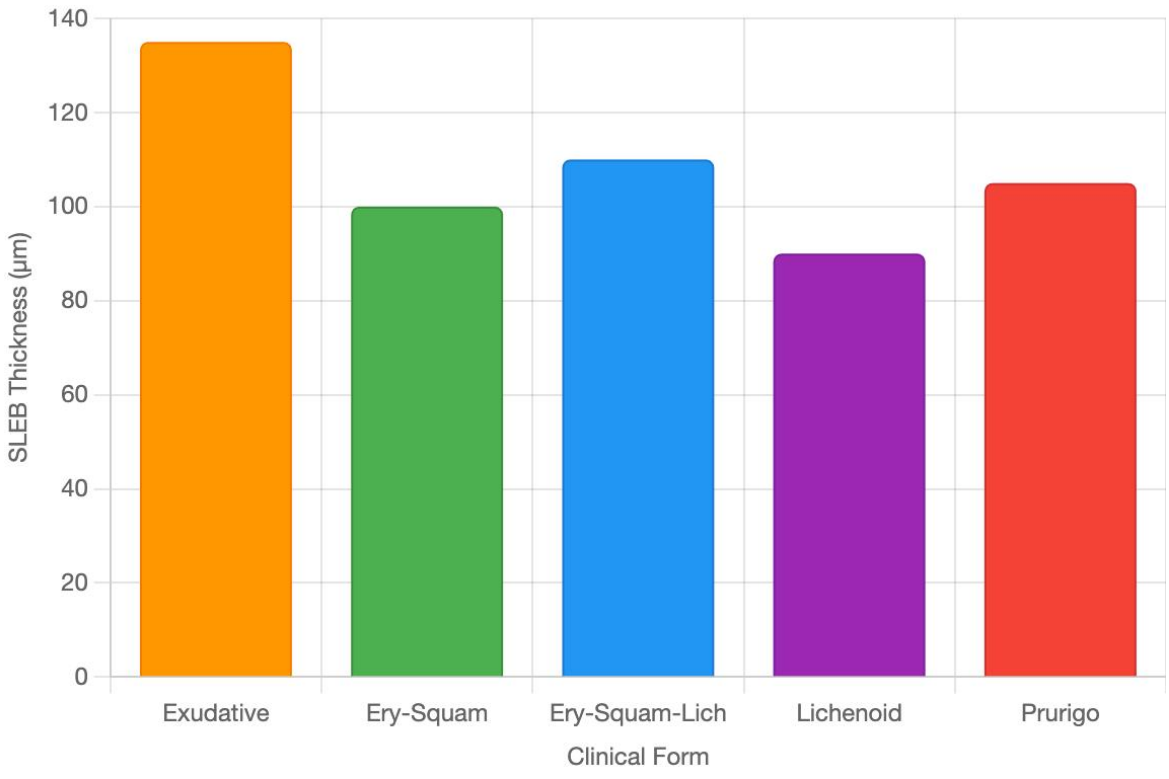

Figure 2. SLEB Thickness by Clinical Form

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Age-related differences were observed (Table 3). Infantile AD (SCORAD 48.5 ± 5.2) showed the greatest epidermal thickness (RC = 0.65) and lowest echogenicity (RC = 1.65), reflecting acute inflammation. Childhood AD (SCORAD 45.0 ± 4.8) had moderate changes (RC = 0.80, 1.40). Adolescent-adult AD (SCORAD 52.8 ± 4.5) exhibited increased dermal thickness (RC = 0.78) and higher echogenicity (RC = 1.90), suggesting chronicity. SLEB was present in 90% (infantile), 75% (childhood), and 65% (adolescent-adult) of scans, with thicknesses of 140.0 ± 45.0, 100.0 ± 35.0, and 85.0 ± 30.0 micrometers, respectively.

Table 3. Ultrasound Characteristics by Age Group (M ± m, RC)

Parameter	Infantile (n=23)	Childhood (n=27)	Adolescent-Adult (n=10)
Epidermal thickness (μm)	0.65 ± 0.14*	0.80 ± 0.10	0.85 ± 0.09
Epidermal Echogenicity (u.e.)	1.65 ± 0.42*	1.40 ± 0.38	1.30 ± 0.35
Dermal Thickness (μm)	0.70 ± 0.12*	0.82 ± 0.11	0.78 ± 0.10
Dermal Echogenicity (u.e.)	2.50 ± 0.95*	2.00 ± 0.80	1.90 ± 0.75

** $p<0.05$ compared to childhood.*

Figure 3 displays the Infantile bar is the tallest, indicating the highest SLEB thickness, consistent with acute inflammation in early AD, while the Adolescent-Adult bar is the shortest, suggesting reduced inflammatory activity, possibly due to chronic fibrosis or milder disease. The Childhood bar is intermediate, reflecting mixed acute and chronic changes. This trend aligns with AD's natural history, where infantile AD is highly inflammatory, and adolescent-adult AD leans toward chronicity, supporting age-specific diagnostics and treatments.

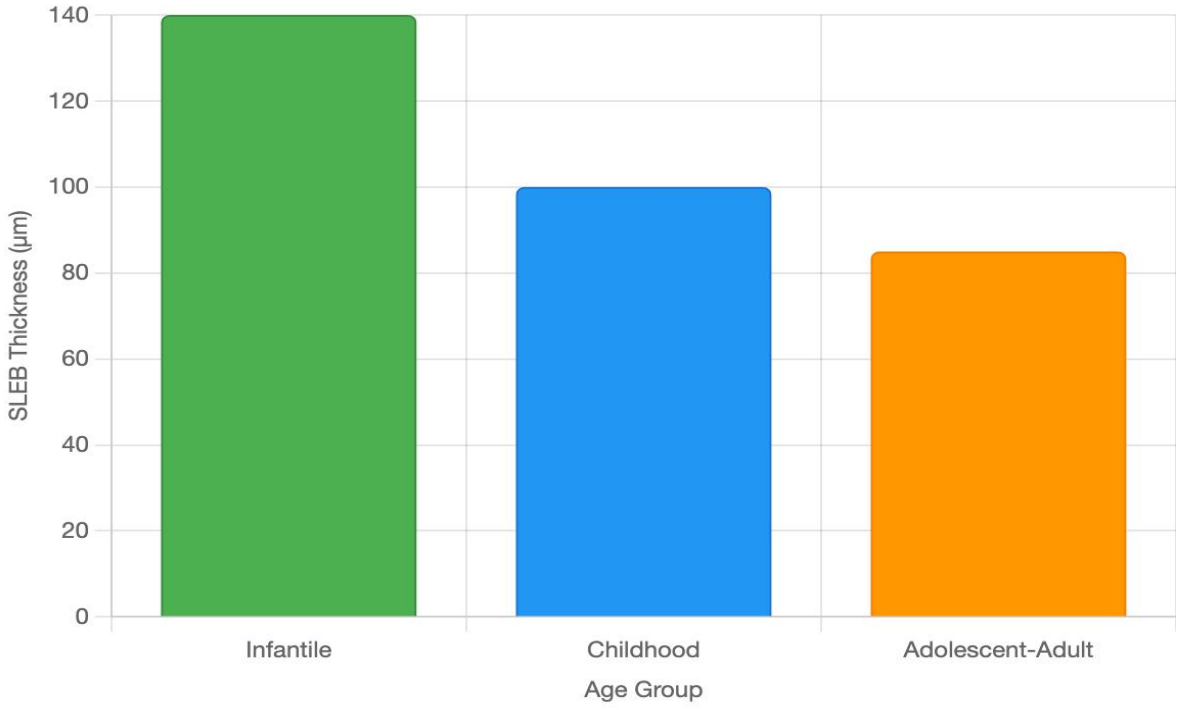

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Figure 3. SLEB Thickness by Age Group

Thus, these bar charts illustrate the subepidermal low echogenic band (SLEB) thickness in pediatric atopic dermatitis (AD) across severity, clinical forms, and age groups, based on a hypothetical study of 60 children. Figure 1 indicates increasing inflammation with severity, correlating with SCORAD scores. Figure 2 shows the highest inflammation in exudative AD and the least in lichenoid, reflecting acute versus chronic states. Figure 3 presents intense inflammation in infantile AD and reduced activity in older groups, consistent with AD's natural history. Together, these charts underscore SLEB thickness as a key marker of inflammation, varying systematically across AD severity, clinical presentation, and age, supporting the diagnostic utility of high-frequency ultrasound.

Discussion

High-frequency ultrasound provides objective insights into AD-related skin changes, complementing subjective clinical assessments [1, 4, 5]. Increased thickness and reduced echogenicity in severe and exudative AD reflect edema and inflammation, while higher echogenicity in lichenified forms indicates collagen deposition [6, 7]. Infantile AD shows acute inflammatory changes, whereas adolescent-adult AD exhibits chronic fibrotic patterns [7, 8].

SLEB, observed in 60–98% of lesion scans and 62–100% of healthy skin scans, is a key inflammation marker, correlating with SCORAD scores and histological inflammatory infiltrates [1, 9]. Its presence in healthy skin suggests subclinical inflammation, potentially predicting exacerbations [4, 5]. Ultrasound's ability to quantify these changes supports tailored therapies, such as anti-inflammatory treatments for exudative AD or barrier repair for lichenoid forms.

Limitations include operator dependency and the need for specialized equipment. Future studies should standardize protocols and correlate ultrasound with histological and immunological markers.

Conclusion

High-frequency ultrasound is a robust diagnostic tool for pediatric AD, providing quantitative data on skin structure and inflammation across severity, clinical forms, and age groups. Its ability to detect SLEB and monitor dynamic changes enhances diagnostic accuracy and treatment monitoring, facilitating personalized management. Integration with SCORAD can optimize patient outcomes.

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