CT Imaging of the Breast
with a Novel New System

Cone Beam CT

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Breast Cancer

No cure
Etiology of the disease is unknown
Mammography is limited in dense breasts
To affect mortality rates and reduce the cancer burden, we need to find cancer in the earliest stages.

5 Years-
Mammography
98%

7 Years-
Palpable
<70%

III
<56%

IV
<16%
Standard of Care for Detection and Diagnosis

Mammography
- Additional views- spot, angled, magnification

Ultrasound
Ductography
MRI
Biopsy
Limitations of Mammography

High spatial resolution but limited contrast resolution especially in dense breasts

Mammography is a 2D projection acquisition of a 3D structure leading to structure and tissue overlap

Extent of disease
- Actual tumor size, multifocality, and multicentricity
Limitations of Ultrasound

Operator dependent and time consuming

ACRIN 6666 (2004-2008)

- Many more false positive biopsies to get to a true cancer

Low spatial resolution and has severe limitations in visualizing and characterizing calcifications
Limitations of Breast MRI

The dependence of MRI on contrast constrains the modality to balance spatial resolution against temporal resolution.

Breast MRI cannot distinguish calcifications
- High sensitivity for invasive breast cancer but limited in detecting DCIS

Breast MRI 3D rendering
- Maximum contrast uptake intensity projection (MIP) used for geographic location only
Why not CT?

- Patient Positioning and Access
- Tissue Coverage
- Resolution/ Image Quality
- Dose
- IV Contrast

Not with current design and configuration:
Current Use of CT in Breast Imaging
First CT from GE
Unit #1- 1975- Mayo Clinic
Unit #2- 1976- U of Kansas
### Specifications: GE CT/M

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice Thickness</td>
<td>5 -10mm</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>.32 lp/mm</td>
</tr>
<tr>
<td>Scan Time</td>
<td>10 seconds per slice</td>
</tr>
<tr>
<td>Dose</td>
<td>39-73 mGy</td>
</tr>
<tr>
<td>Technique</td>
<td>75 kVp - 200 mA</td>
</tr>
<tr>
<td>Reconstruction Time</td>
<td>90 seconds per slice</td>
</tr>
</tbody>
</table>
Results: University of Kansas Medical Center

1976-1979

1625 Patients - All with Contrast

78 Cancers

Increase in CT Number

CT - 94% Sensitivity

Mammo - 77% Sensitivity
Conclusion:

“The CT/M appears to be especially superior to the mammography for detecting cancers in dense, premenopausal dysplastic breasts. The CT/M can detect totally unsuspected very small breast cancers that were unable to be identified by conventional mammography or physical exam. The CT/M scan also seems to be a better test for recognizing precancerous high risk lesions. CT/M evaluation affords definitive diagnostic help in instances where the mammographic and/or physical examinations are inconclusive. Although CT/M will not replace conventional mammography in routine breast examinations, it overcomes the limitations of mammography.”

Cancer 46: 939-946, 1980
Lesion Differentiation Based on CT Number

Japan
154 Cancers
Cutoff Attenuation 60HU
90% sensitivity
77% specificity

The distribution of CT values in early phase; the malignant group vs. the benign group
Multi Detector CT

- Italy
- 61 Birads 4/5 Patients
- Unable to undergo MRI
- 47 to Surgery
- Cutoff Attenuation 90 HU
- 25 of 27 Malignant (92% Sensitivity)
- 20 of 20 Benign (100% Specificity)
2004 - UC Davis Clinical Prototype

Cone Beam Scanner
30 x 40 cm Flat Panel Detector
Neoprene Hammock for Breast Support
16.6 second scan time
10 to 110 kVp Fluoroscopic Operation (6 mA)
0.4 mm x 0.4 mm focal spot
Results: Radiology Jan 08

- Overall equal in visualization
- Better on Masses
- Inferior on calcifications
- More comfortable...but not for everyone
- No visualization difference malignant or benign
- Less coverage of pectoralis and axillary tail
- Dose equal to a two view mammogram

Conclusion: Some technical challenges remain but promising
2006- URMC Clinical Prototype

- Cone Beam/Flat Panel Scanner
- Mammography Tube/ Tungsten Anode (0.3) (49kVp)
- Radiographic Technique
- 10 second exposure
- 140 and 270 micron (isotropic)
- 0.25mm slice thickness
- Slip Ring Technology
- Patient access either side
- Table/ Gantry Elevation to 5 feet
Initial Pilot Study

Comparison with Mammography
- Image Quality
- Coverage
- Dose

23 Patients/44 Breasts
All Birads 1&2
Ages 40-65
7 patients-40 to 45
7 patients-45 to 50

Clinical Study Conducted By:
Highland Breast Center-URMC
Elizabeth Wende Breast Care LLC
## Results: Breast Tissue Coverage

<table>
<thead>
<tr>
<th>Breast site</th>
<th>Mammogram (n=40)</th>
<th>KBCT (n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
<td>40 (100%) (MLO)</td>
<td>40 (100%)</td>
</tr>
<tr>
<td>Inferior</td>
<td>27 (67%)</td>
<td>34 (85%)</td>
</tr>
<tr>
<td>Posterior</td>
<td>21 (52.5%) (CC)</td>
<td>36 (90%)</td>
</tr>
<tr>
<td>Medial</td>
<td>14 (35%)</td>
<td>36 (90%)</td>
</tr>
<tr>
<td>Lateral</td>
<td>5 (12.5%)</td>
<td>37 (92.5%)</td>
</tr>
<tr>
<td>Axilla or Axillary Tail</td>
<td>29 (72.5%)</td>
<td>3 (7.5%)</td>
</tr>
</tbody>
</table>
Results: Average Glandular Dose

Pilot Study, Normal Cohort

- N = 44 breasts
- Average glandular radiation dose (mGy) as a function of x-ray tube current (mA)
  - Voltage [kVp] and time [ms] are constant
  - Determined from prior dose phantom studies
  - The mA-to-mGy relationship was verified using an FDA-approved 16-cm PMMA head dose phantom to measure the weighted computer tomography dose index (CTDIw)
- 2 orthogonal low dose scout images of the breast were obtained prior to the scan.
  - The optimal tube current (mA) to obtain sufficient contrast-to-noise ratio in the reconstructed cross-sectional images at a minimum dose was determined from these scout images.
  - Dose was tailored to each breast, depending on breast size and density

- **Mammogram** (dose per complete exam)
  - Range: **2.2 mGy to 15 mGy**; Mean = **6.5 mGy**; Standard deviation = **2.8 mGy**
- **CBCT** (dose per scan)
  - Range: **4 mGy to 12.8 mGy**; Mean = **8.2 mGy**; Standard deviation = **1.2 mGy**
## Results: Image Quality

<table>
<thead>
<tr>
<th>Findings and Sizes(^1) (n=69)</th>
<th>Seen Better on CBBCT</th>
<th>Equally on CBBCT and Mammogram</th>
<th>Seen Better on Mammogram</th>
<th>p-value(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcifications</strong>(^3) (n=55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 mm (n = 35)</td>
<td>22 (40.0%)</td>
<td>22 (40.0)</td>
<td>11 (20.0)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>≥ 1 mm (n = 20)</td>
<td>3 (15.0)</td>
<td>16 (80.0)</td>
<td>1 (5.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Masses</strong>(^4) (n=11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 mm (n = 3)</td>
<td>6 (54.5)</td>
<td>4 (36.4)</td>
<td>1 (9.1)</td>
<td>0.1793</td>
</tr>
<tr>
<td>≥ 1 mm (n = 8)</td>
<td>3 (37.5)</td>
<td>4 (50.0)</td>
<td>1 (12.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Clips</strong> (n=3)</td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>&lt; 1 mm (n = 0)</td>
<td>0 (0.0)</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>≥ 1 mm (n = 3)</td>
<td>0</td>
<td>3 (100%)</td>
<td>0 (0.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Combined</strong> (n = 69)</td>
<td>28 (40.6)</td>
<td>29 (42.0)</td>
<td>12 (17.4)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>&lt; 1 mm (n = 38)</td>
<td>22 (57.9)</td>
<td>6 (15.8)</td>
<td>10 (26.3)</td>
<td></td>
</tr>
<tr>
<td>≥ 1 mm (n = 31)</td>
<td>6 (19.4)</td>
<td>23 (74.2)</td>
<td>2 (6.5)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Sizes measured in mammogram.

\(^2\) p-values of chi-square test in distribution of better detection between size groups.

\(^3\) Includes single calcification, 2-4 calcifications in the same quadrants, skin calcifications, and calcification clusters.

\(^4\) Includes masses, cysts, intramammary lymph nodes, nodules, and skin moles.
## Results: Image Quality

### Location of the Findings and Impression of Better Detection

<table>
<thead>
<tr>
<th>Location (n=61)</th>
<th>Seen Better on CBBCT</th>
<th>Equally on CBBCT and Mammogram</th>
<th>Seen Better on Mammogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retroareolar</td>
<td>6 (85.7%)</td>
<td>1 (14.3)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Mid-depth</td>
<td>2 (33.3)</td>
<td>3 (50.0)</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>Posterior</td>
<td>2 (28.6)</td>
<td>3 (42.9)</td>
<td>2 (28.6)</td>
</tr>
<tr>
<td>Skin</td>
<td>2 (25.0)</td>
<td>6 (75.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Upper Inner</td>
<td>3 (37.5)</td>
<td>5 (62.5)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Upper Outer</td>
<td>6 (46.2)</td>
<td>6 (46.2)</td>
<td>1 (7.7)</td>
</tr>
<tr>
<td>Lower Inner</td>
<td>3 (60.0)</td>
<td>2 (40.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Lower Outer</td>
<td>4 (57.1)</td>
<td>3 (42.9)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

1 Excluding findings not seen on CBBCT.
Results: Patient Comfort

Comfort of CBCT Table

Comfort of CBCT vs. Mammogram
Koning Corporation

- Privately held Delaware C Corp (2004)
- West Henrietta, New York
- Exclusive License from URMC
- Extensive Intellectual Property
- Virtual Manufacturing
- Financing to date:
  - $2.65 million SBIR Grant
  - $5.0 million Angel and VC Funding
2008- First 2 Production Systems
Additional Features

- Self Shielded
- Independent Operators Console
- Add-on Biopsy Device
- 10 Second Scan Time
- 90 Second Reconstruction
- DICOM Compliant
- PACS, HIS, RIS Connectivity
- Internet Accessible from 4 Separate Locations
Add- On Biopsy