

Principles of Dermatologic Ultrasound Diagnostics

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SUMMARY Ultrasound is a valuable diagnostic tool widely used in medicine. Recently, high-frequency ultrasonography has been introduced to dermatology owing to technical advances. Currently, the most often used frequency for skin imaging is between 20 and 25 MHz. Ultrasound images can be generated in different modes, i.e. one-dimensional A mode, two-dimensional B mode and C mode. This type of skin imaging is known as a noninvasive, reproducible and quantitative method, which can be used to evaluate skin characteristics in a variety of dermatologic diseases. It can find application in the assessment of skin tumors, morphea, psoriasis, lipodermatosclerosis, skin aging and photodamage, hypertrophic scars, wound healing processes and allergic reactions. Although skin ultrasonography and its clinical applications are still being explored, most probably it will be implemented in the routine dermatologic diagnosis in the forthcoming future.

KEY WORDS: high-frequency ultrasonography, dermatologic diagnostics

INTRODUCTION

Ultrasonography is considered to be one of the most frequently used diagnostic methods in medicine. Ultrasound was first discovered by Spallazani and Lazzaro, the zoologists who described an acoustic orientation sense in bats in 1794. Later, in 1881, the Curie brothers presented the piezo-electric effect of the sound waves (1,2). Ultrasound diagnostics has become widely used in medicine since the 1950s. First dermatologic application of ultrasound is dated back to 1979, when Alexander and Miller used ultrasound scanning to determine skin thickness (1-5). Moreover, in 1986 the software technology was introduced and enabled to process the signal as B-scanning (1,4).

BASIC PHYSICS OF ULTRASOUND

The commonly used ultrasound frequency of 3.5-7.5 MHz gives a resolution of 2-3 mm and penetration of more than 15 mm, which enables evaluation of deeper tissues (1,4). Unfortunately, these parameters are not sufficient for the superficial structure imaging. For dermatologic purposes, the ultrasound scanners using high frequencies, i.e. 15 MHz and more, producing a resolution of at least 50 µm, are essential. For such ultrasound characteristics, the term high-frequency ultrasound or high-resolution ultrasound has been introduced (1-4).

During the propagation in the skin, the ultrasound waves undergo reflection, retraction, scattering, attenuation or absorption by the examined

structures, mostly at the border of the adjacent media, generating various amplitudes of echoes influencing the ultrasound image characteristics. The ultrasound image is produced on the basis of the computer wave analysis and consists of different echogenicity areas. The average skin (epidermis and dermis) acoustic velocity is about 1580 m/s (1,6). The ultrasound images can be generated in different modes. The A (amplitude) mode, the one-dimensional presentation was used previously for skin thickness measurements. At present, this type of signal processing is mainly used in ophthalmology. The B (brightness) mode is a two-dimensional presentation producing vertical cross-sectional image of the scanned tissue. The C mode produces images horizontal to the skin surface (1,4,7).

The axial ultrasound resolution refers to the ability to discriminate between two adjacent points or to the smallest thickness of a structure that can be measured and directly depends on the frequency. The lateral resolution refers to the width of the smallest structure that can be resolved and depends on the geometric parameters of the ultrasound beam (2,4,8). Currently, the most often used frequency in dermatology is between 20 and 25 MHz providing an axial resolution of 50-80 μm and lateral resolution of 200-300 μm . When operating at higher frequencies between 40 and 100 MHz, the resolutions are produced as follows: axial resolution of 17-30 μm and lateral resolution of 33-94 μm (1-4,9). The penetration of the ultrasound beam is described as 6-7 mm at a frequency of 20 MHz and even up to 1-2 mm at a frequency of 100 MHz (2,4). The following structures can be evaluated using different frequencies: subcutaneous lymph nodes using 7.5-10 MHz transducers (penetration of 2-3 cm), skin intermediate region down to the muscle fascia using 20 MHz transducers (penetration of 7 mm), and even epidermis and upper corium using 50-150 MHz transducers. Generally, when the frequency is higher, the resolution of the image is better, but at the same time the tissue penetration diminishes. Therefore, the more detailed visualization of the superficial skin layers, the less clear images of the subcutaneous tissues can be obtained. In order to evaluate different skin structures, the transducer probes with various frequencies should be used, according to clinical indications (1-4,6,7,9).

CLINICAL APPLICATIONS

The high-frequency ultrasound diagnostic procedure is known as a noninvasive, reproducible,

quantitative and safe method, which can be used in a variety of dermatologic diseases. Ultrasound imaging has been well established in the diagnosis of different types of skin tumors. Depth and thickness of the following tumors can be evaluated: basal and squamous cell carcinomas, benign nevi, melanoma, dermatofibromas and neurofibromas. It is essential for preoperative margin determination; unfortunately, reliable differentiation between these tumors is not possible using 20 MHz ultrasonography (3,4). Moreover, the high-frequency ultrasound provides additional information on the lesion quality (solid, cystic and combined) and inner structure of tumors (homogeneous, inhomogeneous, hypoechoic, hyperechoic, calcification foci and necrosis) (8).

The measurement of skin thickness is one of the main applications for ultrasound imaging. Skin thickness changes may be due to acanthosis, atrophy, edema, collagen accumulation and its configuration, degree of hydration in the dermis or inflammatory cell infiltration. They can also develop as the result of treatment as an intended or side effect. Therefore, among often evaluated dermatoses, besides different skin tumors, are morphea, psoriasis, lipodermatosclerosis, skin aging and photodamage, hypertrophic scars and wound healing processes (1-4,6,7,10-14). Rippon *et al.* used 20 MHz ultrasound in monitoring wound healing and were able to visualize and quantify such wound healing components as collagen accumulation, re-epithelialization and wound volume (7). In psoriasis ultrasound can be used to determine the severity index and to monitor therapeutic efficacy in plaque psoriasis (1,2,15). Ultrasound can become a very important diagnostic tool to detect some skin changes like skin thickening in scleroderma or gravity influence on the skin in monitoring skin water balance, even before clinical manifestation (4,16). Moreover, in scleroderma ultrasound B-scans can provide information on the corium, subcutaneous fat tissue and muscle fascia, and permits evaluation of the extension of the sclerotic process (17). Skin atrophy due to corticosteroids can also be evaluated by measuring dermal echogenicity and skin thickness prior to any clinical signs of thinning (18). The assessment of dermal edema in patients with venous leg ulcers performed with high-frequency ultrasound enabled Hu *et al.* to suggest that the edema due to chronic venous insufficiency is located in the papillary dermis (19). As reported by Gniadecka, in lipodermatosclerosis edema is located subepidermally (12).

Other clinical applications of high-frequency ultrasound include evaluation of the progressive inflammatory reactions and acute or chronic inflammatory processes including atopic dermatitis, eczematous lesions and patch test reactions (2,4,20,21). Moreover, visualization of calcification and even foreign bodies is possible (3). It is important to note that ultrasound skin imaging can become a very important noninvasive, painless and reproducible dermatologic diagnostic tool in children (22).

In case of a dynamic process evaluation, there is the need of frequent clinical observation and objective methods in the assessment of the disease evolution. Ultrasound diagnostics procedures are also suitable for the follow up of chronic inflammatory dermatoses and their therapeutic efficacy by the measurement of skin thickness changes and modifications of skin echogenicity (2,9,14,15).

CONCLUSION

The clinical applications of high-frequency ultrasonography are quickly expanding. This dermatologic diagnostic technique provides a precise, sensitive, noninvasive and reproducible method of skin evaluation, which enables objective visualization *in vivo* providing information on the dynamics of the pathologic processes and skin reaction to therapy applied.

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