High Resolution Ultrasound Imaging System for Soft Tissues

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Abstract: The ultrasonic properties of human thyroid have been studied over the frequency 27MHz to 55MHz with a C-scan ultrasound backscatter microscope system. For evaluation the tissues quantitatively, a C-scan microscope system equipped with a broadband 35MHz PVDF transducer has been developed in our laboratory. The three typical acoustic parameters: speed of sound, attenuation coefficient and backscatter coefficient were measured and studied. Besides, the high resolution ultrasound images are produced with the C-scan system, the comparison of ultrasound images with the histological slice diagrams gave satisfied results. The measured ultrasound properties are qualitatively related to their histological structure and ultrasound image.

INTRODUCTION

Clinical Ultrasonography of surface tissues and organs has been widely used in the medical diagnosis. The thyroid gland which is a two-lobed endocrine gland located in front of and on the either side of the trachea in human can be image with the high ultrasound frequency scanning system. Scheible et al described the ultrasonicographic characters of thyroid and gave the clinical assessment for the thyroid lesions in diagnostics. Usually the traditional ultrasonography produces the images in the frequency lower than 20MHz, therefore the image resolution is limited due to the longer wavelength at low frequency. Besides, the bandwidth of the transducer is not broad enough, so when using ultrasonic spectroscopy to analyze the ultrasound signal received from human tissues, some useful information may be lost. The new scanning system, which is equipped with ultrasound transducers operating at the frequency higher than 20MHz, can produce the ultrasound images with higher resolution, for example the anterior segment of eye, endocuminal structure etc. The new developed scan system is called ultrasound backscattering microscope (UBM) which was proposed by Foster et al. In this study, based on the principle of ultrasound backscattering microscope, a 35MHz PVDF focused transducer was designed and fabricated and a C-scan system was set up in our laboratory. The developed system can be used to study the ultrasound characteristics and to produce high resolution images of human soft tissues in the frequency range from 27MHz to 55MHz. The ultrasound properties of normal and diseased thyroid were studied and the resulted ultrasound images for thyroid tissue were obtained. The results can be related to the histological structure of the tissues.

EXPERIMENTS AND RESULTS

The sample was fixed in the sample-holder between a quartz and a thin plastic membrane and was mounted in water bath. A 35MHz focused, f/1.6 copolymer PVDF transducer with a lateral full width at half maximum of 140μm and depth of field of 1mm was used in the measurement. The design and characters of the high frequency focused ultrasound used here was described by Liu et al. With this transducer, the ultrasonic spectroscopy is used to analyze the attenuation and backscattering coefficient over the frequency range from 27MHz to 55MHz. The focused ultrasound transducer was excited with a pulse (300Vpp in amplitude, 15ns in width) and after exciting ultrasonic pulse passing through the membrane, sample and reflected from the quartz flat, the echo signal was received by the same transducer. Moving the transducer up and down carefully and moving the step motor, the region of interest in the sample can be located in the focus area and the focal depth of the transducer. The scan parameters for raster motion were downloaded by MTM250pp (Newport Co. U.S.A). The attenuation signal and backscatter signal were recorded using a 400MHz digital scope (HP5402A, U.S.A). An IEEE-488 bus transfer digitized signals to the control computer for further processing.

The measurement process and the equations used to obtain the acoustic parameters were described by S.G.Ye et al. The first step of the measurement process consists of moving the transducer in a raster
fashion over(10mm×10mm), and generating a backscatter image of the sample using C-scan mode. The region of homogenous tissue were selected for quantitative measurement.

The fresh thyroid samples were obtained from the hospital, then the sample was kept in refrigerator. The sample was clamped between plastic membrane and reflector quartz flat in a special designed sample holder and was cut the both sides of the sample at temperature (-10°C) using Cryostat 2700 (Frigocut, Reichert-june, Germany) to make the surfaces with a homogenous thickness ranging from 0.5mm to 1.5mm. Then the sample was thawed in saline solution and sealed with a thin plastic membrane. In the study, four normal thyroid samples and five diseased (adenomas) thyroid were used. A piece of slice from every sample was stained and relative histological diagram was obtained, it can be related to the ultrasound image.

From the experimental results it was shown that the image of adenomas is different from that of normal one (Fig1). The adenomas images show there are some big lumen in adenomas thyroid. The histological slice diagram of follicle adenomas is that there is extra colloid in the follicle, the follicle expands especially. So the experimental image is coincided with the histological feature.

![Figure 1(a)](image_url_a) Image of normal thyroid  
![Figure 1(b)](image_url_b) Image of adenomas thyroid

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<th>Table 1 Parameters of normal and adenomas thyroid</th>
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<td>Samples</td>
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<td>Normal</td>
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Both of the measured sound of speed and the measured attenuation for adenomas is larger than that of normal one. The thyroid follicle exists as a continuous cell layer and the colloid which is a kind of viscosity proteinaceous solution is surrounded by thyroid follicle. In adenomas thyroid, the number of colloid mass is much larger than in normal thyroid, therefore, the sound speed is larger than the normal, the attenuation coefficient is higher than normal thyroid. The frequency dependent backscatter coefficient is some different between normal and diseased thyroid, although both of these two coefficients increase as the frequency goes high. The scatters sources existing in thyroid come from follicle and colloid. There are bigger scatters in adenomas, and the distances between scatters are shortened, so the backscatter coefficient for adenomas is larger than that for normal thyroid.

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