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Acoustic versus ultrasonic breast imaging

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ABSTRACT

Vibro-acoustography (VA) is an emerging imaging technology. In this method, radiation force of ultrasound is used to vibrate tissue at low (kHz) frequencies. The resulting vibration produces an acoustic field that is detected by a sensitive hydrophone. VA can provide detail information at high resolution that is not available from conventional B-mode ultrasound (US) imaging. Here, we compare VA and US in breast imaging. An experimental VA system was used to image breasts of patients with known lesions of various kinds. Results were compared to US. Image quality was assessed based on contrast, resolution, lesion boundaries, and artifacts. VA images displayed breast cysts with well-defined borders. Fibroadenomas were seen with identifiable texture, and in some cases, with enhanced boundaries. Post-lumpectomy scars were displayed with characteristic structure. Some malignant masses were seen with identifiable spiculations. Compared to US, VA images were speckle free, had high contrast and high signal to noise ratio. Microcalcifications were particularly visible with VA. The combination of features offered by VA, such as lack of image speckle, enhanced lesion boundaries, and sensitivity to microcalcifications, are important advantages of VA over US for breast imaging. It is concluded that VA may become a choice modality for breast imaging.

INTODUCTION

Ultrasonography and x-ray mammography are the common modalities used for breast imaging. Ultrasound is normally used to image soft tissue and detect possible lesions in breast.

X-ray mammography is the only imaging modality clinically used for detection of breast microcalcifications. The widespread use of screening mammography has resulted in the increased detection of microcalcifications [1].

A wide spectrum of breast lesions is associated with microcalcifications, ranging from benign (fibrocystic changes, vascular changes, fat necrosis) to malignant [2].

Ultrasonography and mammography both have limitations in breast imaging. For this reason, alternative methods are being sought. Especially, non-invasive imaging methods that can show both the soft tissue and microcalcifications are of particular interest.

During the past few decades, ultrasound pulse-echo technique has been widely used to image various types of organs and identify pathologies in soft tissue. In some cases however, the echo pattern and the morphological structure of the lesion are not specific enough for differential diagnosis or even lesion detection. This problem has prompted investigators to try other noninvasive methods to visualize tissue in terms of various tissue properties, including its viscoelastic characteristics.

Recently, the attention has been paid to the low-frequency portion of the spectrum. It is speculated that the properties of the tissue at audio frequencies (a few hundred Hertz to a few tens of kHz) would add additional information that are not available from the ultrasound methods.

To study the object by low frequency vibration, one may use various methods of excitation, including inducing vibrations directly to the object. Recently, use of the radiation force of ultrasound for inducing low-frequency vibration in biological tissues has been studied for a number of applications [3-7].

Vibro-acoustography is a new imaging method based on the radiation force of ultrasound [4, 5]. This method can be particularly useful for detecting hard inclusions in soft material. For example, vibro-acoustography has been used to image calcifications in human arteries [6-7]. A comparative study of vibro-acoustography with other radiation force methods for tissue elasticity imaging is presented in [8]. The spatial resolution of vibro-acoustography is in the sub-millimeter range, making the technique suitable for high-resolution imaging [7, 9]. The investigational studies of in-vitro and in-vivo breast VA has been reported (10- 14).

The purpose of this paper is to bring together the results of various studies on vibro-acoustography of breast tissues to demonstrate the potentials of this technology and the role that it may play in future as a breast-imaging tool

MATERIALS & METHODS

Vibro-acoustography is based on vibro-acoustic response of the object to a vibrating force [3-9]. Principles of vibro-acoustography technique have been described before [4, 5].

A vibro-acoustography image depicts two types of information about the object: 1) Ultrasonic properties of the object, such as the scattering and power absorption characteristics; 2) The dynamic characteristics of the object at frequency Δf, which also relates to the boundary conditions and coupling to the surrounding medium [4]. The former properties are those that are also present in conventional ultrasound imaging. The latter properties, which are related to object stiffness, can be described in terms of object mechanical impedance at Δf. Such information is not available from conventional ultrasound.

Matching vibro-acoustography and mammography images of human breast are acquired using a combined mammography/vibro-acoustography machine. Images of various types of breast masses are investigated and their characteristics features are compared. Image features, such as lesion borders, interior texture, and speculation pattern, are studied.

RESULTS

Resulting images show soft tissue structures, breast lesions and microcalcifications within breast with high contrast, high resolution, and no speckles. The results have been verified using x-ray mammograms of the breast. Vibro-acoustography images demonstrate that calcified and benign masses normally show sharp borders, benign non-calcified masses have smooth texture, and malignant masses have ill defined borders and, in some cases, malignant masses are characterized with spiculation.

Examples of in-vivo breast VA images:

Subject 1: Mammography and breast VA image of a healthy volunteer with fatty breast is shown in figure1. VA image demonstrates the tissue structure and some microcalcifications (MCs).

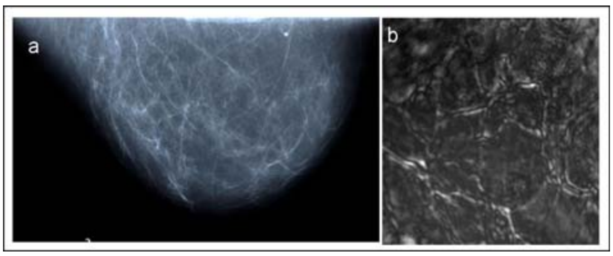

Figure 1. a) Mammography shows some MCs. In a breast, b) VA image of the same breast shows a clear appearance of beast tissue structure and MCs.

Subject 2- Mammography and breast VA image of a volunteer are shown in figure2. Mammography reveals a dense breast parenchyma with a very few scattered punctuate calcifications and 3mm eggshell calcification. VA image of this patient demonstrates the scattered microcalcifications as well as the eggshell calcified lipid cyst.

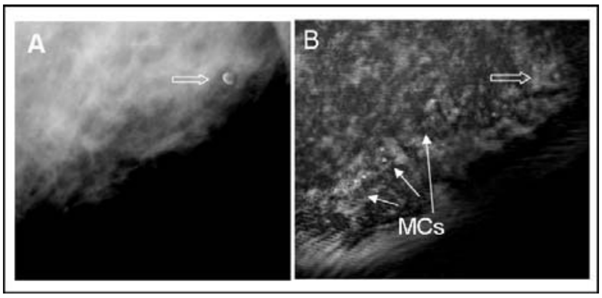

Figure 2. **(A)** x-ray image of a breast, arrow points an egg shell calcification, **(B)** VA image of this breast at depth 3.5cm is shown. The eggshell calcification can be seen at the same location of x-ray (block arrow); three arrows point some small microcalcifications in left medial and lower part of the image.

Subject 3- In Figure 3 mammography of a volunteer demonstrates a dense breast with fibroglandular breast tissue with microcystic changes. In this figure VA images demonstrate the same pattern and microcysts are more evident.

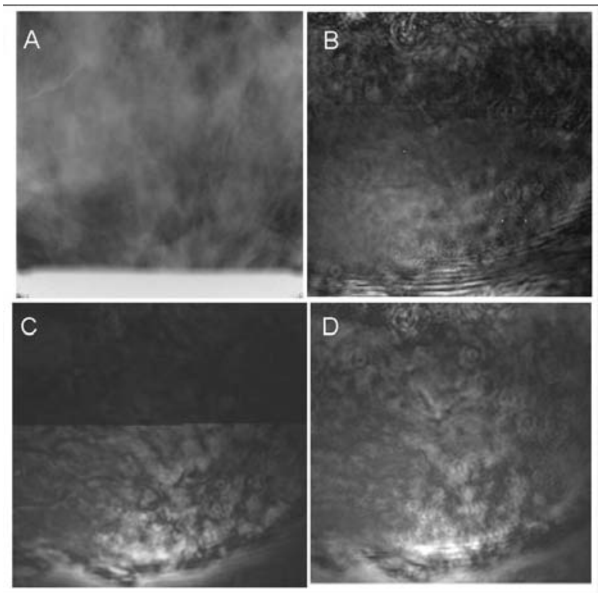

Figure 3: A) x-ray of a breast shows fibroglandular breast tissue with multiple microcysts (fibrocystic changes), B, C, D) VA image of the same breast at 0.5 cm, 1cm and 1.5cm depths respectively. All VA images are taken at 50 KHz. VA demonstrates multiple small cystic appearances.

Subject 4- Mammography and VA images of a patient volunteer with benign adenosis associated with microcalcifications are shown in figure 4. Mammography indicates scattered fibroglandular densities and a cluster of indeterminate MCs which magnification view confirms the presence of MCs. VA images demonstrates MCs clearly.

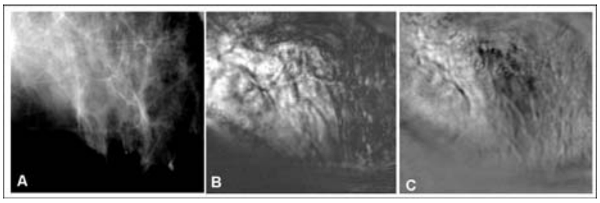

Figure 4: A) x-ray, the cluster of MCs is not clearly visible. B), C) are VA images at 2cm and 2.5cm depth and 50kHz frequency, the cluster of MCs are visible.

Subject 5- Mammography and VA image of a patient with previous lumpectomy is shown in figure 5. Scar tissue with 4 surgical clips inside is seen in x-ray. VA image demonstrates architectural distortion in a predominately radial pattern due to resection of an invasive carcinoma approximately 5 years earlier.

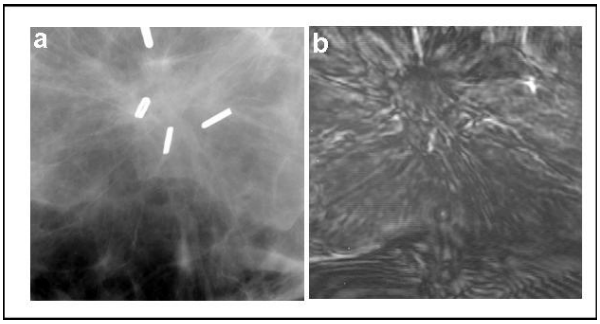

Figure 5: a) x-ray mammography shows 4 clips. b) VA images of the breast shows a radial pattern distortion and the clips are seen.

Subject 6: Patient has a biopsy proven fibroadenoma in the medial right breast with a clip, a partially calcified fibroadenoma laterally on the right, and a biopsy proven fibroadenoma just behind the left nipple (no clip). VA in 2cm depth demonstrates the mass lesion; calcification is not visible at this depth (figure 6).

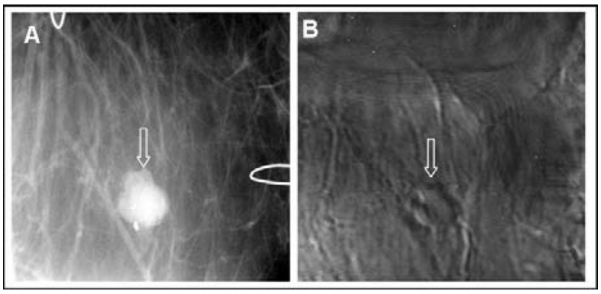

Figure 6: A) x-ray mammography showing partially calcified mass, B) VA scan at 40 kHz, in 2cm depth show the mass, but not calcification.

Subject 7- The patient has a lesion about 1 cm in diameter and 4 cm deep in her left breast as seen with ultrasound and as a faint spot in the mammogram. In Figure 7, the x-ray hardly shows an ill defined round mass lesion. The VA image shows a lesion with irregular border, which is suggestive of a solid and perhaps malignant mass. Biopsy result was invasive ductal carcinoma**.** This experiment demonstrates that VA image features may be used to distinguish malignant masses.

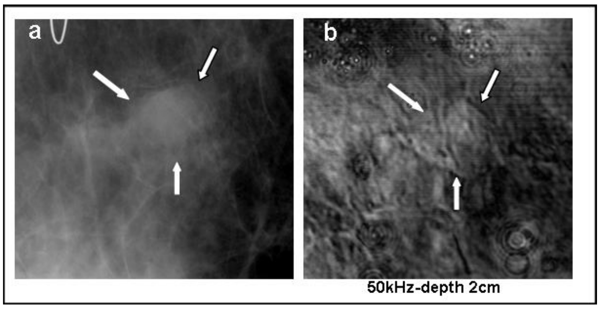

Figure 7: (a) Mammogram. A round lesion about 1cm in diameter is seen at the upper part of the mammogram indicated by the arrows. The VA image (b) at 50 kHz and demonstrate the breast lesion appear as a relatively circular region with defined boundaries as shown with arrows.

DISCUSSION AND CONCLUSION

The imaging method described here is a non-invasive method based on ultrasound. However, the images ore constructed from the acoustic emission at low frequencies. Unlike conventional ultrasound images, vibro-acoustography images have no speckle. Such images may be valuable for diagnostic purposes, especially for breast imaging. Further investigation is needed to fully explore the potentials of vibro-acoustography for clinical imaging.

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