Advances in CBCT for Breast Imaging

Breast Tomography Project
University of California Davis

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Anaheim • July 14, 2015

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International Commission on Radiation Units

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P30 CA•093373 (CCSG)
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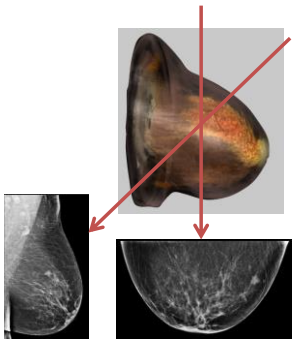
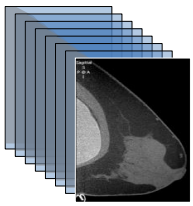
Mammography:



Breast CT



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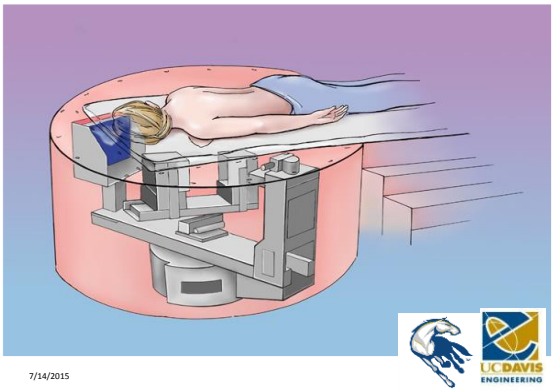

7/14/2015

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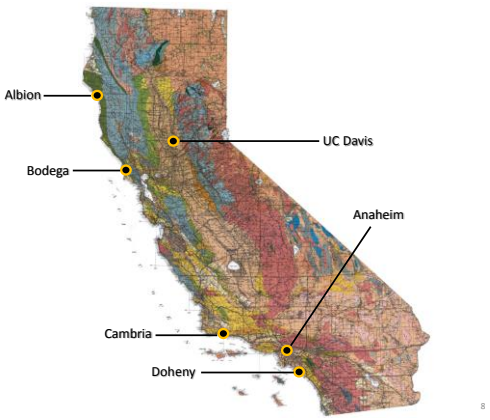
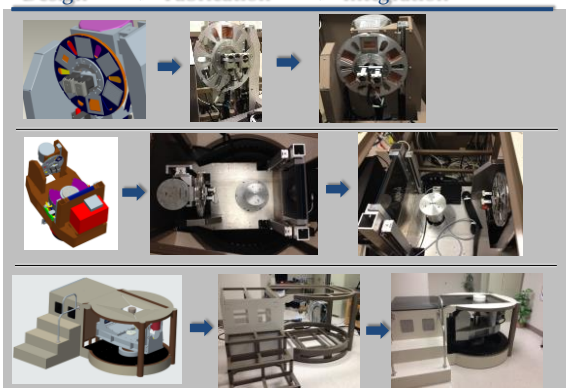
2015 Annual AAPM Meeting / Anaheim / July 14, 2015

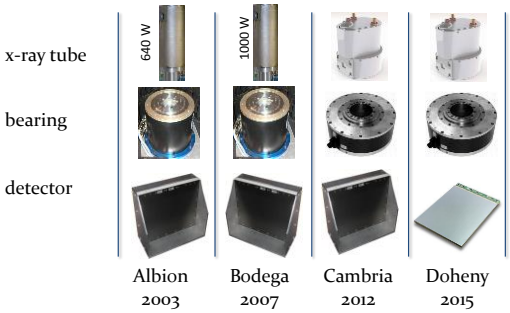
UC Davis Breast CT scanner development



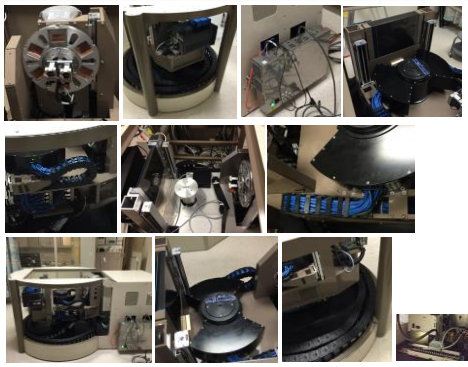
Design ➡ Fabrication ➡ Integration



Hardware component evolution



Doheny: Other Components



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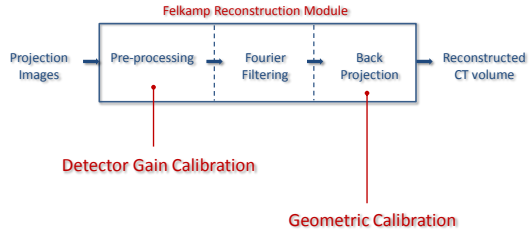
Calibration Software



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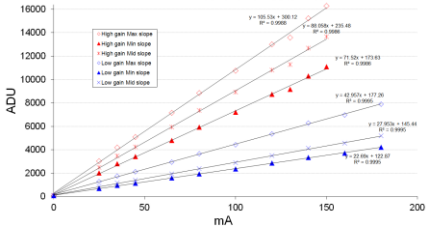
Detector calibration: Flat field correction

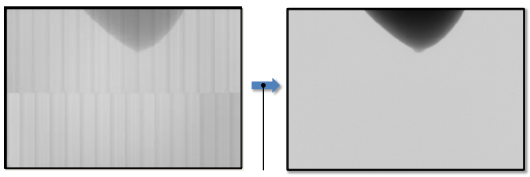
Gain variation between dexels ≈ 48%

$$ADU(x,y) = \boldsymbol{A}(x,y) + \boldsymbol{B}(x,y) \times mA$$

calibration data files



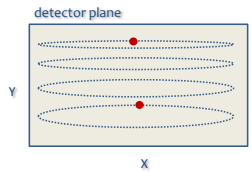
Detector calibration: Flat field correction



$$I(x,y)_{corr} = \bar{g}\ \frac{[I(x,y)_{raw} - A_{raw}(x,y)]}{[B(x,y) - A(x,y)]}$$

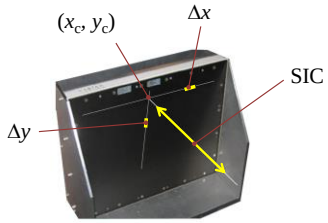
calibration data files

Geometric calibration



$$u_{wr} = y_{obj} \cdot \frac{D + u_{wr} \cdot \sin\phi}{C + x_{obj}} \cdot \frac{1}{\cos\phi},\ v_{wr} = z_{obj} \cdot \frac{D + u_{wr} \cdot \sin\phi}{C + x_{obj}}$$

Geometric calibration



Physical scanner geometry ⟶ Reconstruction algorithm

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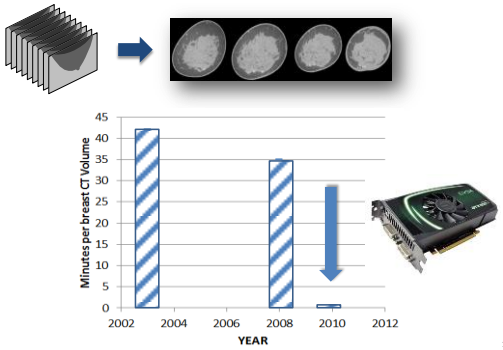
Feldkamp Reconstruction



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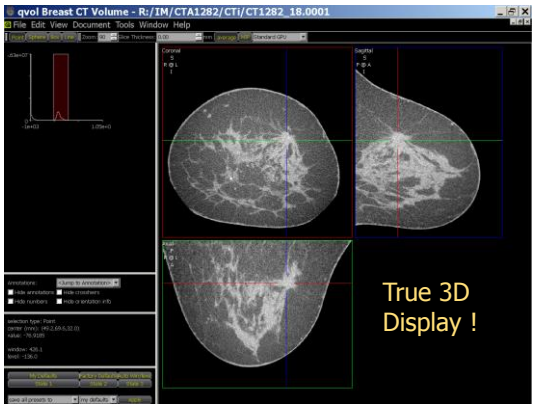

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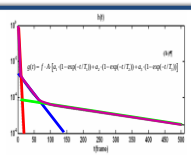
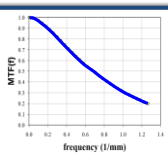
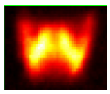
spatial resolution modeling



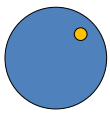
detector lag



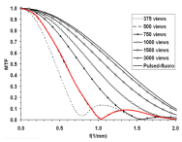
detector MTF



focal spot size



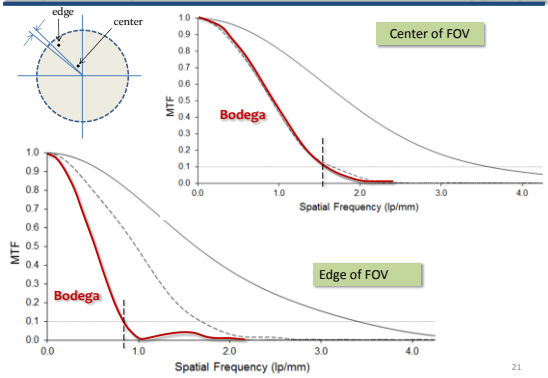
gantry rotation



Yang *et al.*, Computer modeling of the spatial resolution properties of a dedicated breast CT system, Med Phys 2008

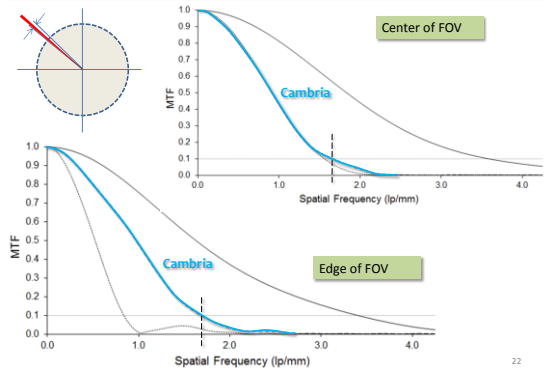
Engineering impacts resolution

Continuous x-ray (33 ms)



Engineering impacts resolution

pulsed acquisition (4 ms)



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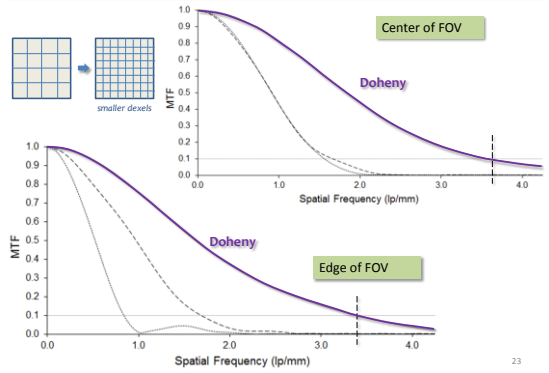
Engineering impacts resolution

pulsed acquisition (4 ms)
+ higher resolution detector



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Detector Performance (noise)

total noise

anatomical noise

quantum noise

$$NPS(f) = NPS_a(f) + NPS_q(f)$$

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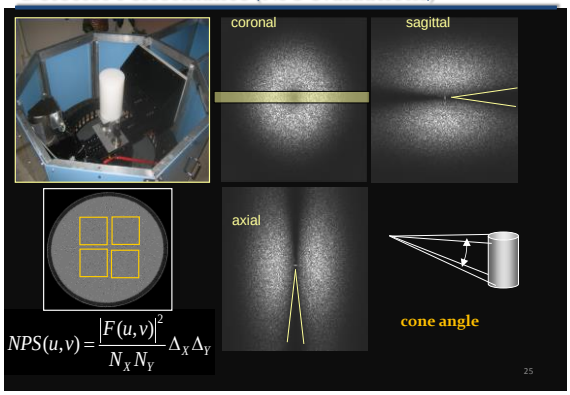
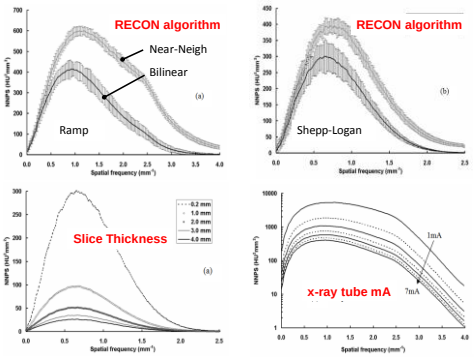
Detector Performance (NPS evaluations)



Noise Power Spectrum (NPS) measurements (Bodega)



Yang *et al.*, Noise power properties of a cone beam CT system for breast cancer detection, Med Phys. 2008

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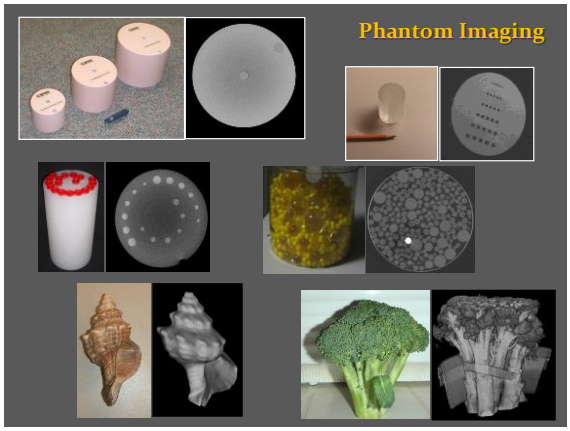

Clinical Imaging

1. Over 600 women on UC Davis scanners
   Funded for 400 more
2. Suspicion of BC (BIRADS 4 or 5)
   Contralateral (normal) breasts imaged as well
3. 16 second scan (breath hold)
   ~10 sec on new scanner
4. 500 projection images acquired (1024 x 768)
   400 – 800 views on new scanner (2048 x 1536)
5. About 200 have had contrast injection
   400 more to go, with DCE-MRI comparison also
6. Radiation dose same as 2V mammography
   Developing AEC for Doheny

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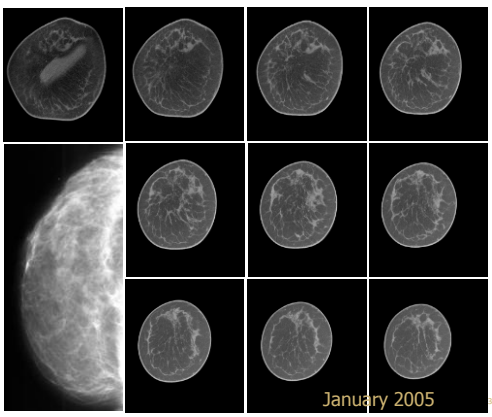

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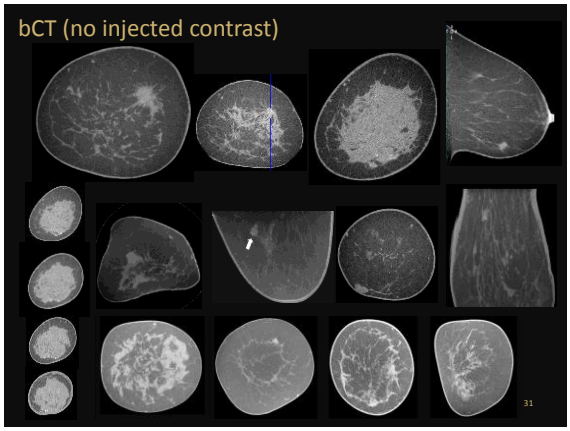
bCT (no injected contrast)
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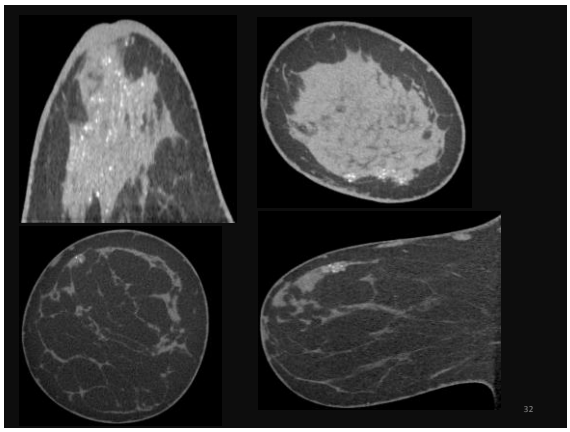
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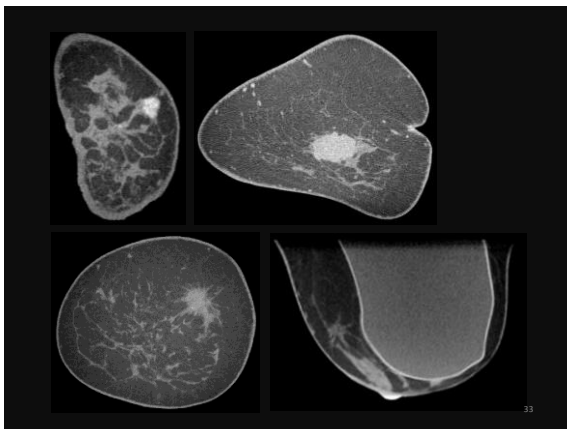
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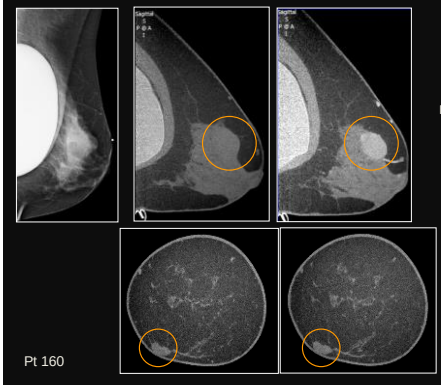
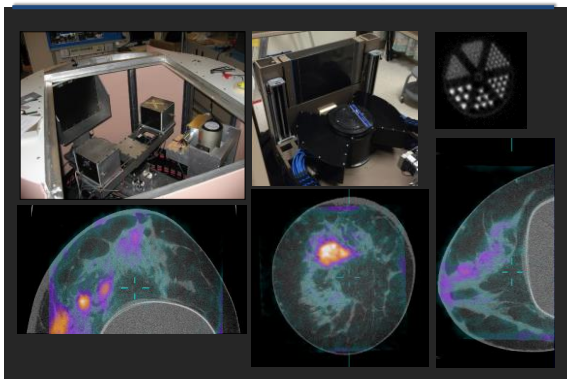
Contrasted Enhanced breast CT



Dedicated breast PET-CT imaging system



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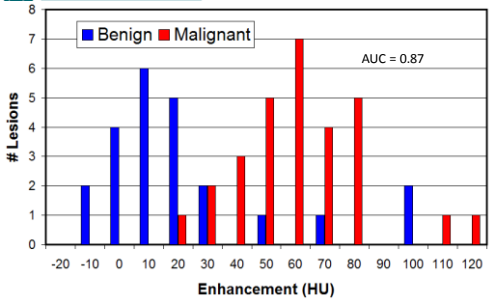
Radiology 2010

Contrast-enhanced Dedicated Breast CT: Initial Clinical Experience[1]



Prospective Clinical Trial

Shadi Aminololama-Shakeri, M.D.

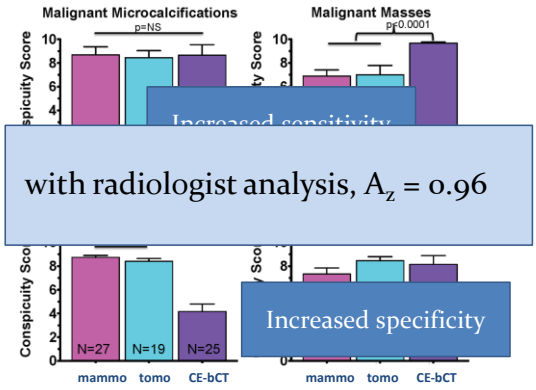
105 patients /103 lesions (BIRADS 4 or 5)
- imaged on VCO mammo / tomo / CE-bCT
- all biopsied

	microcalcifications	masses
malignant	31	27
benign	27	18
total	58	45

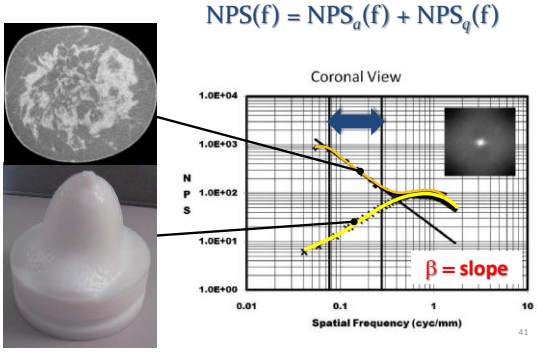
2 Radiologists Rated Lesions using a 0 to 10 Conspicuity Score

0 = not seen 10 = excellent

one-way ANOVA with correction for multiple comparisons



$$NPS(f) = NPS_a(f) + NPS_q(f)$$



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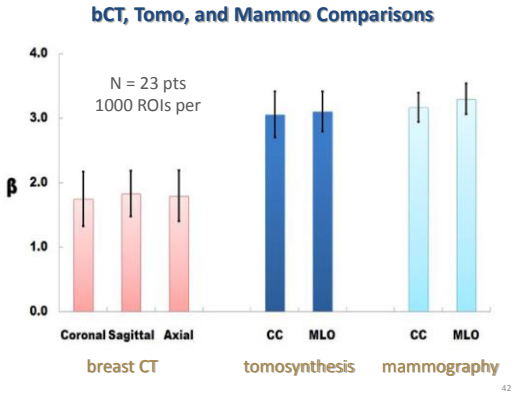

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PWMF Observer Performance Analysis

Effect of slice thickness on detectability in breast CT using a prewhitened matched filter and simulated mass lesions

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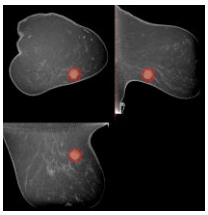

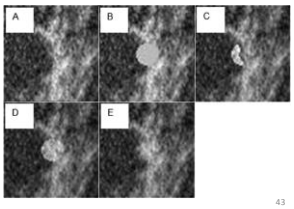

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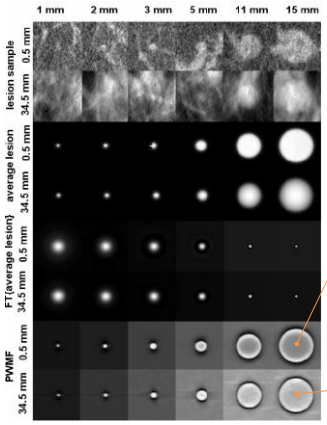
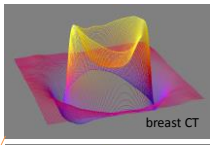
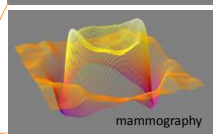


Pre-whitened Matched Filter

$$PWMF = FT^{-1}\left\{\frac{FT\{\overline{S}(x,y)\}}{\overline{PS}(x,y)}\right\}$$





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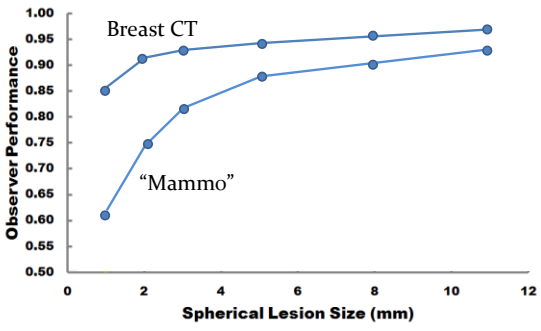
PWMF Observer



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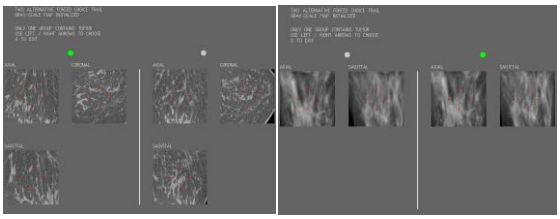
Human Observer Study: 2-Alternative Forced Choice Design



CT images projection images

3 radiologists / 6 physicists

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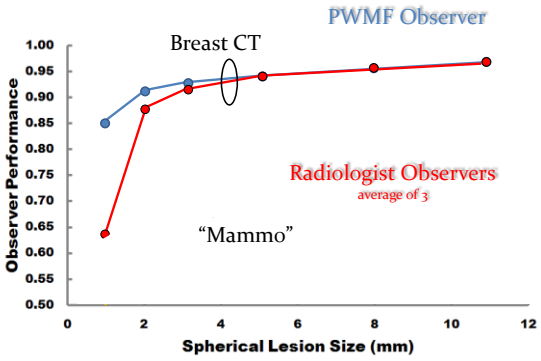

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Advances in CBCT for Breast Imaging

- Breast CT shows promise by all comparative metrics for mass lesions (beta, AUC, %correct)
- Observer performance results show enhanced mass lesion detection
  - Computer observer (PWMF)
  - Radiologist observers
- Breast CT (Koenig) FDA approved for diagnostic breast imaging Feb 2015
- microcalcification detection performance needs to be equivalent to mammography for bCT screening
- CE-breast CT is virtually identical as DCE-breast MRI

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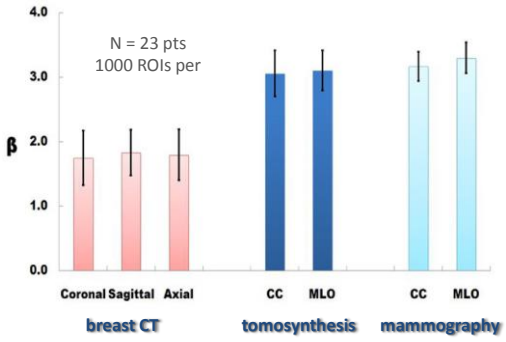
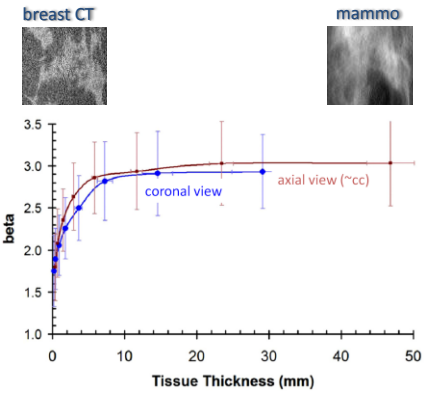
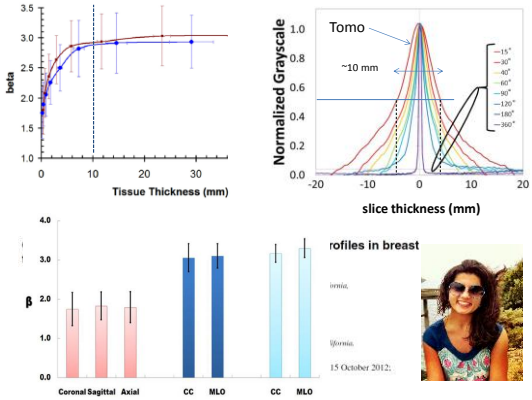
bCT, Tomo, and Mammo Comparisons

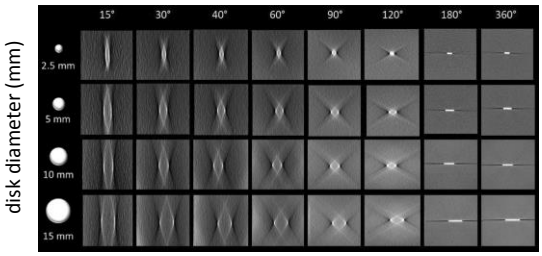


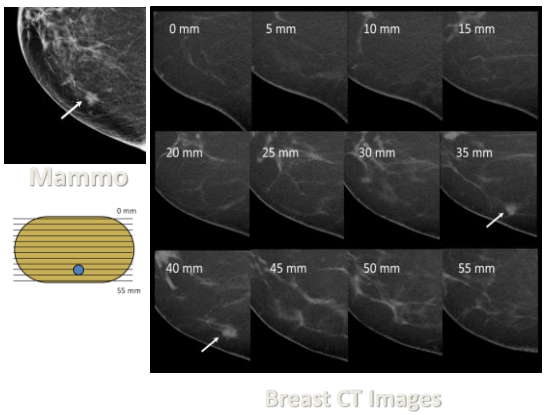


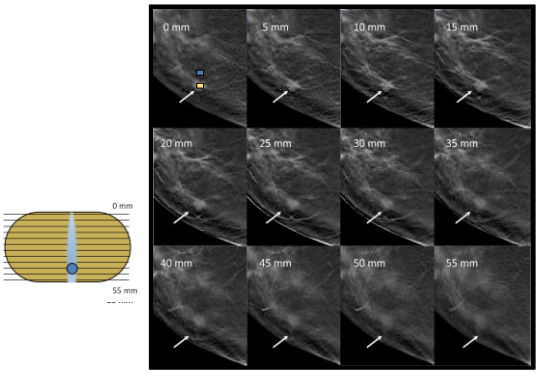


measured data on the breast CT system

tomographic angle







Tomosynthesis Images

Hardware component evolution