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Ultrasound Propagation Speed of Polymer Gel Mimicked Human Soft Tissue in 23 days

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Abstract. A Polymer gel mimicked human soft tissue was being fabricated using a monomer named 2-Hydroxyl-Ethyl-Acrylate (HEA) with the present of gelatin. The readymade gel which is the concentration for HEA fixed at 5% was then undergoes an ultrasonic evaluation to test for the propagation of sound speed through it. Sonic Waves Analyzer is absolutely the most accurate technique to determine the aims (changes of speed as function of polymer structure based on increasing day). The fixed frequency of transducers involved is at 4 MHz by using the seismic reflection concept. In the observation of relationship between the ultrasound propagation speed and the increasing day showed that the propagation speed still varies between 1390 to 1500 m/s which is still in the range of speed of sound for human tissue.

Keywords: tissue mimicking, ultrasound phantom, abdominal ultrasound, ultrasound propagation speed

1. Introduction

The ultrasound propagation speed of polymer gels was being characterized. The fabrication of the gel used monomer 2-Hydroxyl-Ethyl-Acrylate (HEA), gelatin as gelling agent and ascorbic acid as the anti-oxidant. The design and fabrication of this tissue equivalent phantom should mimics human soft tissue. Comparing with the multipurpose manufactured phantom, this fabricated phantom has several advantages, i.e the phantom is easily made, low cost, less fragile, and the preparation using less hazardous chemical can last for 23 days based on visual inspection from the ultrasound image. Thus, the phantom can be used for biopsy training. Polymer gel phantom were manufactured consisting of 5% (by volume/weight) 2-Hydroxylethyl Acrylate (HEA), 3% N,N' – Methylene – bis – Acrylamide comonomers dissolve in aqueous gelatin (5% gelatin by total weight and 89% de-ionized water). By using the ultrasound machine, imaging evaluation was made to ensure that the gel can replace the former phantom (manufactured).

At constant room temperature, the most important thing is velocity of sound of the gel, is in the range of human tissue 1460 m/s to 1650 m/s[2] within 23 days. The measurement made by using Sonic Waves Analyser. The Multichannel Analyser (MCA) software and collimated radiation beam photons from a ^{241}Am source, the linear attenuation coefficient, μ of the polymer gel was measured [1]. Furthermore, density measurement showed that this polymer gel phantom is equivalent to human soft tissue. This polymer gel tissue phantom still undergoes some characterizations and these preliminary results proved that the polymer gel is equivalent to human tissue.

2. Materials & Methods

2.1. Polymer gel dosimeter manufacture

Preparation of polymer gel phantoms by using 5% (by volume)(HEA) (Sigma Aldrich,) completed by comonomers, 3% N,N' – Methylene – bis – Acrylamide (BIS) (Sigma) dissolved in aqueous gelatin (8% gelatin by total volume) and 84% de-ionized water. After the production finished, the gel were leave to cool down to room temperature (22 ˚C) by maintaining the stirring rate. The gel were poured into ependorf tube, sealed with parafilm tape (Sigma) (to minimize the oxygen contamination inside gel) for linear attenuation coefficient measurements or small empty vials for density and velocity of sound measurement. Then, the remainder gels were poured into the designed container for ultrasound diagnostic imaging. Lastly, those three samples with different shape were then kept in a refrigerator at approximately 10 ˚C for 2 hours until a visual detection concluded the gel already solidified.

2.2. Ultrasound Propagation Speed measurements

As shown in figure, the measurement was done by using the Sonic Waves Analyzer (SWA) under room temperature with the existence of TDS 1012B Oscilloscope completed by LABVIEW software. The SWA consist of two transducers which act as transmitter and receiver.

The longitudinal speed in the pulse echo mode is defined as

$$v = d/t \qquad (1)$$

Where v = longitudinal velocity, m s^{-1}, d = thickness of gel in vial, m, t = time of flight,[4]

There are two 6 mm transducers involve in this experimental method, transmitter and receiver. The transducers were aligned properly, and the vial occupied with the gel, located in between those transducers. Before the measurement started, the coupling transmission gel was covered by all the sensor area of transducer. Then, a dampening circuit was used to reduce the transmitted signal length to a sinusoid of one cycle. The maximum reflected signals received by the transmitting transducer which frequency (4 MHz). Each transducer detected every signals by were displayed on a digitizing oscilloscope (Tektronics TDS 1000). The sinusoidal signal from oscilloscope was digitized and transferred to a PC for some processing step such as waves filter and windowing by using LabView software (version 2.5.1). The repetitions have done three times to determine the ultrasound pulse echo *(time of light, t)* from the average signal. The propagation speed was calculated with the time of light, *t,* data obtained from the waves generated to PC.

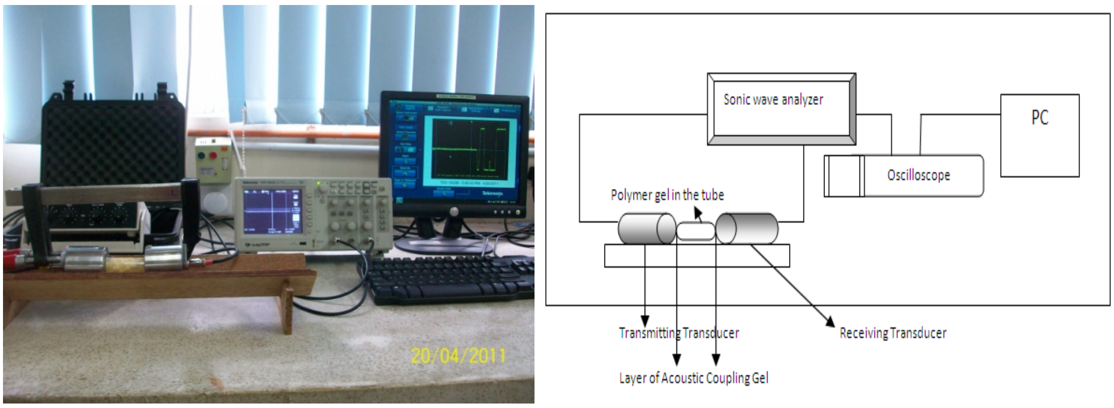

Fig 1: Sonic Wave Analyzer

3. Results & Discussion

Based on the results, the propagation speed increase for the first seven days and maintain in the range between 1390 to 1500 m/s within 16 days afterwards. The variation of the density of the sample increased based on the increasing day. This is may be due to some changes in the elastic properties of the polymer gel, which given as *K* is bulk elastic modulus [3]:

$$K = v^2 p \qquad (2)$$

Where *p* is bulk density and *v* is acoustic speed. Regarding to equation (2), an increase in acoustic speed will result to increase the elastic modulus. But, an increase in density should leads to decrease the propagation speed. The increasing day will result the change in polymer structure based, in other words the polymerization was occurred (formation of cross-linked) naturally and absolutely tends to increase the elastic modulus and also rigidity inside the gel. The value of acoustic speed is not expected to be fluctuate in case there any distorted of ultrasonic pulse through the gel in the experimental procedure.

Based on inspection through observation towards the gel, as the increasing day, the gel will getting whiter which is originally the colour of the gel is light transparent yellow. On the 20th day, there is some white solid appeared inside the gel and this situation proved that the polymerization was coming to the saturated level but the value of acoustic speed of the gel until 23rd day still behave in the small interval from the previous day. It can be concluded that this type of gel have considered match to the acoustic properties of human soft tissue based on the ultrasonic propagation speed.

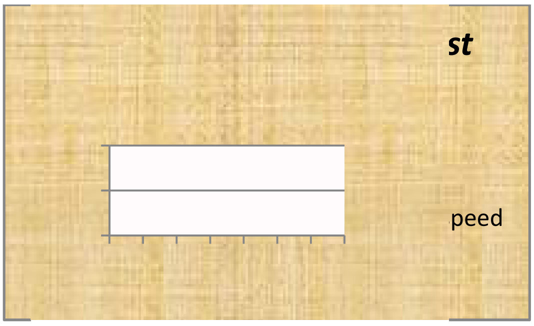

Fig 2: Graph of ultrasonic speed against days

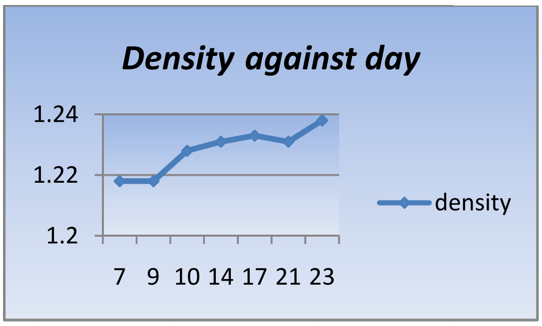

Fig 3: Graph of density against days

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