Vibro-Acoustography and its Applications
(compiled by Ahmed Bulut)

Abstract
Ultrasound is a widely used diagnostic imaging modality. It is beneficial in producing 2D construction of organs images where various kinds of tissues could be differentiated. Moreover, there is a new modality that utilizes ultrasound that looks promising by using what is called Vibro-acoustography. The radiation force is the basic idea behind it. This relatively new method could be applied in imaging calcification in artistries, hard objects and could be useful in breast cancer detection.

Introduction
The main imaging modalities available nowadays are: Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Fluoroscopy, Single Photon Emission Tomography (SPECT), Positron Emission Tomography (PET) and Ultrasound. Each single one has its own use and application. Ultrasound is considered the safest and cheapest modality among them. It needs less space and gives instant images. The basic theory behind the ultrasound is the acoustic properties of the tissues and Doppler Effect (sound speed and frequency). Vibro-acoustography is another application of ultrasound but it is based on radiation force using two frequencies at the same time instead of a single frequency (at one time), as being applied now.

Elasticity of soft tissues
In our daily lives, physicians usually palpate on an organ in order to sense any abnormality. Similarly, we could try to detect vibrations of organs that are located deeper in the body. This response could be categorized as mechanical response and is related to the stiffness of the tissue. When high frequency waves are used in the process. The other physical property that is needed is acoustic emission. When such the waves are sent to the body and the vibrations of the organs (or whatever located) are recorder by special devises, an image of various acoustic emissions could be constructed.
**Vibro-acoustography**

Vibro-acoustography (VA) is a new imaging method introduced on 1999. which deals with the acoustic responses of excitation produced by radiation force of two interfering ultrasound beams Figure(1). This method combines three mechanical responses of an object for forming the final image: reflectivity, stiffness, and acoustic emittance. Due to absorption or reflection, the energy density of the object changes which produces a force called radiation force. This ultrasound radiation force is found to be more beneficial in imaging than other mechanical modalities for several reasons. Ultrasound is a non-invasive technique and could be readily modifies to be used in VA. In addition, the radiation force does not interfere with superficial layers of tissue and it could be produced in wide ranges of desired frequencies. Moreover, high spatial resolution could be achieved since the radiation force can be highly localized.

![Vibro-acoustography system](image)

**Figure (1).** Vibro-acoustography system.

A confocal transducer produces two continuous waves of slightly different frequencies. These two beams intersect at the object. This remote intersection of beams eliminates the interference of the transducer and the object acoustic emissions. The vibrations of the object (sound waves) are detected by hydrophone (microphone or vibrometer). In order to form a 2D image, the whole area is covered by raster scanning motion of the confocal transducers. The filter aids in eliminating surrounding unwanted sound waves.
Whereas, the frequency \((f)\) is in order of MHz, the difference frequency \((Δf)\) is in order of kHz.

VA images have many noticeable characteristics; two of them are mentioned here. First, VA images are speckled, which is a common artifact in traditional ultrasound images. It results from interference of backscattering signal with scattering from surrounding inhomogeneities. In VA, the acoustic emission from the object is larger than the surrounding. Hard objects could be seen in VA images. The reason for this (as discussed before) is that the acoustic properties of soft tissues and hard objects are very different.

**Vibro-acoustography applications**

VA method and its resultant images have positive characteristics compared to other imaging modalities. Researchers tried to apply VA in medical and industrial fields and in fact it gave very promising results. We will discuss only some of medical applications.

1- Calcified Arteries in breast tissue

VA showed more details than high-resolution x-ray mammography units. The experiment was conducted on 207 post surgical excised human breast tissue specimens. Images were taken using mammography and VA methods. 14 calcified arteries were in the initial mammograms. VA images showed all calcified arteries as fragmented linear structures. Figure (2)

Using another property of VA, detecting material properties, a goal of one of the studies is to evaluate the pathological condition of breast tissue. This may lead to earlier detection of breast cancer especially in dense breasts.
Calcified regions in an artery produces oscillation shifts different normal artery. This
shifts gives more details in VA image than x-ray. Figure (3)
3- Brachytherapy metal seed imaging:

Transrectal Ultrasonography (TRUS) is widely used for imaging prostate gland and finding its volume accurately. After implanting the radioactive seeds in the gland (to kill prostate cancer), these seeds can be seen in TRUS’s images. So a CT scan is used which has limited soft tissue contrast. VA method has overcome this problem by being able to show the metal seeds in the image. VA could replace TRUS during seed placement process in the operating room since the physician will be able to see a live seed position (independent of seed orientation in the gland). Figure (4)

Figure (3). Human iliac arteries. (A) X-ray image of normal (left) and calcified (right). (B) VA amplitude image at a fixed difference frequency of 6 kHz. The arterial walls are dim.

Figure (4). VA image at 34 kHz difference. Left and right for 90° and 0° incidence respectively.
Imaging methods comparison with VA

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Conclusion

Vibro-acoustography looks like a very promising imaging modality. It does not require one to buy a new system or to modify the current facility building (room .. etc). Having the capability to image arteries with calcification, detecting hard objects (i.e. metals) and producing instant high contrast images leads to have a beneficial diagnostic imaging tool. This adds more unique medical applications to ultrasound systems.

References:


