Ultrasound in non-tumoral pathology of the skin

Mircea Negrutiu¹, Sorina Danescu¹, Theodor Popa², Adrian Baican¹

¹Department of Dermatology, ²Department of Rehabilitation, “Iuliu Hatieganu” University of Medicine and Pharmacy, Cluj-Napoca, Romania

Introduction

Currently, a series of imaging techniques such as videodermoscopy, high-frequency ultrasound (HFUS), reflectance confocal microscopy, and optical coherence tomography are used in dermatology [1]. They are meant to improve the quality of the diagnosis.

Ultrasound (US) is a noninvasive real-time imaging method with an application in many medical fields [2]. In dermatology, ultrasonographic frequencies vary in the range between 7.5 and 200 MHz for a better evaluation of epidermis, dermis, and subcutaneous fat tissue [3]. The 20 MHz transducer is feasible for cutaneous evaluation; however, it lacks the ability to assess the characteristics of the epidermis [4]. Ultra-high frequency US (UHFUS) is a diagnostic technique recently introduced in dermatological care, characterized by frequencies ranging from 30 to 100 MHz. Higher frequencies allow better spatial resolutions by sacrificing penetrability, for a frequency of 70 MHz the penetration being limited at 10 mm [5]. In inflammatory skin disorders such as psoriasis vulgaris it offers details that can be missed during clinical evaluations leading to treatment option changes [6]. In scleroderma, US allows the examination of parameters such as skin thickness, texture, and stiffness [7].

US elastography is a relatively new technique used to quantify tissue stiffness, in the evaluation of normal and pathological skin [8].

In this narrative review we aimed to overview the main uses of skin US in non-tumoral pathology (inflammatory and autoimmune pathology).

Keywords: ultrasound; inflammatory skin diseases; connective tissue diseases

Abstract

Skin ultrasound (US) is a relatively new imaging technique, for which interest has grown significantly in the last decade. Properties such as mobility, real-time imaging and lack of irradiation or sedation, have made it a useful tool in completing the clinical examination. The use of probes of different frequencies has managed to improve the US technique, offering the possibility of obtaining high quality images. Thus, by using high-frequency and ultra-high frequency US, subclinical information can be obtained with a wide applicability in dermatological pathology. In this paper we aim to discuss the main uses of skin US in non-tumoral pathology (inflammatory and autoimmune pathology).

Keywords: ultrasound; inflammatory skin diseases; connective tissue diseases

Inflammatory cutaneous diseases

Hidradenitis suppurativa

Hidradenitis suppurativa (HS) is an inflammatory debilitating disease associated with a series of systemic manifestations. Patients develop inflammatory painful nodules, abscesses, sinusous tracts and fistulas in typical areas such as the axillary, inguinal, gluteal and perianal region.

Cutaneous US was proved to be useful in visualizing a series of subclinical manifestations of the HS disease such as lower dermis echogenicity, higher echogenicity
of the subcutaneous tissue, larger hair follicles, pseudocysts without or with low echoic signal, fluidic collections and fistulous tracts [9].

Wortsman et al [10] showed that the fistulous tracts, visible only through US, seem to be the key signs of HS. Their evaluation can modify the severity index of the disease, and help in initiating a more aggressive therapy. The US aspect of the fistulous tracts is recognized as a bandlike anechoic or hypoechoic structures, connected to the base of the hair follicle (fig 1). The inflamed tissue returns normal echoes while hair thread trajectories are hyperechoic linear structures.

The role of US in diagnostic and monitoring of HS is also supported by Nazzaro et al study [11]. The authors compared the clinical score of evaluation with 6 degrees of severity, Physician Global Assessment (HS-PGA), with their own score, a score in which they introduced US criteria. They concluded that the HS-PGA clinical score underestimated the severity of the disease, especially in advanced HS.

The use of power Doppler can provide relevant information regarding the severity of the disease and help to anticipate the need to change the treatment approach. The lesions have been classified according to vascular morphology (minimal, moderate, and high) and distribution (peripheral, internal, mixt). In HS with prolonged chronic evolution the mixed vascular distribution suggests a higher degree of inflammation and activity. The size of the lesion was generally correlated with the presence of power Doppler signal and mixed vascularization. Vascularization can vary from peripheral (present in nodules and small or medium abscesses) to mixed (present in large abscesses and sinuous tracts) [12].

Also, US allows for a more accurate intralesional corticosteroids administration in the areas where the disease is active [13] and can enhance the result of surgery by evaluating the excision margins before the intervention, thus reducing the risk of recurrence at 24 weeks [14].

Psoriasis vulgaris

Psoriasis vulgaris, an inflammatory chronic disease defined by the appearance of erythematous placards covered by scale with variable distribution [15] is diagnosed mostly through clinical evaluation [16]. Cutaneous US brings important assistance to clinical examinations at diagnosis, disease management, but also in evaluating evolution and therapeutic response.

HFUS allows direct measurement of the thickness of different structures of the tegument. US in psoriasis vulgaris describes 4 bands with different echo structures: a hyperechoic band that represents the epidermis with hyper- and parakeratosis followed by a hypoechoic band that represents the elongation of the dermic papillae fol-

lowed by a hyperechoic band that is correspondent to the reticular dermis and last, the subcutaneous tissue visualized as a hypoechoic band [17] (fig 2).

Gutierrez et al [18] revealed that the most consistent US sign for a psoriasis plaque is the thickening of the epidermis and dermis (compared to the neighbouring skin). Furthermore, they identified disease activity signs such as higher Doppler flow, hyperechoic band present in the superior dermis (inflammatory oedema and vasodilation in the papillae dermis) and the absence of subcutaneous tissue damage.

The signs of therapeutic efficacy are the reduction of epidermis and dermis thickening, the disappearance of the hyperechoic band and the reduction of Doppler signals [18]. A series of studies revealed the advantages of US imaging in monitoring plaque evolution and medication efficacy. Dini et al [19] used UHFUS (70 MHz) in evaluating the psoriasis lesions before and after Ixeki-
zumab treatment by assessing the hypoechoic band and the local vascularization. The band thickness correlates to epidermal and dermal histological acanthosis, thus proving to be a useful parameter in evaluating its efficacy and therapy response. Lacarruba et al [20] studied the variations in skin thickness during treatment with clobetasol propionate 0.05% foam using ultrasound imaging with a frequency of 20 MHz in 30 patients that developed mild and moderate psoriasis vulgaris. Musumeci et al [21] evaluated the therapeutic response to cyclosporine treatment on 20 patients with moderate to severe psoriasis, through videodermoscopy and US, at 2, 4 and 8 weeks. They found that the skin thickness measured through ultrasonography was the first parameter that improved.

A complication of prolonged therapy with corticosteroids is cutaneous atrophy [22]. Cucoş M et al [23] compared the efficacy of the US with a 20 MHz transducer frequency to 40 MHz transducer frequency in detecting early corticosteroid induced cutaneous atrophy. Sixteen psoriasis plaques were evaluated during treatment with Hydrocortisone acetate 1% at onset and after 6 weeks. Epidermis and dermis thickness was assessed. Both exploration methods were proven useful in psoriasis evaluation for treatment management and morphology.

Additionally, US can be used in the evaluation of nail and nail bed psoriasis [24]. Nail involvement in psoriasis has been described as an important risk factor for psoriatic arthritis. Thus, an early diagnosis of this condition is necessary [25]. Due to the variation of nail plate thickness (decreasing from the thumb to the 5th finger) an adequate scan should include all nails and the evaluation should include both the longitudinal and transverse axis [26]. In the nail psoriasis US changes are thickening of the nail bed, poor definition of the ventral plate with hyperechoic focal areas, thickening of the ventral and dorsal plate as well as an increase in Doppler flow at the level of the nail bed [27]. In a study conducted by Ruscitti P et al [28], on 59 patients with psoriasis and psoriatic arthritis, US revealed a thickened matrix, echogenic inhomogeneity of the nail bed and increased flow during the power Doppler examination.

**Lichen planus**

Lichen planus (LP), an immune mediated chronically inflammatory pathology that influences skin, nails and mucosa, was also studied by US. Ianoși et al [29] described the LP lesions as having a hypoechoic fusiform band that corresponded to epidermal acanthosis and dermal inflammatory infiltrate. Yazdanparast et al [30] found that the thickness of the dermis was significantly higher and the density lower in LP patients compared to the control tegument, explaining these findings in relation with the dermic inflammatory infiltrate.

Izzetti R et al [31] presented an innovative US technique using a high frequency (70 MHz) transducer to evaluate lichen planus on oral mucosa. Different clinical types of LP (reticular, papular, bullous, plaque-like and erosive) were evaluated by US imaging. All lesions presented thickening and hypoechogenic in the superficial layer of the mucosa suggesting that the modifications distinguished in US imaging can be pathognomonic for oral LP. The lesions can be detected with a high accuracy in the superficial layer of the mucosa (fig 3).

**Paniculitis**

Panniculitis is a disease that affects the subcutaneous fatty tissue and is classified through its histological characteristics into septal (centered on fibrovascular interlobular septs) or lobular (centered on the adipose lobules). The diagnostic usually requires only clinical observation, but it must be confirmed through histopathology [32]. The aspect on ultrasonography is relatively specific through hyperechoic subcutaneous tissue, non-compressible hypoechoic septs and increased vascular Doppler signal [33]. Romani et al [34] proposed an ultrasound score to differentiate between septal and lobular panniculitis with a sensitivity of 86.19% and a specificity of 88.75%. They proposed the following criteria for septal panniculitis: hyperechoic septal thickening (thickness equal or over 1 mm in 3 or more septs) preferable in the proximity of non-compressible lobules, hyperechoic signals of adipose lobules, increased Doppler flow and a jigsaw overall aspect. The panniculitis that is predominantly lobular was defined as: lack of criteria for septal panniculitis, hyperechoic adipose nodules that are blurred and without Doppler flow [34].
Sarcoidosis

Sarcoidosis is a multisystemic granulomatous, non-caseating disease with unknown etiology. Sarcoid granulomas are described as hypoechoic lesions, with heterogeneous echogenicity, perilesional hyperechoic aspect and abnormal Doppler signal [35]. A higher Doppler flow can be seen inside the granuloma and in the surrounding dermis [36]. López-Llunell et al [37] observed the cutaneous patterns of sarcoidosis through US in 14 patients. All sarcoidosis lesions presented hypoechoic signals in dermis or subcutaneous nodules with a high echogenicity of the neighboring subcutaneous tissue and increased vascular Doppler signal.

Hypertrophic scars and keloids

Hypertrophic scars and keloids are caused by skin injuries, trauma, insect bites, burns, surgical interventions, acne, folliculitis and skin infections. The diagnostic is established through clinical examination, but ultrasound imaging can bring detailed information for a better management. Lobos et al [38] described the keloid as a hypoechoic or heterogeneous thickness of the dermis that displaces the epidermis upwards, follows the major axis of the skin (with or without laminar pattern) and that can reach the deep tissues. Subclinical fistulous tracts, calcifications in hypodermis and muscle damage were also observed (fig 4). The keloid was considered active if vascularization on Doppler examination was found. Guo et al [39] evaluated the scar thickness, Doppler flow and stiffness on 139 patients. The stiffness was statistically higher in the keloid group than in the healthy tegument. Shear wave elastography allows for a quantitative measurement of keloid stiffness. This new, noninvasive real-time technique helps evaluate the therapeutic response with a good correlation to Vancouver scar scale.

Autoimmune bullous diseases

Pemphigus and pemphigoid are two autoimmune bullous pathologies mediated by IgG antibodies against the structural proteins of desmosomes and hemidesmosomes. Pemphigus is a chronic, debilitating pathology characterized by antibodies against desmoglein 1 and 3 at the level of desmosomes, resulting in acantholysis and intraepidermal blistering on the skin and mucous membranes. Pemphigoid diseases are characterized by the presence of anti-BP 180 and anti-BP 230 antibodies against structural proteins at the level of hemidesmosomes, resulting in subepidermal blistering on the skin and mucous membranes [40]. Skin US in pemphigus vulgaris (PV) bullae reveals semi-arcuate anechoic patches in the epidermis with definite boundaries as well as a prominent hyperechoic line at the base of the anechoic area, indicating that the blister is situated intraepidermally [41]. The US appearance of bullous pemphigoid (BP) bullae is of subepidermal cystic structures with dermal hypoechogenicity. In the perilesional area, the dermis is hypoechoic, compared to normal skin. The Doppler signal is increased in both situations. These findings correlate histologically with the subepidermal bulla and the dermal inflammatory infiltrate [42].

UHFUS proves to be useful in the differential diagnosis of autoimmune bullous diseases. Zheng et al [43] observed that early-stage PV and seborrheic dermatitis (SD) can be differentiated with UHFUS. The US findings for PV were increased epidermal echo (57%), linear or oval intraepidermal hypoechoic/anechoic areas (86%), linear anechoic areas at the dermal-epidermal junction (100%), reduced echo of superficial to whole dermis (64%), and slightly increased dermal thickness (100%). The highest level of specificity (100%) was demonstrated by the intraepidermal hypoechoic/anechoic bands for PV while for SD the most specificity (100%) was found in the epidermal unevenness. Izzetti et al [44] showed that UHFUS has 75% diagnostic sensitivity for PV and 66.7% for mucous membrane pemphigoid (MMP), being able to establish the location of the blister (intraepidermal or subepidermal) with good concordance with histology.

Skin and soft tissue infections

The differentiation between abscess and cellulitis is necessary in establishing the optimal therapeutic management and is sometimes difficult to do clinically. US brings information about the location, size, cavity, content and surrounding tissues, helping to establish the diagnosis and the choice of therapy, contributing to the improvement of the patient’s outcome [45]. When cellulitis is mistaken for an abscess, an unneeded incision and drainage is made, along with the discomfort, anxiety,

Fig 4. Keloid: a) HFUS shows a hypoechoic dermal structure, well delimited, oval, with a linear fibrillar pattern; b) Color Doppler shows increased vascularity in the lesion.
and the need for procedural sedation that goes along with it [46]. The US appearance of a soft tissue abscess is as a well-circumscribed, hypoechoic fluid collection with peripheral hyperemia, swirling with compression, with posterior acoustic enhancement, that have cobblestoning or branching interstitial fluid [47] (fig 5).

Point-of-care US (POCUS) is an effective technique in the differential diagnosis between cellulitis and the abscess, which was introduced into emergency physicians’ training. According to Barbic et al [48] POCUS has a sensitivity of 96.2% and a specificity 82.9% in the diagnosis of abscess, both for adults and pediatric patients. Russell et al [49] proved in a study that included 162 patients confirmed with an abscess by the POCUS technique, that lesions deeper than 0.4 cm require drainage, and those less than 0.4 can be treated with antibiotics alone, with a sensitivity of 85%.

Elastography has the potential to aid in the diagnosis and treatment of developing soft tissue infections as they change from induration to fluctuant abscesses. Gaspari et al [50] proved that elastography found several abscess cavities and tissue induration that were not visible on B-mode imaging. They concluded that both the pattern and the color of the elastographic signal may be used to classify the abscesses.

We summarized the main ultrasound features of inflammatory diseases of the skin in Table I.

Table I. Summary of the main ultrasound aspects in inflammatory pathologies of the skin.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Ultrasound aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidradenitis suppurativa</td>
<td>Bandlike anechoic or hypoechoic structures connected to the base of the hair follicle (fistulous tracts)</td>
</tr>
<tr>
<td></td>
<td>Normal echoes (inflamed tissue)</td>
</tr>
<tr>
<td></td>
<td>Hyperechoic linear structures (hair thread trajectories) [10].</td>
</tr>
<tr>
<td></td>
<td>Mixt vascular distribution (prolonged chronic evolution) [12].</td>
</tr>
<tr>
<td>Psoriasis vulgaris</td>
<td>Hyperechoic band that represents the epidermis</td>
</tr>
<tr>
<td></td>
<td>Hyperechoic band that represents the elongation of the dermic papillae</td>
</tr>
<tr>
<td></td>
<td>Hyperechoic band that is correspondent to the reticular dermis</td>
</tr>
<tr>
<td></td>
<td>Hyperechoic band, that is correspondent to the subcutaneous tissue [17].</td>
</tr>
<tr>
<td>Lichen Planus</td>
<td>Hyperechoic fusiform band [29].</td>
</tr>
<tr>
<td></td>
<td>Thickness of the dermis higher and the density lower compared to the control tegument [30].</td>
</tr>
<tr>
<td>Septal panniculitis</td>
<td>Hyperechoic subcutaneous tissue, non-compressible</td>
</tr>
<tr>
<td></td>
<td>Hypoechoic septs and increased vascular Doppler signal [33].</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>Hyperechoic structures</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>Heterogenous echogenicity</td>
</tr>
<tr>
<td></td>
<td>Perilesional hyperechoic modifications</td>
</tr>
<tr>
<td></td>
<td>Abnormal Doppler signal [35].</td>
</tr>
<tr>
<td>Keloid</td>
<td>Hyperechoic or heterogeneous thickness of the dermis that displaces the epidermis upwards, follows the major axis of the skin (with or without laminar pattern) and that can reach the deep tissue [38].</td>
</tr>
<tr>
<td>Autoimmune bullous</td>
<td>PV: semi-arcuate anechoic patches in the epidermis with definite boundaries</td>
</tr>
<tr>
<td>diseases</td>
<td>Prominent hyperechoic line at the base of the anechoic area [41].</td>
</tr>
<tr>
<td></td>
<td>BP: subepidermal cystic structures with dermal hypoechogenicity;</td>
</tr>
<tr>
<td></td>
<td>Increased Doppler signal [42].</td>
</tr>
<tr>
<td>Soft tissue abscess</td>
<td>Well-circumscribed, hypoechoic fluid collection</td>
</tr>
<tr>
<td></td>
<td>Peripheral hyperemia</td>
</tr>
<tr>
<td></td>
<td>Swirling with compression</td>
</tr>
<tr>
<td></td>
<td>Posterior acoustic enhancement</td>
</tr>
<tr>
<td></td>
<td>Cobblestoning or branching interstitial fluid [47].</td>
</tr>
</tbody>
</table>
**Connective tissue disorders**

**Lupus erythematosus**

Lupus erythematosus (LE) is an inflammatory autoimmune disease. The subtypes of LE-specific skin disease are acute cutaneous LE, subacute cutaneous LE, and chronic cutaneous LE. US can be used for differential diagnostic and evaluation of the therapeutic response to medication for the multitude of different lupus subtypes. US was proved to be of assistance in choosing the place of biopsy indicating the region with most evident inflammation [51].

US aspects can range from active (inflammatory) to atrophic stages, depending on the degree of the disease’s activity. The dermis thickens and becomes less echogenic during the inflammatory stages, which are often accompanied by increases in the echogenicity of the subcutaneous tissue and local blood flow (fig 6). In contrast, the main US findings during the atrophic phase include decreased dermal and subcutaneous tissue thickness and a lack of anomalies in blood flow [52].

Kimball et al [53] studied the imagistic characterization through US, computer tomography and magnetic resonance in a case of face lupus panniculitis. US imaging revealed inflammatory and hyperemic modifications in the subcutaneous affected tissue and the neighboring areas. Panniculitis was described as a hyperechoic pseudo mass that could be distinguished from the subcutaneous perilesional tissue through a hypoechogenic rim layer without cystic components. A rise in central vascularization was spotted through Doppler. The main role of US was the differential diagnosis with abscess, liquid collection, or presence of a tumor [53].

**Systemic sclerosis**

In systemic sclerosis (SSc) cutaneous US can determine the subclinical extension of the disease assisting the clinical examination [54–56]. US is recommended for the qualitative and quantitative evaluation of skin layers, the differentiation between disease forms, and the staging and monitoring of skin abnormalities in SSc patients [57]. US examination of patients with SSc must include thickness and echogenicity measurements (B-mode US) of the skin, and elastography to measure stiffness in areas with modified Rodnan skin score (mRSS), using a linear HFUS probe of ≥18mHz and a large amount of gel to avoid compression [58].

Naredo et al [59] found significantly higher thickness of the dermis in patients that developed SSc compared to the control group. US’s ability to determine subtle modifications makes it a promising candidate for diagnosing and monitoring patients with SSc. Subclinical dermal involvement in individuals with limited cutaneous systemic sclerosis (lcSSc) may be visible by US even in skin regions with a normal mRSS. Sulli et al [7] proved that even in individuals with lcSSc who had a normal local mRSS, subclinical dermal involvement was found by US in the skin regions.

Determining tegument thickness and rigidity can help estimate individual responses to treatment [60]. Chen et al [61] measured the cutaneous thickness and stiffness in patients with lcSSc and diffuse systemic sclerosis (dSSc). Compared to the control group, the cutaneous thickness was significantly higher in patients with lcSSc and even higher in patients with dSSc and thickness was positively correlated to histological thickness measured on biopsy. Kaloudi et al [62] concluded that the use of US to identify digital dermal thickness in SSc is a trustworthy method that yields repeatable findings. In the entire group of individuals with SSc, US revealed a substantial dermal thickening. A significant correlation between the global mRSS and the local dermal thickness was found.

Shear wave elastography (SWE) is a useful tool for quantifying skin stiffness in patients with SSc. Santiago et al [63] proved that compared to mRSS, SWE measurements are more sensitive to changes. Sobolewski et al [64] compared the effectiveness of SWE with mRSS in patients with SSc and found that in hands and fingers a high positive correlation between elastographic skin strain and mRSS value was obtained.

**Morphea**

Morphea is an autoimmune connective tissue disease with variable clinical presentation. The subtypes that are usually evaluated are circumscribed, linear, coalescent plaque, pansclerotic and mixed. Valid measurements for evaluating activity and damage are necessary in case management. There are a multitude of clinical and paraclinical scores for morphea evaluation [65]. US was proven to be extremely useful in diagnosing early stages and disease evolution follow-up, allowing for a fast efficacious intervention and an optimal patient management. It can offer quantitative and qualitative anatomical data such as tissue thickness and structural anomalies while
allowing the possibility to grade inflammation through color Doppler and spectral curve analysis. Recent guidelines [66] recommend using transducers with frequencies ≥15 MHz while discouraging the use of very high frequency transducers (≥30 MHz) because they cannot detect structural anomalies, hypervascularization in the dermic-hypodermic junction, fascia or muscle structures. US signs in morphea in the inflammatory phase are loss of definition of dermic-hypodermic junction and the expression of the hypodermic diffuse or partial echogenicity. Hypervascularization of dermis and hypodermis can be observed. In the inactive phase there is a thinning of dermis and hypodermis with areas that lost adipose subcutaneous tissue, the dermis coming in direct contact with the fascia. In the final stage of atrophy, the dermis and hypodermis show high echogenicity with a fibrillary pattern due to the presence of collagen fibers [67]. Vera-Kellet et al [68] (fig 7) showed on 22 morphea patients under Methotrexate therapy, that US is useful in monitoring treatment response. In all cases, Doppler US showed subclinical signs of activity, more intense than the clinical visible limits.

We summarized the main ultrasound features of connective tissue disorders in Table II.

### Future perspectives

Currently, there are several studies that attest to the importance of skin US in inflammatory skin pathology, but being a relatively new field, additional research is needed. Although HS and psoriasis are intensively researched, future directions may also lie in the case of LP, particularly in the diagnosis of its malignant change and avoiding serial biopsies. Related to skin infections,
US has proven useful both in the diagnosis and in the evaluation of the therapeutic response in cutaneous larva migrans and cutaneous leishmaniasis showing specific patterns regarding the location and extent of pathological involvement [69, 70]. Using high-frequency probes, specific US aspects could be identified depending on the etiological agent.

Furthermore, information about the involvement of blood vessels such as the digital arteries can be performed [52]. These vessels can present thrombotic and vasculitis phenomena, which may complicate the treatment and/or prognosis of the rheumatic diseases.

Skin thickness was quantifiably measured by HFUS, and it corresponds with an accurate indicator of SSc activity, with the identification of a barely perceptible difference [71]. So HFUS could be used to anticipate visceral involvement and assess skin changes more efficiently and objectively in future studies.

As the field of aesthetic medicine continues to expand, there is a need for a non-invasive evaluation method to assess the efficacy of various treatments and products. Ultrasonography can fulfill this role by enabling evaluation of anti-cellulite therapies, identifying different types of tissue fillers in volumetric procedures, planning procedures and assessing their outcomes by evaluating body anatomy, assessing skin changes after anti-aging treatments such as microdermabrasion and fractional laser therapy, and guiding ultrasound-assisted procedures. Additionally, shear wave elastography has been demonstrated to be useful in evaluating skin tone for high-intensity focused ultrasound (HIFU) therapy, and further research is needed to expand its range of applications [72].

**Conclusion**

Skin US is a non-invasive, reproducible imaging technique that provides the dermatologist with information specific to each pathology. The major benefit of using US is to enhance clinical diagnosis, which lowers the risk of unneeded biopsies. In inflammatory pathologies, the accuracy of clinical activity scores increases by detecting clinically imperceptible changes and thus helps to promptly initiate a correct treatment. US is useful in monitoring the therapeutic response and can guide the administration of medications.

In order to incorporate the use of US into standard dermato logical practice, it is crucial to conduct additional research to establish standardized protocols, provide training to users, and increase awareness of this technique.

**Conflict of interest:** none

**References**


54. Ferreli C, Gasparini G, Parodi A, Cozzani E, Rongioletti
53. Kimball H, Kimball D, Siroy A, Tuna IS, Boyce BJ, Albay-
52. Wortsman X, Gutierrez M, Saavedra T, Honeyman J. The
51. Giavedoni P, Podlipnik S, Fuertes de Vega I, Iranzo P,
50. Gaspari R, Blehar D, Mendoza M, Montoya A, Moon
49. Barbic D, Chenkin J, Cho DD, Jelic T, Scheuermeyer FX. In
47. Santiago T, Santos EJF, Ruaro B, et al. Recommendations
44. Vera-Kellet C, Meza-Romero R, Moll-Manzur C, Ramirez-
43. Szymańska E, Walecka I. Applicability of shear wave elast-
42. Russell FM, Rutz M, Rood LK, McGee J, Sarmiento EJ.
41. Abscess Size and Depth on Ultrasound and Association
40. Russell FM, Rutz M, Rood LK, McGee J, Sarmiento EJ.
37. Mertens JS, Seyger MMB, Thurlings RM, Radstake TRDJ,
36. Szymańska E, Walecka I. High-resolution ultrasound imag
35. Szymańska E, Walecka I. High-resolution ultrasound imag
34. Szymańska E, Walecka I. High-resolution ultrasound imag
33. Mertens JS, Seyger MMB, Thurlings RM, Radstake TRDJ,
32. Dźwigała M, Sobolewski P, Maślińska M, Zakrzewski J, Paluch L,
28. Szymańska E, Walecka I. High-resolution ultrasound imag
26. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
24. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
22. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
21. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
20. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
19. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
18. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
17. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
16. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
15. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
14. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
13. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
12. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
11. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
10. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
9. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
8. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
7. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
6. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
5. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
4. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
3. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
2. Mlosek RK, Migda B, Migda M. High-frequency ultrasound
1. Mlosek RK, Migda B, Migda M. High-frequency ultrasound

Received 3 May 2020; Accepted 21 October 2020

Keywords: Ultrasonography; skin disease; Systemic sclerosis; Sitcklecell disease; Inflammatory bowel disease; Dermatomyositis; Scleroderma-Like Disorders; Morphea; Eosinophilic fasciitis; Ultrasound features; diagnostic role; correlation with histology; markers of disease activity; skin involvement in systemic sclerosis; a preliminary report.