PROGRESS IN CANCER DIAGNOSIS WITH ULTRASOUND

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Abstract-**Despite successes in using ultrasound to characterize tissues at many sites in the body, the diagnosis of cancer, especially in the female breast, has remained challenging. Besides devising methods to analyze the data, there are difficulties with collecting data from enough patients to validate a variety of new methods, and in coping with changes in the hardware. We have been conducting an integrated effort for nine years that has minimized these difficulties and is approaching success.**
Keywords – **Ultrasound, imaging, cancer diagnosis**

I. INTRODUCTION

Ultrasound is an ideal modality for medical diagnosis. It is non-ionizing and thus is used for many routine screening and follow-up studies. Current work using contrast materials promises that it will be used for more primary diagnoses. Much equipment is installed worldwide, and it is affordable in the developing world. Continuing success in expanding the ability of ultrasound to characterize tissues encourages us [1]. Our effort is organized as a Program Project, in which a number of investigators collaborate to improve the efficacy of ultrasound for diagnosis of cancer of the breast. The methods we are deriving may have many other applications.

Close medical collaboration is essential for data collection, such as setting up the process in such a manner that no additional visits or significant patient time is needed. Data collection of the radio-frequency echo signal in digital form allows all image formation and processing to be done later in software, as initiated by Lizzi [2]. We thus can use all the patient data for new methods devised after the beginning of the study, without the need to develop new hardware and to repeat the studies..

The diagnostic methods are being devised by several signal processing projects. They are all model-based, and fit the data to a model so that the model parameters can be used for characterization of a lesion as malignant or benign. The results so far show promise of competing with conventional determinations by a radiologist.

Additional projects are developing very wideband transducers and new contrast agents. These products will assist our efforts and the contacts between the project leaders are valuable in keeping us all current.

The final step of data fusion is next, where we are combining results from all projects to improve diagnostic accuracy. Future efforts would benefit from having research equipment that affords access to data from the individual elements as well as control of the transmit function. The ultrasound industry has far lagged behind the MRI industry in providing such ability. MRI imaging would be very poor indeed if investigators had no control over pulse sequences and subsequent image processing.

II. METHODOLOGY

A. Imaging Projects

These projects are aimed at the development of a system that processes the raw radio-frequency (rf) ultrasound signals from the breast to give quantitative information about the different pathologies of the breast tissue. The goal is to develop a system that extracts more information than that available by visual inspection of the B-scans of the breast.

Data collection is done at Thomas Jefferson University Hospital. Our procedure is designed to minimize disturbance to the patients' and the clinicians' normal routine and thus to maximize the amount of data. The equipment is located in a breast center, which includes the mammography suite, and is convenient for everyone. All patients with solid masses that are scheduled for biopsy are entered into the study. They are asked to sign an approved patient consent form and additional scans are taken for entry into our database. Scans are made using an ATL Ultramark 9 HDI scanner, modified by ATL, Bothell WA USA, to include a post TGC pre-demodulator signal output to disk storage media. Several scans are made of each breast. These disks are hand carried, or the data transmitted over the internet, to Drexel University. In addition, radiologist identification of tumor areas is drawn on the screen images. The biopsy findings are transmitted when known.

Additional scans have been taken of commercially available test objects and of custom phantoms that were designed to provide test signals for the different projects. These have variable numbers of scatterers and of spacings, for example.

Each project has access to the digital data files, and is using different methods to model the signals. Two projects are using the approach of matching the data to the parameters of models, and using the parameters to characterize the normal and abnormal tissue [3,4]. Two others are matching the data to the parameters of amplitude distribution functions [5,6] One project is investigating the application of scaling concepts to the signals [7].

B. Contrast study

Several types of injectable bubble-forming materials are being developed with the goal of increasing their echo output, particularly at harmonics of the transmitted frequency [8].

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Much effort has gone into reducing the size of the bubbles. Tests are being made in rabbits with excellent results.

C. Transducer Development

A new type of PVDF transducer is being developed that uses a layered construction with the layer spacing based on a signal code [9]. The ultrasonic output is the convolution of the transmitter electrical signal and this code. When received the signals from the layers add, since the receiver is a matched filter for the signal, to produce a transducer response that is the impulse response of the code. Since this response is very short without significant time sidelobes the system has a very wide useful bandwidth, which should be wide enough to encompass both subharmonic and higher harmonics of the signal. Modelling, simulation, and construction are being carried out, with considerable research into materials and construction methods. New designs are being proposed that have a minimal number of connections to through the layers and hence should be simpler to produce.

III. RESULTS

A. Imaging Projects

Initially we used a scanner with less resolution and an unreliable digitizing interface. These data records are available but are not used in current work.

So far we have data files from the current machine for 140 patients, of which 31 had malignancies and five had no diagnosis. In all, there are 151 lesions. Although some projects have not been able to process all of these files with their most recent methods, the Receiver Operating Characteristic (ROC) analyses are approaching or exceeding an A_z of 90%. The referenced papers give the results in more detail than can be covered here [3-7]. The most promising models or methods so far are: Wold Decomposition [3], Generalised Spectrum [4], Shot-noise, alpha-stable distributions [5] and "K" and Nakagami distributions [6].

Preliminary studies indicate that a combination of results from different analysis methods will improve the results. This is an ongoing effort that will be the subject of our next efforts.

B. Other Projects

The contrast developments have succeeded in finding some excellent materials [8]. However, commercial support is required for approval to allow them to be used in humans, and this is being sought.

Transducer development has recently devised simplified construction schemes [9]. Test models of the earlier proposed designs have operated as expected, and show a considerable improvement over ceramic materials.

IV. DISCUSSION AND CONCLUSIONS

The use of ROC analysis is common in medical decision-making. However, individual decisions are based on a combination of factors, so that any new method cannot completely be evaluated by itself. Additional considerations in cancer diagnosis involve care to avoid false negatives. Current practice uses biopsy to make many final decisions.

These cases can be viewed as false positives. Taking this view, some of our A_z values compare favorably with current radiology practice. Much clinical experience will be required before we can claim complete success. We believe that we are on the way, and that the Program Project type of organization has promise as a model for similar efforts.

The future effort will be to combine results from all imaging projects. This promises to improve results, although much work will be needed to accommodate to the differing formats used by the groups.

It is essential to obtain the cooperation of the manufacturer of the ultrasonic instrument if a modern, digital, device is to be used. Unfortunately there are no commercial clinical research machines available to investigators, so that the ultrasound community is handicapped-as compared to the MRI folks. A desirable instrument would include the capture of Doppler flow information to add a functional measure to the analyses. We currently do not have this ability.

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