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# Study on Ultrasound Detection of Arteries

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**Abstract**- In earlier days the diagnosis of arteries were done using X-rays. Now the common scanning method is CT, MRI scanning. Ultrasound scan is used for the diagnosis of fetus. In this study we analyze the scope of ultrasound in diagnosis. Ultrasound is the high frequency sound waves; waves more than 20 kHz (above the audible frequency). These waves can be used for distance measurement, disinfection, detection of objects, scanning purpose etc. In medical field US waves are used for scanning and diagnosis. In this paper different methods to detect arteries and the possibilities of ultra sound waves in the diagnosis of arteries are discussed.

## I. INTRODUCTION

They says a “picture is worth a thousand words.” In the diagnosis of human body scanning gives the image of the inner body part. Commonly used scanning methods are X-ray scanning, MRI, and CT scanning [6],[8]. For the analysis this image now we take the help of computers also which makes it more easy and accurate. This is called image processing. This scanning process uses lethal waves and they are costly. There is ultrasound scanning which is now commonly used for scanning carrying women. These waves are not harmful and they are cost effective.

Ultrasound waves have a frequency above 20 kHz. It can absorb, reflect, refract, interfere and transmit through a medium. It has so many applications and the biomedical application uses a frequency of 1-30 MHz. this ultrasound is passed through the body part and reflected wave is analyzed to study about the reflecting point (diagnosis). This reflected wave can be converted into image and this image has to be processed for more resolution using any algorithm and software. In this study let us see what the different scanning methods of arteries are. Our main concern is if we can develop a system which can produce good quality image and to process them with an efficient software for better reproducible and legible images.

## II. ULTRASOUND WAVES

Ultrasound is a mechanical disturbance with a frequency more than 20 kHz (audible frequency). It can be described by the wave parameters like pressure density, propagation direction, and particle displacement etc. [7]. It transports energy and propagates through the medium as pressure waves. In the case of scanning the medium is the tissue. Interaction of ultrasound waves with the tissue is subjected to the law of geometrical optics; reflection, refraction, scattering, diffraction, interference and absorption. For the diagnostic purpose 1-30 MHz ultrasound waves are used [1][2]. Diagnostic ultrasound imaging depends on the computerized analysis of reflected ultrasound waves, which non-invasively build up fine images of internal body structures. When ultrasonic pulse signal is targeted towards an object, it is reflected by the object and echo returns to the sender. The time travelled by the ultrasonic pulse is dependent on the distance of the object.

In most diagnostic applications ultrasound waves reflected from interfaces between different tissues in the patient are used. The fraction of the impinging energy reflected from an interface depends on the difference in acoustic impedance of the media on opposite sides of the interface. The acoustic impedance Z [2][4] of a medium is the product of the density ρ of the medium and the velocity c of ultrasound in the medium:

$$Z = \rho c. \quad (1)$$

For an ultrasound wave incident perpendicularly upon an interface, the fraction $\alpha_R$ of the incident energy that is reflected. The reflection coefficient:

$$\alpha_R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2. \quad (2)$$

Where $Z_1$ and $Z_2$ are the acoustic impedances of the two media.

The fraction of the incident energy that is transmitted across an interface is described by the transmission coefficient $\alpha_T$, where $\alpha_T = \frac{4 Z_1 Z_2}{(Z_1+Z_2)^2}$ and $\alpha_R + \alpha_T = 1$.

With a large impedance mismatch at an interface, much of the energy of an ultrasound wave is reflected, and only a small amount is transmitted across the interface or the resolution attainable is higher with shorter wavelengths, with the wavelength being inversely proportional to the frequency. However, the use of high frequencies is limited by their greater attenuation (loss of signal strength) [1][4][5]in tissue and thus shorter depth of penetration. For this reason, different ranges of frequency are used for examination of different parts of the body:

3–5 MHz for abdominal areas
5–10 MHz for small and superficial parts and
10–30 MHz for the skin or the eyes.

## III. ULTRASOUND WAVES GENERATION

**Piezoelectric crystals** [2][3] are able to convert mechanical energy into electrical energy or the alterations in the thickness of the piezoelectric crystal can be converted into corresponding voltage on their surface. This is piezoelectric effect. Conversely, voltage applied to the opposite sides of a piezoelectric material causes an alteration in its thickness. This is the indirect or reciprocal piezoelectric effect. If the applied electric voltage is alternating, it induces oscillations which are transmitted as ultrasound waves into the surrounding medium. The piezoelectric crystal, therefore, serves as a transducer, which converts electrical energy into mechanical energy and vice versa. [3]

**Ultrasound transducers** are usually made of thin discs of an artificial ceramic material such as lead zirconate titanate. [3] The thickness (usually 0.1–1 mm) determines the ultrasound frequency. [3] Ultrasound is emitted in extremely short pulses as a narrow beam comparable to that of a flashlight. When not emitting a pulse, the same piezoelectric crystal can act as a receiver.

A crystal exhibits its greatest response at the resonance frequency. The resonance frequency depends on the thickness of the crystal. The most efficient operation is achieved for a crystal with a thickness equal to half the wavelength of the desired ultrasound. A crystal of half-wavelength thickness resonates at a frequency:

$$\upsilon = {}^{c}/_{2t} \quad (3)$$

Where c is the velocity of ultra sound; t is the thickness of the crystal and the wavelength of the ultrasound $\lambda = 2t$

If gas bubbles are present in a material through which a sound wave is passing, there is a great chance of stable and dynamic cavitations [2]. That causes scattered waves which add noise in the reflected beam. When the ultra sound wave comes in contact with bones they absorb the ultrasound energy. This causes high attenuation and reduction of the beam. So in the field of diagnosis the presence of gas bubbles and bones limit the accuracy.

## IV. ULTRASOUND IMAGING

The use of ultrasound in the diagnosis and assessment of imaging organs and soft tissue structures as well as human blood, is well established. Because of its non-invasive nature and continuing improvements in imaging quality, ultrasound imaging is progressively achieving an important role in the assessment and characterization of carotid plaques [1] and assessment of carotid artery disease [1]

The main disadvantage of ultrasound is that it does not work well in the presence of bone or gas, and the operator needs a high level of skill in both image acquisition and interpretation to carry out the clinical evaluation [1][2][3].

For some years, B-mode ultrasound imaging or intravascular ultrasound (IVUS) has emerged and it is used for visualizing carotid plaques and assessment of plaque characteristics related to the onset of neurological symptoms. [1] IVUS is done by inserting the transducer to the targeted blood vessel. In that a high quality image production is difficult because of the irregularities in the target and the spectacle noise[1][4]. Also in that there is a certain risk too.

### *A. Imaging Technique*

Mainly 2 principles are used in medical ultrasound diagnostics, the echo impulse technique and the Doppler technique [1][10].

The display of ultrasound beam characteristics can be done with a set of pulse-echo response profiles.[2] Here an ultrasound reflector is placed at some distance from the transducer and scan in a direction perpendicular to the axis of the ultrasound beam. During the scan, the amplitude of the signal induced in the transducer by the reflected ultrasound is plotted as a function of the distance between the central axis of the ultrasound beam and the reflector (a steel sphere or rod with a diameter of three to ten times the ultrasound wavelength.). [2] This is influence by several factors like the stimulating voltage applied to the transducer, the characteristics of the electronic circuitry of the receiver, and the shape, size, and character of the reflector. [2] Isoecho contours help depict the lateral resolution of a transducer, as well as variations in lateral resolution with depth and with changes in instrument settings such as beam intensity, detector amplifier gain, and echo threshold.[2]

The second principle used in ultrasound diagnostics is the Doppler principle [1][2].This technique is based on the principle that the perceived frequency of sound echoes reflected by a moving target is related to the velocity of the target. The frequency shift (Doppler frequency shift) $\Delta f$, of the echo signal is proportional to the flow velocity v (cm/s) and the ultrasound transmission frequency $f$ (MHz). The Doppler shift

$$\Delta f = {}^{2f_0(v\cos\theta)}\Big/_{U_{sp}} \quad (4)$$

Where $f_0$ is the transmitted frequency of the signal; $\theta$ is the angle between the direction of movement of the moving object and the ultrasound beam and $U_{sp}$ is the speed of sound through tissue that is approximately 1540 m/s. [1]

Doppler ultrasound waves are produced by a vibrating crystal using the piezoelectric effect, whereas the returned echoes are displayed as 2D signal [1][2][3] Based on the fact that blood flow velocity varies in different areas of a vessel, the Doppler signal contains a broad frequency spectrum. In normal ICA the spectrum varies from 0.5 kHz to 3.5 kHz and is less than 120 cm/s when an ultrasound beam of 4 MHz is used. [1]

### *B. Ultrasound mode*

The two main scanning modes are A mode and B mode. Other modes used are the M-mode, Duplex ultrasound, colour coded ultrasound, and power Doppler ultrasound [1][10][11].

In A-mode or amplitude mode the strength of the detected echo signal is measured and displayed as a continuous signal in one direction. Here recorded signal is 1D with limited information which is no longer used.

In B-mode or brightness mode[ 4][6] echoes are displayed as a 2D gray scale image. The amplitude of the returning echoes is represented as dots (pixels) of an image with different gray values. This is used for blood vessel scan [1] [8][10]

The M-mode is used in cardiology and it is actually an A scan plotted against time and display of consecutive lines are plotted against time.[1]

Flowing blood generates a Doppler frequency shift in the reflected sound. This frequency shift can be used to calculate the velocity of the moving blood, using the Doppler equation [1][2][3]. Velocity sampling at different depths and positions and its subsequent combination with B-mode real-time ultrasonic imaging led to the development of Duplex ultrasound. Several types of Doppler systems are used in medical diagnosis, Continuous Wave (CW) Doppler, Pulsed Wave (PW) Doppler, Duplex ultrasound and Color Flow Duplex.

In colour-coded ultrasound,[7] every pixel is tested for Doppler shift and the movement of the red blood cells is depicted through colour. Finally the image is produced by superimposing the colour-coded image on the B-mode image.

Power Doppler is the depiction of flow, based on the integrated power of the Doppler spectrum rather than on the mean Doppler frequency. This modality results in an angle, which is independent of the resulting enhanced sensitivity in flow detection as compared to the colour-coded Doppler and therefore the detection of low flow is better viewed.[1]

## V. Deep Seated Arteries

The arteries are the blood vessels that deliver oxygenated blood from the heart to the body tissues. Each artery is a muscular tube lined by smooth tissue and has three layers: The intima (the inner layer lined by a smooth tissue called endothelium), the media (a layer of muscle that lets arteries handle the high pressures from the heart) and the adventitia (connective tissue anchoring arteries to nearby tissues). Compared to the veins, arteries are located deep into the body. This generally makes them difficult to locate clearly with ultra sound detection systems.

The largest artery is the aorta; the main high-pressure artery connected to the heart's left ventricle. It branches into a network of smaller arteries that extend throughout the body. Smaller branches of arteries are called arterioles and capillaries. Examples of arteries are pulmonary arteries, carotid arteries, and peripheral artery.

## VI. Diagnosis of Arteries

In the field of diagnosis a picture is more legible and reproducible than any medium of analysis. Medical imaging technology has experienced a dramatic change in the last 30 years [1]. Some years back only X-ray radiographs were available. It showed the organs as shadows on photographic film. With the advent of modern computers, new imaging modalities like computer tomography (CT or CAT computer assisted tomography), magnetic resonance imaging (MRI), positron emission tomography (PET) and ultrasound, which deliver cross-sectional images of a patient's anatomy and physiology, have been developed. Among the imaging techniques employed are X-ray angiography, X-ray, CT, ultrasound imaging, MRI, PET, and single photon emission computer tomography (SPECT). MRI and CT have advantages compared to ultrasound, in the sense that higher resolution and clearer images are produced. [1] The resolution of the scan can be improved using depth gain compensation (DGC) [1],[4] Motexafin Gadolinium (MGd) [8]

Imaging techniques have long been used for assessing and treating cardiac and carotid disease. Today's available imaging modalities produce a wide range of image data types for disease assessment which includes, 2D projection images, reconstructed three-dimensional (3D) images, 2D slice images, true 3D images, time sequences of 2D and 3D images, and sequences of 2D interior view (endoluminal) images. [9][10]

Ultrasound scanning is widely used for the diagnosis of fetus Now a days it is used for the detection of arteries.

## VII. Ultrasound in Diagnosis

Ultrasound scan is most commonly used for the diagnosis of the foetus. Now-a-days ultrasound is used for the diagnosis of other body parts also. The presence of air bubble and bones will reduce the quality of the image. So there is a difficulty in using ultrasound for scanning deep seated arteries. Since carotid artery is comparatively nearer to the skin ultrasound is used for the detection of the plaque in the carotid artery [1][10]. To Identify Subclinical Vascular Disease and Evaluate Cardiovascular Disease ultrasound detection of Carotid Intima Media Thickness test is used [1][11]. Stroke can be predicted by analyzing the intima-media thickness and external diameter of carotid artery using ultrasound wave.[study in]

Ultra sound waves are used for the Evaluation of Carotid Artery Stiffness in Obese Children. It is to investigate the difference in carotid arterial stiffness in obese children compared to healthy children and to study the correlation between carotid arterial stiffness parameters and obesity using ultrasound (US) radiofrequency (RF) data technology [11][12]

To compare the diagnostic value of trans-cranial color-coded real-time sonography and contrast-enhanced color-coded sonography in detection and characterization of intracranial arterio-venous malformations. [1][5]

Lower limb peripheral arterial disease [10][11][13] and coronary artery disease [15] can be detected using ultra sound. But because of the disadvantages of ultra sound it is not common. Cannulation of the radial artery can be done using under ultrasound guidance [15] .

They are trying to reduce the size of tumor using ultrasound waves by inducing cell death within a target tumour in order to destroy it. [5] It is used for the detection of the thickness and strength of the artery walls ultra sound systems are used..

Volume of Preclinical Xenograft Tumors Is More Accurately Assessed by Ultrasound Imaging Than Manual Caliper Measurements Noninvasive imaging technologies suitable for measuring xenograft volume are increasingly available, [9][14].

Sonoporation is a tehnique to increase cell membrane permeability with ultrasound waves.[5]

Ultrasound detection and diagnosis is a very fast growing field because it uses harmless waves and it is of low cost. If the problem of less resolution is once cured ultrasound systems will replace other diagnostic technique.

## VIII. LIMITATIONS

One of the performance limiting factors in visual lesion detection in ultrasound imaging is Speckle noise which makes the lesions difficult to detect and diagnose by the expert. Speckle is multiplicative noises that reduces both image contrast and detail resolution, degrades tissue texture, reduces the visibility of small low-contrast lesions and makes continuous structures appear discontinuous. [1]. It limits the edge detection.

Geometrical and diffraction effects, where spatial compound imaging may be employed to correct the image

Inter-patient variation due to depth dependence and inhomogeneous intervening tissue, where normalisation techniques may be applied to standardise the image

Low echogenicity due to shadowing effects.

Low signal-to-noise ratio in anechoic components and difficulty in edge detection. This may be overcome by employing the use of colour coded images

Legibility and reproducibility of the ultrasound images are less.

## IX. FUTURE WORK

Compared to other diagnosis system the ultrasound system and waves are less harmful. It makes no wounds so it is acceptable by the people. It is comparatively less costly. The problem with this method is the images produced have less resolution. The cause for this is the speckle noise. If we use more accurate transducer more SNR (signal to noise ratio) can be obtained. For removing the speckle noise proper image processing should be done. It can be done with snake segmentation, neural and fuzzy image processing for edge detection and resolution improvement, 3D imaging, video segmentation etc can be applied for getting more good images.

## X. CONCLUSION

Deep seated arteries are commonly scanned using X-rays, CT scan, MRI scan etc. The images produced are good and reproducible. But these methods use harmful waves. So as an alternate ultrasound scan can be considered. But the image produce by this has less resolution. If we can improve the resolution and edge detection by using any signal processing methods with the help of computers we can use ultrasound for the diagnosis of deep seated arteries and for the treatment of tumor, stroke, arteriosclerosis etc.

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