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DEVELOPMENT OF COLORECTAL PHANTOM TO EVALUATE NEW ULTRASOUND ELASTOGRAPHY TECHNIQUE

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Abstract: *Colorectal cancer is the second most frequent in Europe. Standard screaming methods are uncomfortable for the patient, invasive, and/or are ionizing. An alternative ultrasound elastography method, has been developed as complementary diagnostic imaging technique. This method intends to use a magnetic stress-strain - provide from ferromagnetic fluid inside of colon - to produce relative elastography maps by ultrasound. However, this alternative technique needs to be evaluated in vitro before clinical applications. In this study we developed paraffin based phantom that mimic colon region to ultrasound B-mode and elastography images. This phantom will allow to evaluate potential technique limitation. Varying granular wax from 0% to 4%, we estimate the Young's modulus to determine the material relative stiffness. The phantom has four inclusions with different elastic modulus (from 3.6kPa to 5.7kPa). We measured the ultrasound propagation velocity and acoustic attenuation. This study developed paraffin-based phantom that mimics soft tissue mechanical proprieties and simulate a colon lesion.*

Keywords: *Ultrasound, phantom, cancer, elastography*

Introduction

Colorectal cancer (CRC) is the second cause of death from cancer in Europe [1] and screening helps mortality reduction. Currently, colonoscopy is the most frequent method used to detect and diagnostic CRC. However, it may not be effective to whole colon assessment , is uncomfortable and can be painful [2].

Ultrasound elastography (UE) is an useful technique to diagnose cancer [3], by differentiation between tissue stiffness. UE is usually used as diagnostic method to breast, thyroid and part of gastrointestinal system [3]–[6], among others. Attempts of diagnosing colorectal cancer using UE have been reported [7]. However the static UE may not be helpful to some CRC cases [8], because ultrasound endocavity probe cannot achieve deeper colon regions.

Phantoms are largely used to test new techniques, methods and equipment [9], [10]. Recently, we developed a hybrid transducer (HT) [11], composed of an ultrasound transducer and coils system, that could possible overcome physics' limitation to perform colon UE. Using the magnetic field from HT coils to pull a ferromagnetic fluid located inside a cavity ultrasound detect displacements[12]. In this setup, the magnetic force pulls the magnetic fluid inside colon tube making a stress on CRC region. The ultrasound detects tissue strain and process UE maps. However, this alternative technique must be evaluated *in vitro* before clinical applications.

In this study, we developed a paraffin-based phantom to mimic the colorectal region to evaluate the hybrid transducer applied to colon UE exam. We approximate colon region to a cylindrical cavity. Above cylindrical region isoechoic inclusions - with different stiffness – simulate typical lesion [7].

Materials and methods

Tissue mimicking phantom – The colon phantom was made of paraffin-based material [13]. Samples to characterize the mechanical and ultrasound proprieties were manufactured varying the percentage of granular semi-refined paraffin wax from 0% to 4 %.

Mechanical proprieties measurements – Rectangular samples (40mm X 5mm thickness) were tested by TA.XT plus® texture analyzer (probe A/TG tensile grips). The Young's modulus (*Y*) was estimated from the slope of stress-strain loading curve. (Equation 1)

$$Y = \frac{F/_A}{\delta l/_l}, \quad (1)$$

Where F is tensile force, A is the contact area, δl is the change in length and l is the length of sample.

Ultrasonic properties measurements – We used a standard technique [14] (transmit-receive) to characterize velocity and attenuation at 1MHz. Cylindrical samples tubes with 7.5 cm diameter and 2.5 cm thickness were used. A pulser-receiver (Parametrics model 5601A) excited a transducer (central frequency 1MHz) and a second similar transducer received the signal. Velocity and attenuation were estimated from the phase difference between transmitted and received pulse.

Colon phantom– A fluid with acoustic scattering particles (yogurt with 20% of ferrite) filled the cylindrical cavity (4 cm diameter) of the phantom. Four isoechoic inclusions with different stiffness were placed above cylindrical cavity, as shown in figure 1. Using a – Sonix RP– (Ultrasonix, British Columbia, Canada) – we manually acquired elastography images with linear probe (L14-5/38) and micro convex (EC9-5/10). The images were compared.

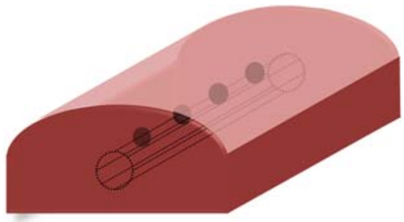

Figure 1 : Phantom sketch up. Four spherical inclusions above a cylindrical cavity.

Results

Mechanical proprieties - We obtained Young's modulus from slope of the linear region of stress/strain plot with Exponent software (for TA.XT Plus). The Young's modulus for each sample is shown in Figure 2.

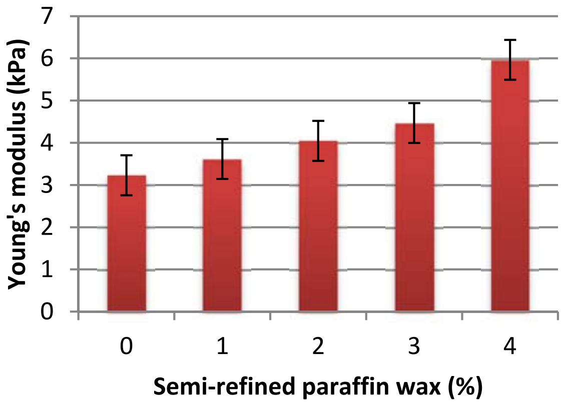

Figure 2: Mean values of Young's modulus of each percent of granular wax.

Ultrasonic proprieties – Table 1 show the acoustic parameters obtained from granular percentage variation.

Table 1: Measurements of velocity and attenuation.

Granular wax (%)	Velocity* (m/s)	Attenuation at 1 MHz (dB/cm)
1	1398.4±1.4	0.48±0.12
2	1389.0±1.3	0.78±0.24
3	1398.4±2.1	0.82±0.18
4	1400.0±1.8	0.73±0.22

Figures 3A and 3C show B-mode images overlaid by elastography maps using linear and micro convex probe respectively. Figure 3 B and D show colon phantom B-mode images and isoechoic inclusions above cylindrical cavity.

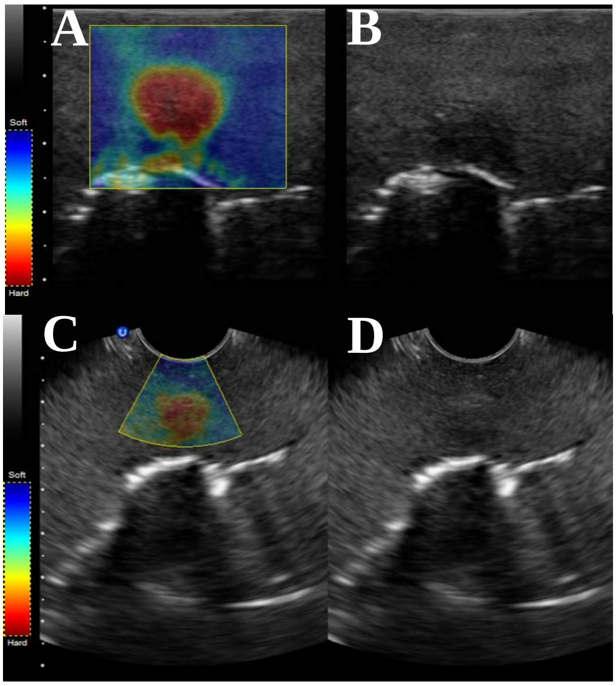

Figure 3: B-mode images of inclusions A and B –linear probe - C and D –micro convex probe.

Discussion

We characterize isoechoic paraffin-based material with different stiffness. Higher granular wax concentrations increased material stiffness. Figure 1 shows a nonlinear relation between Young's modulus and granular wax percentage. It was possible get inclusions twice stiffener when compared with initials concentrations.

Table 1 show that granular wax concentrations up to 4% do not change ultrasound velocity, significantly. In spite of ultrasound velocity in this material (~1400m/s) is not the same in soft tissue (1540 m/s); the image processing can easily offset it.

We choose isoechoic inclusions because are typical cases of CRC and are not easily visible in B-mode images The images in Figure 3 shows shadows when using linear probe . For granular wax concentrations higher than 4% shadows do not show the same characteristics that CRC cases. Only granular wax variation is not enough to increase Young's modulus difference between phantom background and inclusions stiffness without produce shad.

We still need to improve the material stiffness to achieve higher difference between background and inclusions.

Conclusion

This study developed paraffin-based phantom that mimics soft tissue mechanical proprieties (velocity, attenuation and Young's Modulus) and simulate the colon rectal cancer. The phantom had all necessary parameters characterized to evaluate the technique.

Granular wax enable stiffness control in paraffin based material. However concentrations up to 4% cause shadows on B-mode imaging. The phantom can also be used to perform conventional elastography.

The results of the present study suggest that the phantom background material should have 1% of granular wax and the inclusions a maximum concentration of 4%.

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