Development of an Ultrasound-Based Elasticity Imaging System for Early Cancer Detection

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Globally Breast Cancer is the major killer disease among WOMEN

- 1.5 million women were affected globally in 2010
- 1 in every 8 women will develop breast cancer in the lifetime
- 15000 women die Every Year in Bangladesh from breast cancer

Improve non-invasive diagnosis of breast cancer and reduce mortality in Bangladesh
Objectives

• To procure clinical ultrasound scanner with accessories and research facility.
• To acquire *in vivo* data from females with breast mass.

• To develop new methods for *Elasticity Imaging* for cancer detection.
• To study the efficacy of the developed imaging system using the simulation & experimental phantoms, and *in vivo* patient data.
• To develop USG+ELASTOGRAPHY based combined Ultrasonic Tissue Characterization algorithm for CAD.
• To demonstrate the benefits of *ELASTOGRAPHY* in cancer detection to the medical professionals.
Why Elasticity Imaging?

- To detect breast cancer at an early stage
- To facilitate CAD for benign/malignant classification
- To improve diagnostic accuracy
- To reduce unnecessary biopsies

Breast screening and diagnostic modalities

- Ultra-Sonography
  - Tissue attenuation
  - Tissue stiffness
- MRI
  - Benign/Malignant?
- Mammography
- Elastography
- MR-EIT
- Microwave Imaging

EMERGING Breast Imaging Modalities
Stiffness Image vs. Attenuation Image

ELASTOGRAM

Ultrasonogram

Stiffness Ratio: 3.00

Strain Ratio: 3.04

Attenuation (Back): 0.50

Attenuation (Mass): 0.50

\{\text{attenuation, stiffness}\} \quad f(\text{pathology})
## Stiffness Contrast vs. Attenuation Contrast

<table>
<thead>
<tr>
<th>Breast Tissue Type</th>
<th>Tissue Elastic Modulus (kPa)</th>
<th>Tissue Attenuation (dB/cm/MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Fat</td>
<td>3.25±0.91</td>
<td>0.4353±0.0925</td>
</tr>
<tr>
<td>Normal Glandular Tissue</td>
<td>3.24±0.64</td>
<td>0.6516±0.1166</td>
</tr>
<tr>
<td>Fibroadenoma</td>
<td>6.41±2.86</td>
<td>0.5571±0.1260</td>
</tr>
<tr>
<td>Low-grade IDC</td>
<td>10.40±2.6</td>
<td>0.5767±0.1198</td>
</tr>
<tr>
<td>ILC</td>
<td>15.62±2.64</td>
<td></td>
</tr>
<tr>
<td>DCIS</td>
<td>16.38±1.55</td>
<td></td>
</tr>
<tr>
<td>Fibrocystic Disease</td>
<td>17.11±7.35</td>
<td></td>
</tr>
<tr>
<td>Int.-grade IDC</td>
<td>19.99±4.2</td>
<td></td>
</tr>
<tr>
<td>High-grade IDC</td>
<td>42.52±12.47</td>
<td></td>
</tr>
<tr>
<td>Fat Necrosis</td>
<td>4.45±2</td>
<td></td>
</tr>
</tbody>
</table>

*stiffness contrast is better than attenuation contrast*

Can we measure **tumor stiffness** non-invasively?
How to Obtain Relative Stiffness?

**ELASTOGRAM: SIMULATION PHANTOM**

<table>
<thead>
<tr>
<th></th>
<th>Stiffness Ratio</th>
<th>Strain Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesion1/Background</td>
<td>0.30</td>
<td>0.32</td>
</tr>
<tr>
<td>Lesion2/Background</td>
<td>3.00</td>
<td>2.78</td>
</tr>
<tr>
<td>Lesion3/Background</td>
<td>8.00</td>
<td>7.51</td>
</tr>
</tbody>
</table>
What is Strain?

One-Dimensional Uniform Spring System:

Strain = \frac{\text{Change of Length}}{\text{Original Length}} = \frac{L_n - L_o}{L_o}

Normal State

Compressed State
One-Dimensional Non-uniform Spring System

What is Strain?

Normal State

Compressed State

Strain Estimation from Displacement Field

Direct Strain Estimation

Robust Techniques

STRAIN CALCULATION

Pre-compression RF scan-line

Post-compression RF scan-line

Local Similarity
Fluid inside a Cyst can be confirmed in elastogram.
Elastography Video: Carcinoma

Necrosis inside a malignant tumor is visible in elastogram
RESULTS: Elasticity Image

(Phantom)
RESULTS: Elasticity Image (in vivo)

B-MODE

ELASTOGRAM

CARCINOMA

ABSCESS
Direct Mean Strain Estimation for Elastography Using Nearest-Neighbor Weighted Least-Squares Approach in the Frequency Domain

Md. Kamrul Hasan*, †, S. Kaisar Alam†, Soo Yeol Lee‡

* Department of Electrical and Electronic E
† Riverside Research, New York, NY
‡ Department of Biomedical Engineering, K

IEEE TRANSACTIONS ON ULTRASONICS, FERROELECTRICS, AND FREQUENCY CONTROL, VOL. 59, NO. 8, AUGUST 2012

Direct and Gradient-Based Average Strain Estimation by Using Weighted Nearest Neighbor Cross-Correlation Peaks

Mohammad Arafat Hussain, Emran Mohammad Abu Anas, S. Kaisar Alam, Senior Member, IEEE, Soo Yeol Lee, and Md. Kamrul Hasan, Senior Member, IEEE

ULTRASONIC IMAGING 34, 93-109 (2012)

Robust Strain-Estimation Algorithm Using Combined Radiofrequency and Envelope Cross-Correlation with Diffusion Filtering

Mohammad Arafat Hussain, S. Kaisar Alam, Soo Yeol Lee, and Md. Kamrul Hasan

15
Using Nearest Neighbors for Accurate Estimation of Ultrasonic Attenuation in Spectral Domain

Achievements-Publications

International Journal Publications:


International Conference Publications:


Achievements Contd.

- **Submitted Journal Papers:**

- **Ongoing Works:**
  1) Breast Elastography vs. Ultrasound: A Comparative Study Using Computer Aided Diagnosis
  2) Ultrasonic Tissue Characterization for Breast Tumor Classification.
Patient Data Collection @ BUET

Engineering Team in the Project

Dr. Md. Kamrul Hasan
Dr. M. I. Hassan Bhuiyan
Dr. Md. Ariful Haque
Dr. S. M. Mahbubur Rahman

Medical Doctors Involved in the Project

Dr. Rayhana Awal Shumi, FCPS,FRCS (DMCH)
Dr. Farzana Alam, PhD (BSMMU)
Dr. Sharmin Akhter Rupa, M.Phil, FCPS (EMCH)
# Equipment Procured for Data Collection @ BUET Medical Centre

<table>
<thead>
<tr>
<th>Equipment Procured</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Ultrasound Machine with transducer and necessary accessories</td>
<td>1</td>
</tr>
<tr>
<td>Standard Ultrasound Phantom</td>
<td>1</td>
</tr>
<tr>
<td>Online UPS</td>
<td>1</td>
</tr>
<tr>
<td>Color Laser Printer</td>
<td>1</td>
</tr>
<tr>
<td>Multimedia Monitor</td>
<td>1</td>
</tr>
</tbody>
</table>
Statistics of Patients Scanned @ BUET

- No. of patients: 293 (March-December 2012)
- Age range: 13 – 75 years
- Mean±STD: 30.37±11.60 Y

Breast Lesion Type | No. of Patients
--- | ---
Cyst | 50
Fibrocystic Change | 39
Fibroadenoma | 145
Carcinoma | 41
Suspicious | 7
Phylloid | 1
Galactocele | 5
Fat Necrosis | 5
Tuberculosis | 1
Duct Ectasia | 6
Chronic Abcess | 9
Mastitis | 5
Ductal Papiloma | 3
Inflammation | 12
Lactating Adenoma | 3

Sonix Touch Research Ultrasound System
FDA approved
Probe: L14-5/38

- Protocol is approval by IRB, BUET
- Patient consent form is signed
- No Test FEE
Harmless Protocol

No Conflict between RESEARCH & DIAGNOSIS

Patient Data were used only for the Performance Analysis of New Elastography Algorithms

Diagnosis was made by the Radiologist using the Clinical Machine
Benefits of Elastography

**USG**
- 088 27Y
- 273 28Y
- 057 50Y

**FNAC**
- 061 30Y
- 064 48Y
- 164 38Y

**ELASTO**
- I am saved

**BIOPSY**
- I am saved

**FNAC** may go wrong!!!
RAD-PATH conformation is important
Complementary information is useful
Benefits of Elastography

Sensitivity & Specificity of Radiologic Diagnosis can be Improved Using Complementary Information from Different Imaging Modalities

USG & ELASTOGRAPHY: Two Imaging Modalities in ONE Machine
A seminar was organized at BUET on December 13, 2012 to demonstrate the benefits of ELASTOGRAPHY in cancer detection.
Impact on HE

- Has made cutting-edge research possible in BD
  - Breast cancer
  - Thyroid cancer
  - Heart disease
  - Prostrate cancer
  - Liver cirrhosis

- Will help improve the teaching skill of the faculty members
- Expected to help understand the importance of Biomedical Engineering program in Bangladesh
Utilization of HEQEP Fund

Approved Budget
BDT 97.0625 (in Lakh)

Received Amount
BDT 95.65824 (in Lakh)

Use of fund
BDT 91.112316

- Contingency, BDT 0.79
- Revenue, BDT 20.57
- Refund, BDT 4.545924
- Capital Expenditure, BDT 69.75

4/2/2013
HEQEP SUB-PROJECT CP#096
Conclusions

- Ultrasound-based cancer research facility is established at BUET
- Research outcomes have been published in reputed International Journals
- 293 Patients with Breast Tumor have been examined and in vivo data were collected for Breast Cancer Research
- Cancer was detected at an early stage for several patients
- Benefits of ELASTOGRAPHY has been communicated to medical professionals
It is the high time to think about the Role of Engineering in Medical Diagnosis and Treatment

Thank you