1 Introduction

Human female breast is a modified secretory gland composed of glandular, connective and adipose tissue with different ultrasonic properties. Various types of breast diseases exist and particular type is in general determined by surgical biopsy. Treatment is then planned accordingly. The procedure of biopsy, however, involves risk of infection, blood and health hazards due to local or general anaesthesia. Radiographic and computer tomography techniques are also used these days, for the visualization of these tumours but are complicated, time-consuming and expensive. Due to its non-invasive and non-destructive nature, ultrasound has now been accepted as one of the modalities, both for diagnosis and therapy.

Although diagnosis of different breast tissues and their abnormality by measuring ultrasound velocity and attenuation has been made earlier, more research is yet required to use it in the clinic. A double-probe through-transmission technique as used earlier for various tissues and materials has been utilized in the present study to characterize in vitro breast tumour – in this case ductal carcinoma. The data obtained can be used as an index for identification of a particular type of tumour after proper standardization.

2 Ductal Carcinoma (Adeno-Carcinoma) of Breast

The frequency of adeno-carcinoma of the breast with productive fibrosis is 78%. The prototypical common adeno-carinoma of the breast presents in a peri-menopausal or post-menopausal woman in the sixth decade as a solitary, non-tender, and firm, ill-defined mass.

The tumour characteristically possesses a poorly defined border. Cut surfaces suggest a central radiating stellate tumour with a chalky-white or yellow streak extending into surrounding parenchyma. The histologic picture may reveal variable cellular and nuclear grade. A broad spectrum of variants is observed from in situ to highly anaplastic, suggesting significant heterogeneity. Other lesions can possess bland homogeneity of cellular differentiation throughout the specimen. Neoplastic cells are arranged in small clusters or stacked in single rows (to produce “Indian filing”) that occupy irregular cleft spaces between collagen bundles.

With profound desmoplastic response of tumour growth, the resultant fibrosis and tumour infiltration can shorten cooper’s ligaments as they course from the deep layer of clavicular fascia to the superficial fascia of the corium. With hyalinization, these ligaments become entrapped within the expanding desmoplastic border of the tumour. With progressive growth, cooper’s ligaments are further shortened to initiate the classic physical finding of skin dimpling directly over the tumour and to initiate advanced local and regional presentations.

Ultrasonic propagation in breast tissue with ductal carcinoma

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Received 20 May 2002; accepted 30 May 2002

Ultrasonic parameters of soft tissue tumours are still not known accurately. Breast tissues with diagnosis of ductal carcinoma are studied. A double-probe through-transmission technique is used. Ultrasonic velocity in abnormal breast tissue samples is found between 1438 ms\(^{-1}\) and 1514 ms\(^{-1}\) and attenuation between 741 dBm\(^{-1}\) and 892 dBm\(^{-1}\). Other parameters like acoustic impedance and dynamic modulus of elasticity are also determined. Data may be used as an index in the identification and characterization of particular type of tumours after proper standardization.
3 Materials and Methods

Twenty samples of breast tumour (ductal carcinoma) and five of normal breast tissue of different female patients in peri-menopausal age group (40-45 years) were procured from different hospitals. All these samples were of chalky-white appearance with yellow streaks. In some of the samples, dark fibrous region was clearly visible. Diagnosis for the presence of such carcinoma was confirmed by a pathologist. Out of all these tumor samples of different patients, six parallel sections were prepared with scalpel. For each tumour sample, average of the measurements on the five positions was taken as the measured value. In the two samples, fibrous dense part was clearly visible. In the same manner, five parallel sections of normal breast soft tissues were prepared. Normal breast tissues having connective tissue with surrounding fat were selected. Averages of all those measurements is presented here for comparison. All the samples were fixed in 10% formalin and were one-month old when taken from hospitals. The thicknesses of samples were measured by Vernier calipers.

![Diagram](image)

Fig. 1 — Block diagram of the set-up used to measure ultrasonic velocity and attenuation

For ultrasonic propagation velocity and attenuation measurements, double-probe through-transmission technique was used, which was described and used earlier for measurement on bone, kidney and gall bladder stones, brain and various other types of biological and non-biological materials. Fig. 1 shows a block diagram of the experimental set-up for the measurement of the ultrasonic velocity and attenuation. The samples tested were placed between two transducers, one worked as a transmitting transducer and other as a receiving one. An ultrasonic pulser-receiver (Panametrics Model 5052PR) was used, both to excite the transmitting transducer in narrow-band pulse mode and for receiving the signal from the receiving transducer having matched frequency. The pulses received were then displayed on cathode ray oscilloscope (in this case, OS 300C 20 MHz L&T Gould make).

The transducers used in present investigation were plane-faced of frequency 3.5 MHz and were made at NPL, New Delhi, India, by using discs of PZT-5 material of diameter 10 mm. Ultrasonic velocity and attenuation of the tissues were determined by using the relationship \( v = \frac{d}{t} \) and \( \alpha = \frac{100}{t} \log \left( \frac{V_1}{V_2} \right) \), where \( d \) is the thickness of the tissue sample and \( t \) is the time measured by oscilloscope. \( V_1 \) and \( V_2 \) are the amplitudes of transmitted and received pulses, respectively. For determination of acoustic impedance \( (Z = \rho v) \) and, dynamic modulus of elasticity \( (E = \rho v^2) \), value of density of the samples was required, which was measured by Archimedes' principle. The ratio of the weight of the sample in air to loss of the weight of the sample in distilled water at room temperature, multiplied by the density of distilled water at room temperature gave the density of the sample. As the density of fatty tissues was lesser than that of water, it was calculated by tying it to a piece of iron kept in a measuring flask. For weight measurements a weighing balance (made by E Mettler in Zurich, Switzerland) of accuracy 0.0001 g, was used.

The technique used in the present work was calibrated by measuring ultrasonic velocity and attenuation for standard blocks of perspex. The accuracy for velocity and attenuation is 0.5% and 5%, respectively for the present measuring set-up.

4 Results and Discussion

Ultrasonic velocity, density, attenuation and other parameters determined, are given in Table 1. Average ultrasonic velocity in normal breast tissues as measured has been found to be 1531 ms\(^{-1}\). Variation of ultrasonic velocity observed in abnormal tissue samples has been from 1438 ms\(^{-1}\) to 1579 ms\(^{-1}\). In the excised fibrous part of the abnormal breast tissues, ultrasonic velocity has been found to be 1564 ms\(^{-1}\) and 1579 ms\(^{-1}\), while in
yellow-white tissues, the ultrasonic velocity has been found to lie in the range from 1438 m·s⁻¹ to 1514 m·s⁻¹. The ultrasonic velocity in fat as reported in literature is from 1410 m·s⁻¹ to 1479 m·s⁻¹ (Ref. 16). These results clearly indicate the proliferation of dense fibrous tissues into the fatty tissues of the breast. As the tumour grows, it changes the characteristics of the breast tissues, raising the ultrasonic velocity towards the higher side. In the tissues of tumour, average ultrasonic velocities are higher than fat, which is not the pure velocity in tumour but is actually in tissue containing fat and tumour cells, since, shape of the tumour is not homogeneous. Variation of ultrasonic velocity with density for abnormal breast tissue is presented in Fig. 2.

Attenuation has also been measured. In normal breast tissue, attenuation has been found to be the lowest with an average value of 663 dBm⁻¹. In the abnormal yellow-white tissues, it has been found to vary from 741 dBm⁻¹ to 895 dBm⁻¹ and in the fibrous
tissues, between 998 dBm⁻¹ and 986 dBm⁻¹. Variation of ultrasonic attenuation with density for abnormal breast tissue is presented in Fig. 3.

5 Conclusions

Efforts have been made to find out ultrasonic velocity and attenuation in breast tumours with ductal carcinoma. Higher attenuation in all abnormal tissues and higher ultrasonic velocity has been found in a localized region due to fibrosis in available normal tissue samples. As compared to other soft tissues, relatively higher attenuation is found in normal breast tissues, which is due to the fat-tissue interfaces present in such tissues. Decrease in sound speed in tumour samples is also found due to more fat content. Local increase in collagen content may also be the cause of higher attenuation in diseased breast tissue samples. In future, work on other type of breast abnormalities has been recommended to help the medical fraternity for diagnosis and treatment, which is possible only after proper standardization of data on different normal and abnormal tissues.

Acknowledgements

The authors wish to thank Prof Raj Malhotra and Dr Sanjiv Bhatia for their valuable suggestions and help in collection of the samples.

References


Table 1 — Ultrasonic parameters of breast tumours at 3.5 MHz and room temperature 26°C

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Density  ρ ( 10^{3} \text{kgm}^{-3} )</th>
<th>Velocity ( v ) ( \text{ms}^{-1} )</th>
<th>( v_{SD} % )</th>
<th>Acoustic Impedance ( Z ) ( 10^{9} \text{km}^{2} \text{s}^{-1} )</th>
<th>Dynamic Modulus ( E_{d} ) ( 10^{9} \text{kgm}^{-1} \text{s}^{-2} )</th>
<th>Compressibility ( \beta ) ( 10^{10} \text{kgm}^{-1} \text{ms}^{-2} )</th>
<th>Attenuation ( \alpha ) ( \text{dBm}^{-1} )</th>
<th>( \alpha_{SD} % )</th>
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+ Breast Tumour ++ Normal Breast Tissue


