International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue - AMET-2018

Measurement of mechanical properties of human blood tissue using Doppler Effect

Rucha Kulkarni[1]

[1]Mechanical Engineering, MIT College of Engineering, PUNE, INDIA.

Abstract

Biomechanics has gained a lot of attraction in the recent years due to able correlation of forces acting on a body and some existing mechanical properties of human body system. Recent studies have shown promising results in the amalgamation of Doppler mechanism and blood flow. Ultrasonic Doppler system is devised for non invasive measurement of body tissues. The objective of this review paper could help develop a method which provides the same result with more convenience and fewer restrictions.

Keywords: *Biomechanics, Ultrasonic Doppler System , Soft tissue.*

1. Introduction

The Mechanical properties of biological materials cannot be characterized precisely unlike, most of the engineering materials. Although there is numerous data on mechanical properties of tissues e.g. it gives insufficient insight to predict the intercourse of a prosthetic socket and an amputee's limb.

Before proceeding to how ultrasound can be used for obtaining mechanical properties of live tissue, it is necessary to present the equations of tissue particles.

Continuum mechanics provides an equation:

$$\nabla . \rho\dot{\bar{u}} = -\dot{\rho}$$

Where ρ is the tissue density, $\bar{u}$ is the particle displacement vector and the over dot symbol indicates differentiation with respect to time.

1.1: INTRODUCTION TO DOPPLER EFFECT:

It is the change in frequency or wavelength of a wave for an observer , who is moving relative to the wave source.

When the source of the wave is moving towards the observer, each successive wave crest is emitted from a position closer to the observer than the previous wave.

Therefore each wave takes slightly lesser time to reach the observer than the previous wave. Ultrasonic waves are the pressure waves that are transmitted through matter. We can interpret them as increased and decreased area of pressure in tissues with respect to time. The ultrasound image is based on the differences in the amplitude of the back scattered echoes reflected from interfaces within the body.

Stronger reflector produces brighter echo and weaker reflector produces darker echo.

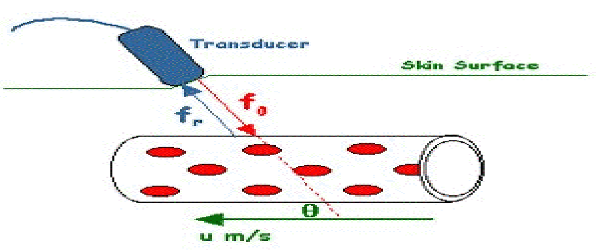

Fig. 1: Transducer

2. METHODOLGY:

2.1.: Velocity measurement using Doppler ultrasound:

The matter of interest in diagnostic ultrasound is the relation between Doppler frequency shift which we can measure using a ultrasound device and the velocity of target, here, blood.

$$F_d = (Fr - Ft) = \frac{2 * Ft * v}{C}$$

Where Ft= transmitting frequency

C= propagation velocity

(Which for a human tissue is $1540 m^2/s$)

Let's assume a transducer transmitting a Doppler frequency of 3 MHz and insinuating a blood cell directly moving. Since the target is moving towards transducer we expect the returning frequency to be slightly higher, which is 3.0039 MHz . Therefore Doppler frequency shift is.0039 MHz . Simple arithmetic allows us to calculate the velocity which here turns out to be 1m/s.

2.2: DOPPLER INTERPRETATION:

At the early days of Doppler was analyzed by listening to Doppler frequency shift because the output is in audible range. The modern ultrasound devices provide a display of the Doppler spectrum. Color Doppler can distinguish when the blood is flowing towards or away from the transducer .when the blood is flowing towards the transducer it s named as positive Doppler shift and represented red in color. When the blood is flowing away from the transducer it is showed blue in color.

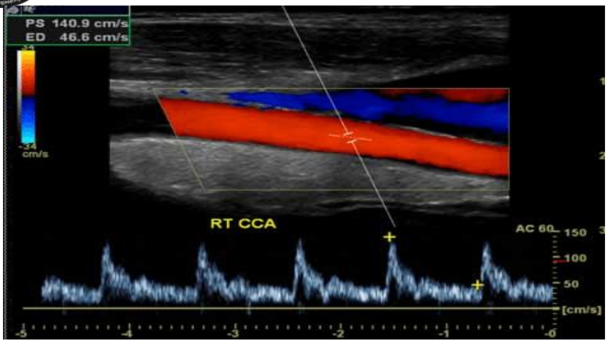

Fig.2 : Color Doppler

To obtain the best Doppler images and to detect the larger Doppler shift using ultrasound, the transducer must be placed at an angle of 0 to the vessel of interest. However due to practical considerations, an angle of 60 is use.

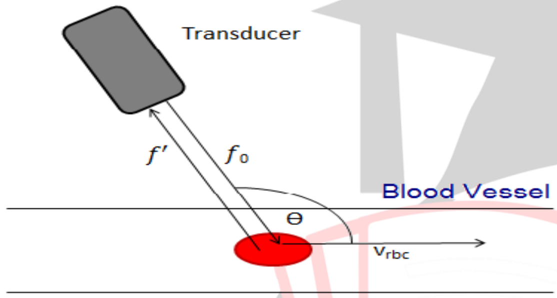

Fig.3: Indicating a desirable angle between Transducer and a blood artery.

2.3: CW vs Pulsed Ultrasound:

Continuous wave Doppler is used for some simple blood pressure measuring devices and typically has two transducers, one transmitting and other receiving. This does not allow to differentiate from which side of the artery the signal is arising.

While in pulse echo method the ranging principle allows to differentiate.

Cardiac ultrasound primarily uses continuous wave Doppler. It is designed to be able of one part of the transducer constantly producing a sound beam and the other part of the transducer constantly receiving the sound wave. It can accurately determine the speed at which blood flows. Post wave Doppler is used for the rest of the vascular system , as the round trip effect unables the greater accuracy about location rather than just blood speed.

2.4: STENOSIS:

Stenosis of a large blood vessel can cause many sudden deceases. Here Doppler effect can be used to find:

- Measurement of diameter reduction.
- Measurement of area reduction
- Measurement of flow change.

2.5: PITFALLS OF VELOCITY MEASUREMENT:

- Improper gain
- Improper angle correction
- Aliasing.

2.6: 2D DOPPLER IMAGING:

Due to the above pitfalls, 2D Doppler imaging was invented. Unlike 1D Doppler imaging, which can only provide one-dimensional velocity and has dependency on the beam of the flow angle, 2D velocity estimation using Doppler ultrasound is able to generate velocity vectors with axial and lateral velocity components.

2D velocity is useful even if complex flow conditions such as stenosis and bifurcation exist.

Vector Doppler which an extension of 1D Doppler imaging based on phase shift . The main idea of vector

Doppler is to divide the transducers into three apertures.

The phase shifts measured from left and right apertures are combined to give lateral and axial velocity components. The positions and the relative angles need not to be tuned according to the depth of the vessel and the lateral position of the region of interest.

3. CONCLUSION:

Our understanding of the Doppler effect has allowed us to learn more about the universe we are part of, measure the world around us and look inside our own bodies.

It images muscle, tissue, and bone surfaces very well and is particularly useful for delineating the interfaces between solid and fluid filled spaces.

Future development of this knowledge including how to reverse the Doppler effect- could lead to technology once only read about in science- fiction novels.

REFERNCES :

1. Gent, R. (1997), Applied physics and technology of diagnostic ultrasound. Adelaide, Milner Publishing.
2. Kruskal, J., Newman, P., Sammons, L. and Kane, R. (2004) Optimizing Doppler and Color Flow US: Application to Hepatic Sonography. RadioGraphics, Volume 24, Number 3, May-June: pp. 657 – 675.
3. Pozniak,M.,J. Zagzebski, and K. Scanlan (1992), Spectral and color Doppler artifacts. RadioGraphics; Volume 12: pp.35 – 44.
4. Rubin J. (1994), AAPM Tutorial: Spectral Doppler US. RadioGraphics, Volume 214, Number 1, January: pp. 139 – 150.
5. Zagzebski, J. (1997), Essentials of ultrasound physics. St. Louis, Mosby Inc.