Ultrasound Characteristics of the Hair Follicles and Tracts, Sebaceous Glands, Montgomery Glands, Apocrine Glands, and Arrector Pili Muscles

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Objectives—To explore the capability of very high-frequency ultrasound (US; 50–71 MHz) to detect the normal morphologic characteristics of the hair follicles and tracts, sebaceous glands, Montgomery glands, apocrine glands, and arrector pili muscles.

Methods—A retrospective study, approved by the Institutional Review Board, evaluated the normal US morphologic characteristics of the hair and adnexal structures in a database of very high-frequency US images extracted from the perilesional or contralateral healthy skin of 1117 consecutive patients who underwent US examinations for localized lesions of the skin and 10 healthy individuals from December 2017 to June 2018. These images were matched with their counterparts from the database of normal histologic images according to the corporal region. The Cohen concordance test and regional mean diameters of the hair follicles and adnexal structures were analyzed.

Results—The normal hair follicles and tracts, sebaceous glands, Montgomery glands, apocrine glands, and arrector pili muscles were observed on US images and matched their histological counterparts in all the corporal regions. There was significant US concordance (κ = 0.82; P < .0001) among observers. Regional mean diameters (millimeters) of the hair follicles, sebaceous glands, and apocrine glands are provided.

Conclusions—The hair follicles and tracts, sebaceous glands, Montgomery glands, apocrine glands, and arrector pili muscles are detectable with very high-frequency US, including some regional and anatomic variants. Knowledge of their normal US appearances is a requisite for detecting subclinical changes, understanding the physiopathologic characteristics, and supporting the early diagnosis and management of common dermatologic diseases.

Key Words—apocrine gland ultrasound; arrector pili muscle ultrasound; dermatologic ultrasound; hair ultrasound; Montgomery gland ultrasound; sebaceous gland ultrasound; skin ultrasound; ultrasound dermatology

Skin conditions are among the leading causes of the global burden of disease.1 However, to date, common dermatologic disorders still present unclear points in their physiopathologic characteristics and management.2 The ability to noninvasively...
detect the normal morphologic characteristics of the hair and adnexal glands can allow identification of early subclinical abnormalities in many dermatologic conditions that affect millions of people worldwide, such as alopecia and acne.3,4

Hair is a complex and dynamic structure that is one of the main hallmarks of mammals and a distinctive characteristic of an individual.5 The presence of an excessive amount or its loss can strongly affect self-esteem.6

Sebaceous glands contribute to the lubrication of the skin and hair.7 Variants of these glands are located in some parts of the body, such as Montgomery glands in the areola.8

Apocrine sweat glands provide support to the thermoregulation and supposedly influence the scent of an individual.9 These are located in some parts of the body, such as the scalp, ciliary glands of the eyelids (Moll glands), external meatus (ceruminous glands), and axillary and perineal regions, among others.10

Currently, ultrasound (US) is a suitable and rapidly growing imaging modality for studying skin and nail disorders because of the development of high-frequency transducers (≥15 MHz).11 Although the US characteristics of the hair follicles and tracts have been reported at 15 MHz,12,13 this frequency does not allow distinction of the internal part of the hair tract located inside the hair follicle or the adjacent adnexal structures, such as sebaceous glands, apocrine glands, and the arrector pili muscle.

Besides a few attempts to describe the morphologic characteristics of the hair and sebaceous glands using experimental US devices in small series,14-16 to date, there are no reports on the US morphologic characteristics of the rest of the adnexal structures such as the apocrine glands and the arrector pili muscle on devices that are available worldwide. This study aimed to explore the capability of very high-frequency (≥50 MHz) US for detecting the normal morphologic characteristics of the hair follicles and tracts, sebaceous glands, apocrine glands, Montgomery glands, and arrector pili muscles.

Materials and Methods

A retrospective study of the database of dermatologic US examinations approved by the Institutional Review Board (approval number 055-2018) was performed from December 2017 to June 2018. Before the US examinations, all patients signed an informed consent form following the standardized protocol for education and research of our center, and all of the examinations and images were analyzed under the Helsinki principles of medical ethics. In the case of children, the parents or guardians signed the informed consent, and all images were deidentified. The database was composed of 1127 examinations; 1117 of them were consecutive patients examined by dermatologists. The rest were 10 healthy adults.

In patients’ examinations, the dermatologic US protocol typically includes a comparison with the healthy skin located in the perilesional area or the contralateral side. The patients underwent very high-frequency US studies of the healthy skin after examinations with another US device (LOGIQ E9 XD Clear; GE Healthcare, Waukesha, WI) equipped with a transducer working at a maximum frequency of 18 MHz. The healthy individuals underwent very high-frequency US examinations of the face (right cheek), right axillary region (middle third), and right thigh (upper and inner third) region, and the diameters (millimeters) of the hair follicles, sebaceous glands, and apocrine glands were measured. All cases were studied with the same very high-frequency transducer that operates at a range of frequencies from 29 to 71 MHz (Vevo MD, UHF 70; VisualSonics, Toronto, Ontario, Canada). This transducer had an axial resolution of 30 μm and a lateral resolution of 65 μm. An automatic setting for superficial structures that comprises a range from 50 MHz (center) to 71 MHz (maximum), a minimum gain of 43 dB, low persistence, and a dynamic range of 65 dB was used. Automatic adjustment of the frequency of the transducer according to the depth of the observation was enabled. Since the targets were composed of very superficial structures located in the first 5 mm; the transducer automatically set the frequency at the higher values of the bandwidth. The maximum depth for this transducer is 10 mm; the focal depth is 5 mm; and the view was adjusted by using a copious amount of gel, according to the diameter and depth of the structure and the thickness of the skin in each corporal region. The spatial resolution was 0.05 mm (50 μm). There were 2 more transducers available for use with the very high-frequency device (Vevo MD; VisualSonics): UHF 48 (range, 20–46 MHz) and
UHF 22 (range, 10–22 MHz). However, neither of these very high-frequency transducers nor the available 18-MHz transducer (maximum frequency) working on the LOGIQ E9 XD Clear machine was used in the study for detecting or identifying structures.

The inclusion criteria were patients with localized skin lesions on one side of a corporal segment who were otherwise healthy and healthy adults with no history of cutaneous procedures or surgery in the examination regions. The exclusion criteria were a history of systemic dermatologic diseases and a history of cosmetic or plastic surgery procedures.

**Ultrasound Technique and Staff**

A copious amount of gel was applied on top of the skin, and the structures were registered in at least 2 perpendicular axes. The axis of the transducer was aligned with the major axis of the hairs and adjacent structures in the different corporal regions. The protocol of the study followed the previously published guidelines for performing dermatologic US examinations.17

The US and histologic matching of the images was performed by a single senior radiologist trained and working on dermatologic US for more than 15 years and 2 senior dermatopathologists, both with more than 15 years of experience. The US morphologic characteristics of the hairs and glands were analyzed according to the corporal regions (head, neck, trunk, and upper and lower extremities) and subdivided into more specific anatomic areas when particular characteristics were noticed.

**Detection and Identification of Structures**

The structures were detected and identified on US images according to their published and available histologic representations in the database of normal histologic patterns of the Department of Pathology. A pilot catalog of US images and videos was created to start the identification of the structures. This catalog was developed by a radiologist and a dermatopathologist. The histologic specimen was considered the reference standard for matching the US and histologic images. During this process, comparisons and matching of the US and histologic images of the normal hair and adnexal structures at higher and lower levels of magnification, and according to the corporal region, were performed.

A tutorial with comparative histologic and US images of the same cutaneous structures was developed. Then a questionnaire with US images that were different from the ones used in the tutorial was built. Both the tutorial and questionnaire were sent to 5 medical observers from different medical backgrounds and levels of training who were not involved in the generation of the data. These observers included a dermatopathologist, a resident of pathology (second year), a dermatologist, and 2 medical students (second year). These observers blindly and separately answered 15 questions focused on the US identification of structures after a review of the tutorial.

**Statistical Analysis**

The statistical analysis was performed by an independent statistician and included a concordance test (Cohen κ test) with Stata version 12.1 software (StataCorp, College Station, TX), which was applied to the group of 5 observers of different medical backgrounds who were not involved in the generation of data. $P \leq .05$ was considered significant.

**Results**

The 1117 patients in the study had a mean age of 36 years (SD, ±21.2 years; range, 1 month–100 years) and included 1066 adults and 61 children (58% female and 42% male). The 10 healthy adults had a mean age of 40 years (SD, ±17 years; 50% male and 50% female).

The normal hair follicles and tracts, arrector pili muscles, sebaceous glands, Montgomery glands, and apocrine glands were detected and matched their histologic counterparts in all cases (Figures 1–6 and Videos 1–9). The statistical analysis of concordance among observers showed a significant, very good κ value ($\kappa = 0.82$; $P = .0001$). The mean diameters (millimeters) in 2 perpendicular axes (depth and thickness according to the major structural axis) of the hair follicles, sebaceous glands, and apocrine glands in different body regions are presented in Table 1.

**Normal US Morphologic Characteristics of the Hair Follicles and Tracts**

The normal morphologic characteristics of the hair follicles consisted of oblique hypoechoic dermal
bands that matched previous descriptions. Their depth and thickness varied according to the corporal region, being shorter and thinner on the face and deeper and thicker on the scalp (Figure 1 and Videos 1–3). Even though the hair follicles were already detected and identified in most of the corporal regions, the bottoms of the hair follicles located on the hypodermis of the scalp were not fully observed in all cases with the 50–71-MHz transducer and setting, and their complete view required lower-frequency transducers (15–48 MHz), which were also available. However, these lower-frequency transducers were not used for identifying the cutaneous structures in this study.

The hair tracts inside the hair follicles were observed in some corporal regions such as the axillary, perineal, lower extremities, eyebrows, and eyelids. The morphologic characteristics of the internal parts of the hair tracts were similar to the echo structure already reported in their visible parts on the

Figure 1. Hair follicles and tracts. A–D, Normal US morphologic characteristics of the hair follicles in different corporal regions (A, thigh; B, groin; C, face; D, scalp) and the hair tract (A). E, Histologic specimen of a hair follicle and its parts (scalp region; hematoxylin-eosin, original magnification ×40). Notice the bilaminar morphologic characteristics of the hair tract at the thigh region (A).
surface of the skin for the same regions. This pattern was predominantly hyperechoic and bilaminar except the eyebrows and anterior part of the eyelids, which showed monolaminar hairs in their superficial parts. A bifurcation and slight dilatation of the base of the hair tract was detected in some regions, which corresponded to the bulb of the hair (Figures 1 and 2 and Videos 1 and 2).

**Normal US Morphologic Characteristics of the Arrector Pili Muscles**

The arrector pili muscles appeared as well-defined, oblique, hypoechoic, thin bands that emerged from the hair follicle region and ran to the upper dermis. It was possible to observe these muscles in parts of the trunk and limbs (Figure 3 and Video 3).

**Normal US Morphologic Characteristics of the Sebaceous and Montgomery Glands**

The morphologic characteristics of sebaceous glands consisted of oval hyperechoic structures attached to the hair follicles. They were more easily detected on the face and proximal parts of the limbs (Figure 4 and Videos 4 and 5).

The Montgomery glands appeared as clusters of sebaceous glands without distinguishable hair follicles.

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**Figure 2.** Eyelash hair follicles and tracts (lower eyelid). A, Normal US morphologic characteristics of the hair follicles and tracts of the eyelashes. B, Histologic correlation (hematoxylin-eosin, original magnification x20). On the US image, notice the bilaminar pattern of the hair tracts of the eyelashes both outside and within the hair follicle.
These glands were observed in the areolar and periar-eolar regions of the breast and, in some cases, in the mons pubic and perineal regions (Figure 5 and Video 6).

**Normal US Morphologic Characteristics of the Apocrine Glands**

These glands appeared as round or oval hypoechoic structures that contained multiple and tiny anechoic lacunar regions that resembled an ovary; therefore, their appearance was named a “pseudo-ovary pattern.” These glands were observed in the axillary, perineal, perianal, and inner aspects of the proximal parts of the arms and thighs (Figure 6 and Videos 7–9).

In 16 cases (80% of them female), there were prominent apocrine glands in the axillary regions. Some of these cases showed a second row of apocrine glands in the middle thirds of both axillary regions (Figure 6C and Video 9). This variant was not observed in the groin regions.

**Discussion**

The US detection and in vivo identification of the normal morphologic characteristics of the hair and adnexal structures, considering variants and without having to use a contrast medium, provide a safe and powerful tool for detecting and identifying early subclinical abnormalities in a wide range of dermatologic conditions and can support research in this field. To our knowledge, the ability to observe the apocrine glands, which has not previously been reported, may be relevant in the clarification of its role in the physiopathologic characteristics of devastating inflammatory cutaneous diseases such as hidradenitis suppurativa.
This work also describes the US appearance of the normal Montgomery glands that, to our knowledge, has not been reported previously and has been suggested as the origin of areolar cysts. The description of the US appearance of sebaceous glands may support the subclinical diagnosis and treatment of common dermatologic inflammatory entities such as acne and rosacea and the detection of benign and malignant sebaceous tumors.

The appearance of the hair tracts within the hair follicles confirmed the previous descriptions of their outer echo structure pattern and can provide a...
noninvasive tool for observing anomalies in the generation of hair. The description of the mean diameters of these structures in different corporal regions, as well as the presence of normal regional variants, can help in understanding the physiopathology characteristics, early detection, and management of common abnormalities such as sebaceous hyperplasia and folliculitis.

The high concordance in the interpretation of the images among observers with different levels of medical training can be related to the high definition of very high-frequency US images. Hence, US and histologic matching of images may potentially represent an important advance in the dermatologic imaging field. Although imaging is not intended to replace histologic analysis, it could support a more reasonable use of biopsies and prevent the sequelae of scars.

The locations of these structures, including the depth, did not present a limitation for their US detection using a 50-MHz or higher-frequency transducer except the observation of the bottoms of the hair follicles of the scalp in some cases, which required a lower-frequency transducer because of their deeper location; however, the identification of these structures has already been performed with a very high-frequency transducer.
In contrast, other imaging techniques commonly used in dermatology have relevant issues due to their light-based technology, which has low penetration. For example, confocal microscopy had a maximum penetration that goes from 0.2 to 0.3 mm in depth, and optical coherence tomography has a maximum penetration that varies between 1.8 and 2.0 mm. These limitations in penetration mean that a lesion located or involving an area beyond these points could be partially or not seen, which, for example, could be a critical factor for diagnosing the real extent or the origin of a skin tumor. On the other hand, the current commercially available imaging techniques, such as computed tomography and magnetic resonance imaging, do not have enough resolution to distinguish hair follicles and adnexal glands. Magnetic resonance imaging requires immobilization, motion correction, and powerful devices of 7 T or higher for detecting dermal abnormalities, which can be very expensive in comparison with the capabilities of the current US machines that are available worldwide.

Limitations of this study were structures that measured less than 0.05 mm and the detection of pigments. Other potential limitations were that the performance and interpretation of these images required physicians trained on US examinations of superficial structures. However, at the same time, this could also have been an advantage and could have provided consistency to the study because any field of medicine requires proper training for interpreting the results correctly. Regarding the dermatologic US field, there is a broad range of practical applications of US, as well as a growing number of articles and books on this topic. Moreover, nowadays, the possibility of training is available in several countries, and annual courses are provided by international scientific organizations such as the American Institute of Ultrasound in Medicine (www.aium.org) and the European Federation of Societies for Ultrasound in Medicine and Biology (www.efsumb.org), among others.

As presented in this study, the detection of what is normal is a requisite for assessing abnormal US patterns of dermatologic conditions. Furthermore, the high correlations between US and histologic findings can give a confident base for interpreting and validating the imaging findings.

In conclusion, the normal hair follicles and tracts, sebaceous glands, Montgomery glands, apocrine glands, and arrector pili muscles are detectable with US, including anatomic variants. Knowledge of their US morphologic characteristics may provide a valuable and powerful noninvasive tool for detecting subclinical changes, improving the understanding of the physiopathologic characteristics, and supporting the diagnosis, management, and research of common dermatologic diseases.

References


