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ULTRA HIGH FREQUENCY BREAST ULTRASOUND: PRELIMINARY RESULTS

Gatta G.[1], Gallo L.[1], Russo G.M.[1], Falco G.[2], Londero A.P.[3], Brunese L.[4], Grassi Ra.[5], Di Grezia G.[6]
[1] Radiology Department, University of Campania Luigi Vanvitelli, Naples, IT
[2] Breast Surgery Unit IRCCS Santa Maria Nuova Reggio Emilia, IT
[3]Clinic of Obstetrics and Gynecology, University of Udine, Udine IT
[4]Health Science and Medicine Department, University of Molise, IT
[5]University Hospital of Florence, Florence, IT
[6]Radiology Department, "G Criscuoli" Hospital, Sant'Angelo dei Lombardi, Av IT
Email: graziella.digrezia@gmail.com

Abstract

Purpose: Ultra high-frequency ultrasound (up to 70 MHz) allows an extremely accurate assessment of the breast skin layers as well as hair follicles in axilla, areola and nipple. The aim of the study was to evaluate the normal anatomy of the breast within the first 1 cm of the skin surface using ultra high the world's first ultra ultra high-frequency US system for routine clinical use available today and its utility as a diagnostic tool.
Methods: In this study were involved 7 patients (6 females and 1 male) with a mean age of 40.3 yo (range 31-53 yo). Images were acquired on the breast skin on upper outer quadrant, on axilla and in nipple-areolar region.
Results: Periareolar and subcutaneous regions are often difficult to examinate with conventional ultrasound; this method allows to ultra highlight anatomical details such as skin layers, nipple, areolar and ducts structure.
Conclusion: Ultra high frequency breast ultrasound provides important information on the anatomy expecially in nipple-areolar region and in the evaluation of skin thickness and could improve the clinical diagnosis and the preoperative planning.

Keywords: *breast anatomy, periareolar region, papilloma, ultra high frequency ultrasound*

Introduction

Ultra high frequency ultrasonography can be considered the future in ultrasonic imaging thanks to the improved spatial resolution although the reduced depht of penetration [1]. One of the first application of this technique was small animal imaging, followed by blood vessel wall, eye [2] and skin.

The current indication for ultra high frequency probes, that can rise up to 50 MHz are the superficial structures, the preoperative measurements of tumor thickness in melanoma and the evaluation of soft tissue diseases and inflammatory skin disease [3], subcutaneous tissue and deep structures (muscles, tendons, bone margins and regional lymph nodes); blood flow can be estimated with color Doppler use.

Superficial breast disease with skin or first order ductal involvement is often difficult to obtain, although the last generation diagnostic procedures [4,5].

The recent introduction in clinical practice of last-generation ultra ultra high-resolution transducers with frequencies as ultra high as 50 MHz could become progressively an efficient help to improve the diagnosis of skin thickening or retraction, inflammatory carcinoma, papillary lesions, Paget disease or dermatologic diseases of the breast [6,7].

In this study, we analyzed the normal ultrasonography anatomy of the breast skin, the axilla, the nipple-areola complex and retro areolar ducts obtained with the world's first ultra ultra high-frequency US system for routine clinical use available today, with emphasis given to the capability resolution as fine as 30 μm [8].

This paper aims to review the basic principles of ultra high frequency ultrasound and its applications in breast superficial and peri areolar structures.

Methods

Images were acquired by using a commercially available US system (VevoMD; FUJIFILM VisualSonics, Amsterdam, the Netherlands) with a 15–50 MHz linear-array transducer.

In this study were involved 7 patients (6 females and 1 male) with a mean age of 40.3 yo (range 31-53 yo). Exclusion criteria were the presence of malignant breast lesions, previous surgery or breast implants.

All patients underwent breast examination and ultrasonography in the two weeks before the HFBU to exclude breast disease. Patients older than 40 underwent mammography in addition.

Images were acquired on the breast skin on upper outer quadrant, in nipple-areolar region and on axilla. A normal amount of gel was applied on the surface, also with a stand-off pad for nipple-areola complex.

Sagittal and axial B-mode scans were performed in order to obtain data on subcutaneous structures and ducts. Colour Doppler US was also performed to study intralesional vascularity.

Results

Anatomy – ULTRASONOGRAPHY OF THE NORMAL BREAST

To identify breast diseases with ultra high frequency ultrasound is necessary to analyze the normal ultrasonographic findings in the field of view.

The ultra high frequency probes clearly ultra highlights, the different layers of the skin, the cutaneous and subcutaneous structures represented by a succession of hypo and hyperechoic bands (tab.1, ***Fig.1***). The epidermis is presented as a hypoechoic line; the dermis, as a hyperechoic band, less shiny than the epidermis; and the subcutaneous tissue, as a hypoechoic layer with the presence of hyperechoic longitudinal structures corresponding to fibrous septa therein.

In the axilla (***Fig. 2***) there are also hair follicles that appear as hypoechoic structures arranged slantwise; they can be observed in the dermis or subcutaneous tissue.

Anatomy of NAC

The nipple areola complex (NAC) comprises the areola and the nipple.

The areola, with its round shape, is variable in size, from 3 to 6 centimeters, and is normally situated around the forth rib level. Its skin is characterizes for the presence of sebaceous glands that makes projections on its surface, forming tubercle of Morgagni, which during pregnancy become enlarged giving rise to tubercles of Montgomery.

In the center of the areola there is the nipple, averaging from 10 to 12 mm in wide and from 9 to 10 mm in height. Its skin is similar to the areola, but without sebaceous glands. It has 10 to 20 pores corresponding to the output of the main ducts [9,10]. (***Fig. 3***).

The nipple is a hypoechoic structure at the skin surface that occasionally produces an intense acoustic shadow as a result of the dense connective tissue within it (***Fig. 4***).
The NAC has no subcutaneous tissue. The skin of the nipple rests on a thin layer of the areolar muscle,
which fibers have two directions: radial (muscle of Meyerholz) and circular (muscle of Sappey).
Below the areolar muscle there is a thin layer of fat which disappears as it approaches the papilla. In this pre-mammary fat tissue layer vessels are found running on radiated sense [11].
The ultrasound appearance of the skin using the 48-70 MHz linear-array transducer is an echogenic line immediately under the transducer in the near field. It is normally about 2 to 3 mm thick. HFBU provides more important information on the anatomy of the premammary zone (skin and overlying breast fat, in particular breast skin thickness and absence of hair follicles in the areola skin, and of the sub areolar region [12]. For these reasons we believe that the use of ultra high-frequency transducers could be increased for women with nipple discharge.
In addiction ultrasonography showed the superficial layer of superficial fascia (SLSF), in the subcutaneous adipose tissue, and its thick turning point, key structures of the peri areolar area. In fact some authors believe that it is important to suture the SLSF securely, and that the suture should include the thick turning point to reduce scar widening and hypertrophy at the peri areolar incision [13].
The NAC is mainly supplied by internal mammary artery, also known as internal thoracic artery, which is branch of the subclavian artery. Internal mammary artery sends perforating branches along the first, second, third and fourth intercostal spaces, crossing the pectoralis major and irrigating the inner half of the breast, including the NAC. The intercostal arteries, which are branch of the aorta, also cross the pectoralis major and irrigate the deep surface of the breast, complementing the arterial vascularization of the NAC. Because of the presence of retroareolar ducts and blood vessels, there may be marked vascularity in the retroareolar region on color or power Doppler imaging. An understanding of the vascular anatomy of NAC is clinically relevant beyond nipple-sparing mastectomy to the avoidance of ischemic complications [14]

Discussion

Some breast diseases of superficial structures are difficult to diagnose, especially in the evaluation of skin and subcutaneous involvement of neoplastic lesions [15].
In recent years, advances in diagnostic imaging were made possible by developing new technologies preliminarily applied only in preclinical settings on animal models [16,17].
Small animals investigations allowed the development of more powerful systems, such as ultra ultra high-frequency US. This is the first anatomical description of the breast made with ultra ultra high-resolution US equipped with a 48–70- MHz linear-array transducer [10].
The availability of ultra ultra high-frequency US probes equipped with color Doppler could permit an easy, advanced and non invasive evaluation of a variety of superficial targets within the first 1 cm of the skinsurface
Ultra high-resolution frequency ultrasound plays a complementary role to physical examination in the assessment of superficial lesions and is the only imaging modality useful in the evaluation of superficial cutaneous lesions that are too small to be analyzed on conventional ultrasound [18, 19], CT or MRI; it is useful to reduce errors in conventional ultrasound examinations and then to decrease the numbers of invasive procedures like biopsies and fine needle aspirations [20-22].
Ultra high frequency ultrasonography can be use in the evaluation of benign and malignant neoplasms, inflammatory diseases and infectious diseases [23]. Potential indication of this technique are the measurement of thickness, invasion depth, the evaluation of the margins of breast and/or skin tumors and post-surgery follow-up, skin thickening or retraction assessment, inflammatory carcinoma, papillary lesions, Paget disease or dermatologic diseases of the breast. It could be also useful in the monitoring of topical and systemic drugs effects [24-27]
In addition ultra ultra high-frequency US could be useful as guide to biopsy superficial lesions of the breast [28].
However, because its application is relatively new in breast diseases, further studies are needed so that terminology and evolutionary analysis criteria can be

standardized, expanding its practice in routine exams [29]

In conclusion, HFBU holds great promise for addressing important biomedical applications offering unique advantages over the existing non-invasive imaging modalities. Future goals for US trials need to include further validation studies, studies of diagnostic and therapeutic impact and longer term outcomes from clinical and therapeutic decisions based on the US examinations.

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Table 1. Table shows the ultrasonography appearance of skin layers in ultrasound compared with anatomic structures.

ULTRASONOGRAPHY APPEARANCE	***ANATOMY STRUCTURE***
Hypoechoic	Epidermis
Hyperechoic	Dermis
Hypoechoic with hyperechoic longitudinalstructures	Subcutaneoustissue with fibroussepta

Figure 1. Upper Outer Quadrant: a) 15 MHz; b) 30 MHz; c) 50 MHz; d) 50 Mhz image shows E: epidermis, D: dermis; H: hypodermis

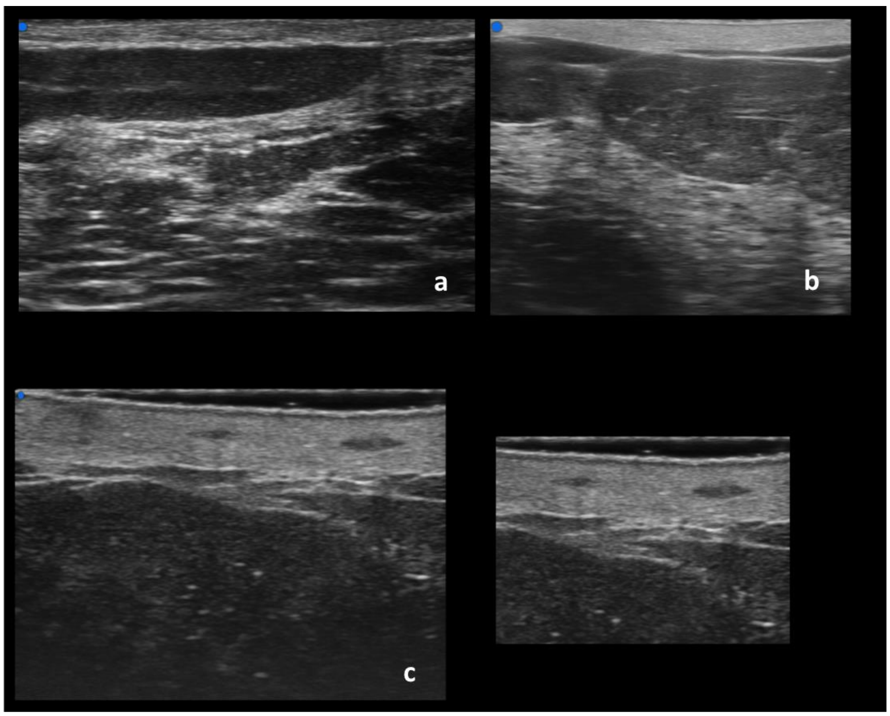

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Figure 2. Axilla The figure shows a reactive lymph .a) 15 MHz linear-array transducer shows a reactive lymph node that appears as an oval, well- circumscribed mass with a hypoechoic cortex and fatty echogenic hilum. b. A better anatomic detail using a 30 MHz linear-array transducer is observed.

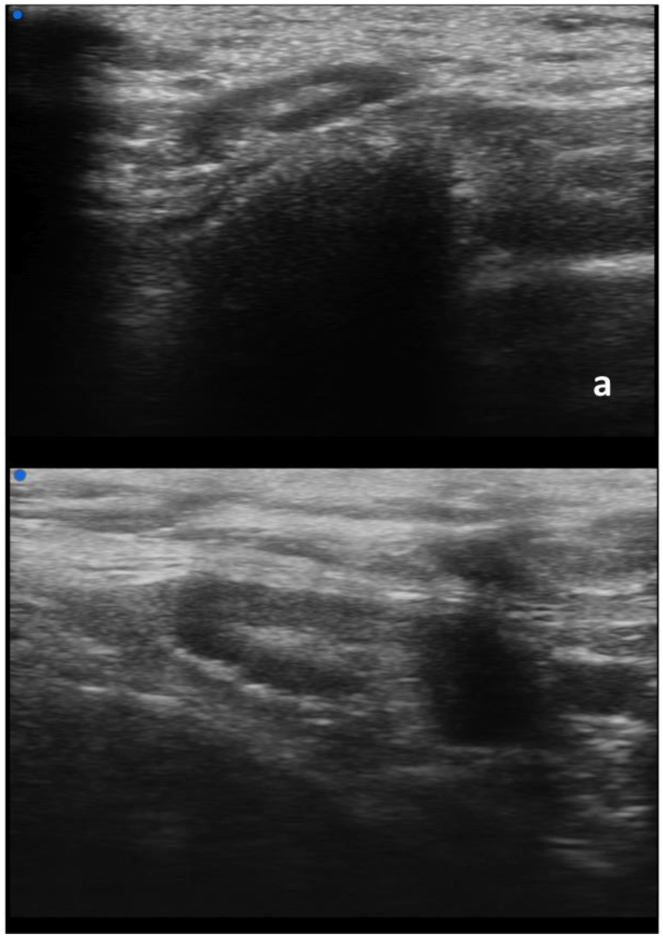

Figure 3. Areolar region: a) 15 MHz; b) 30 MHz; c) 50 MHz

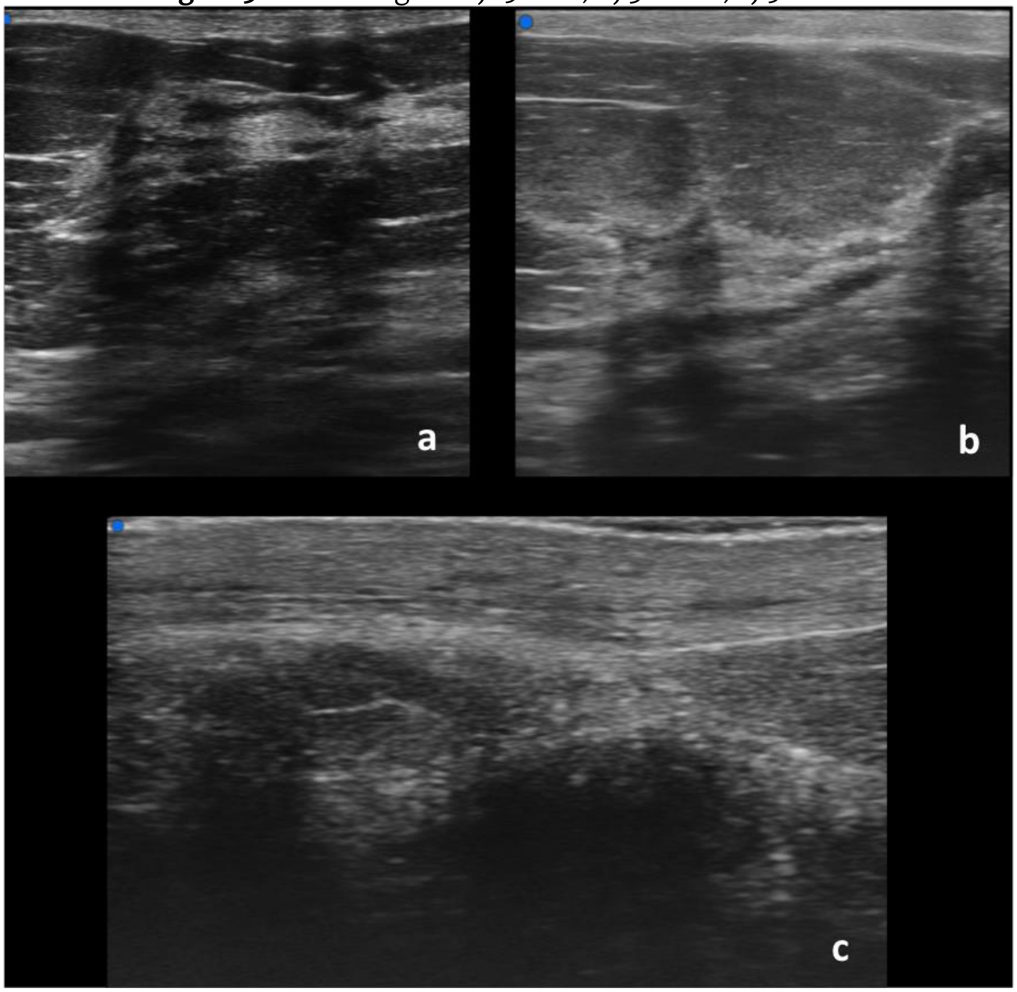

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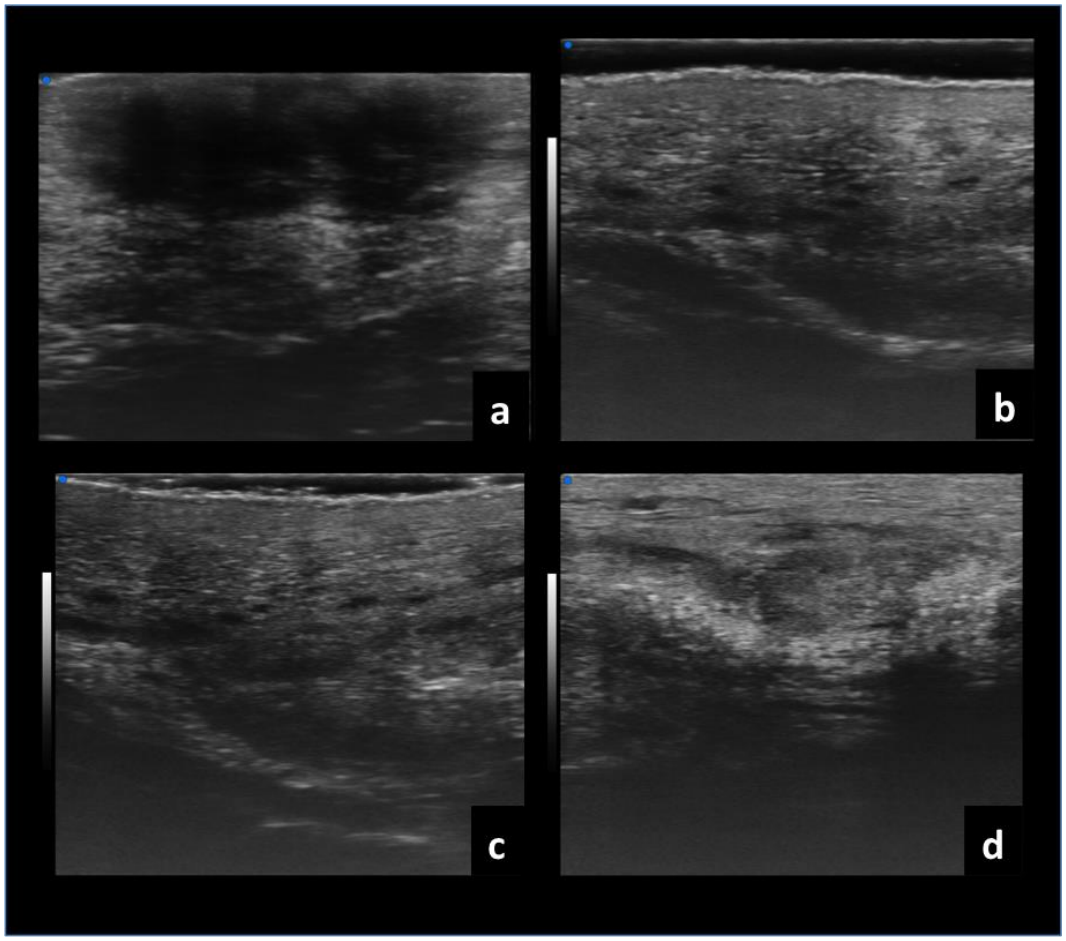
Figure 4. Ultra high Frequency Breast Ultrasound of a normal nipple that appears as a hypoechoic mass in ***a*** (30MHz). The same region, explored with a stand-off pad has homogeneous hypoechoic appearance **b, c, d** (50 MHz) with anechoic ducts



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