Changes in ultrasound echoes of a breast tissue *in vivo* after exposure to heat - a case study.

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Abstract

A B-mode ultrasonography provides structural information on the tissue under investigation encoding the echo strength in gray scale in a two-dimensional image. Interpretation of the B-mode image of breast tissue is done by a physician. The analysis of statistical properties of backscattered RF signal has been recently applied successfully to distinct healthy tissue from tissue lesions regions as a new method of quantitative ultrasound (QUS). Up till now, the most reliable results were obtained for liver and renal tissue lesions, because their normal, healthy structures are nearly homogeneous while a heterogeneous breast tissue classification is still an open issue. The recent study revealed that the medium contraction and expansion induced by a temperature change may cause variations in the relative position of scatterers in a tissue. We have developed a new procedure of heating the patient breast and allowing to observe and record *in vivo* the influence of temperature changes on a B-mode image and properties of unprocessed radio frequency (RF) backscattered echoes. The initial, feasibility studies of influence of the temperature increase in breast tissue on the intensity, spectrum and statistics of ultrasonic echoes will be discussed.

Keywords: breast tissue, RF signal, backscattered signal amplitude statistics, spectral properties

1. Introduction

A B-mode ultrasonography provides structural information on the tissue under investigation encoding the echoes strength in gray scale in a two-dimensional image. Interpretation of the B-mode image of breast tissue is done by a physician. Recently new methods of quantitative ultrasound (QUS) dedicated to estimation of structural changes in tissue are being developed, cf. [4], [6]. Particularly, analysis of statistical properties of backscattered RF signal has been successfully applied to distinct healthy tissue from tissue lesions regions, see [5]. Up till now, the most reliable results were obtained for liver and renal tissues lesions, because their normal, healthy structures are nearly homogeneous while a heterogeneous breast tissue classification is still an open issue. A recent study revealed that the medium contraction and expansion induced by a temperature change can cause variations in the relative position of scatterers in a tissue. We have developed a novel algorithm of heating the patient breast and recording the changes in ultrasonic B-scans and in RF echoes. In the statistics of the signal information is encoded about the type of dissipative structures. The structural information on the type of dissipative tissue is encoded in the statistics of the returning signals. When a signal is backscattered from a large number of uniformly distributed scatterers then random amplitude fluctuations are close to the Rayleigh distribution. Variations of the structure to a more heterogeneous in terms of the appearance of cell clusters in the distribution of scatterers or the scatterers reflectivity variations result in the amplitude distribution close to K-distribution or Nakagami distribution. The experiments were carried out in order to evaluate the temperature influence on variation in statistical distributions of signals recorded in tissue phantoms and samples of soft tissue *in vitro*, cf. [1],[2] and [3]. In what follows the initial, feasibility studies of influence of the temperature increase in breast tissue on the signal intensity, spectrum and statistics of ultrasonic echoes will be discussed. The paper is organized as follows: Sections II introduce the experiment description and methods, Section III presents the results. In Section IV conclusions are drawn about the contributions of this study to the general ultrasonography.

2. Material and Methods

2.1. *Experiment description*

Backscattered ultrasound RF signals and B-mode images have been collected using ULTRASONIX, (SonixTOUCH, Canada) scanner, and standard linear array L14-5/38, 10 MHz transducer. focused at the depth 3,5 cm. The patient breast was scanned before and after heating by physician who has localized the lesion region to be analyzed. The heating process was done directly through the skin to which a rubber seal bag with hot water at c /a 50^oC during 10 minutes was applied.

2.2. *Methods*

The signal frequency spectrum from the regions at two temperature levels has been also obtained. Next, for each sub regions of tissue the statistical parameters have been correlated to scatterer strength, density and distribution. All scan lines were compensated for attenuation and then the amplitudes of all FR lines have been calculated using of Hilbert transform. Next, the fitting of amplitude histograms to different probability density functions together with the evaluation of the accuracy of matching by MSE (mean square error) was performed.

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3. Results

A B-mode image was recorded from the same part of breast before and after heating. Zoomed region of the heated breast regions are presented in Fig. 1.

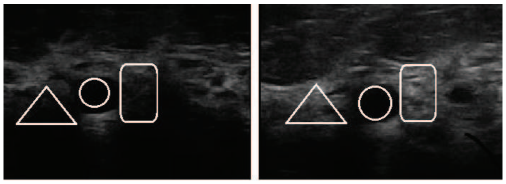

Figure 1: B-mode of breast tissue before and after heating.

The *thermal behaviour* of spectral properties of backscattered signal are shown in Fig. 2, in which the amplitude and the bandwidth changes of the spectrum are marked.

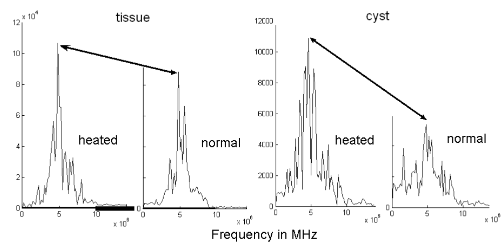

Figure 2: Mean spectrum in cyst and tissue regions gefore and after heating

The statistical properties of signal amplitude are described by two parameters. The SNR (signal to noise ratio), here the ratio between mean value and standard deviation, and the shape or scale parameter of best matched to the amplitude histogram distribution are calculated similarly as in [3]. In Figure 3 the matchings are shown and the chosen characteristic parameter value are given before and after heating of tissue and cyst regions, respectively.

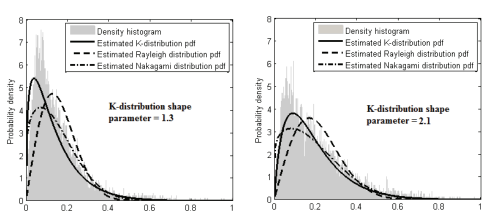

Figure 3: Histogram of signals amplitudes collected from tissue region marked on B-mode and fitings to different probability density functions

In order to illustrate the statistical parameters relation between SNR shape parameter of K-distribution is shown in Fig. 4.

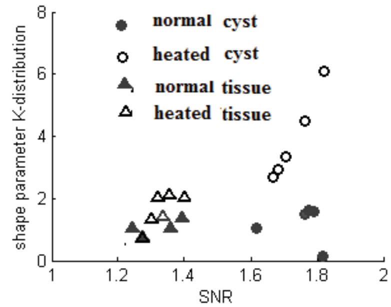

Figure 4: Plot SNR versus the shape parameter of K-distribution for different regions ofbreast

4. Conclusions

Note that the B-mode image quality is significantly improved after heating. The fine details of the cyst structure are clear while the same region before heating was simply dark, water-like. The depth of penetration of ultrasound was increased by about 0.5 cm comparing to the pre-heating scanning, cf. Fig. 1. In the less heated regions (left of the cyst) no visible differences occur, however they are clear when calculated versus temperature change, cf. Figure 6. It should be stressed that the sensitivity of statistical parameters to temperature is very high, particularly in the cyst region as compared to the normal tissue regions. This effect can be explained by a larger increase in speed of sound in a fluid-like cyst volume, than in an inhomogeneous tissue region. After heating the spectrum amplitude increases much larger in the lesion than in the surrounding tissue. In a liquid medium the rise of a spectrum level is much greater than in tissue region.

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