
MAYO CLINIC
Molecular Breast Imaging
Physics and QC Testing
Carrie Hruska, PhD, DABR, FSBI
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AAPM Virtual Annual Meeting, July 2021

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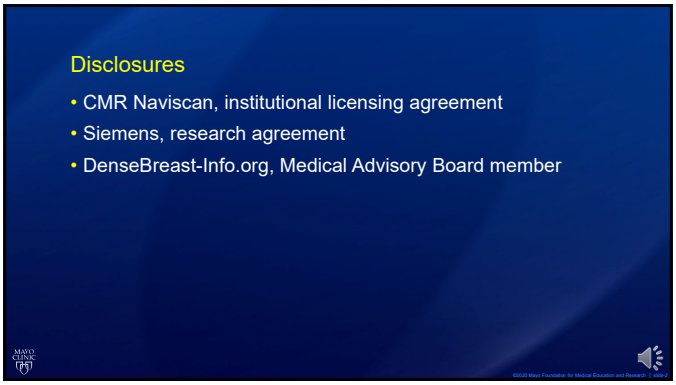
Disclosures
• CMR Naviscan, institutional licensing agreement
• Siemens, research agreement
• DenseBreast-Info.org, Medical Advisory Board member

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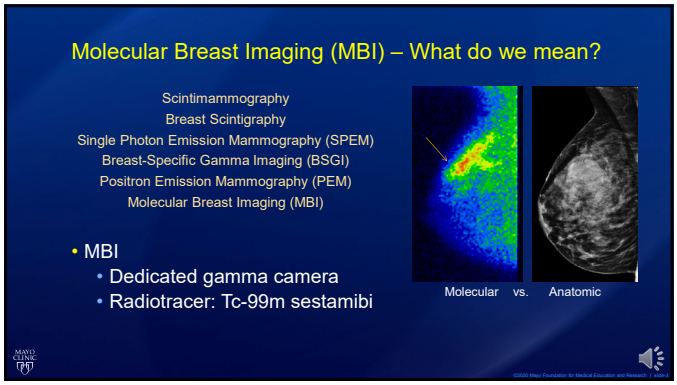
Molecular Breast Imaging (MBI) – What do we mean?
Scintimammography
Breast Scintigraphy
Single Photon Emission Mammography (SPEM)
Breast-Specific Gamma Imaging (BSGI)
Positron Emission Mammography (PEM)
Molecular Breast Imaging (MBI)
• MBI
• Dedicated gamma camera
• Radiotracer: Tc-99m sestamibi
Molecular vs. Anatomic

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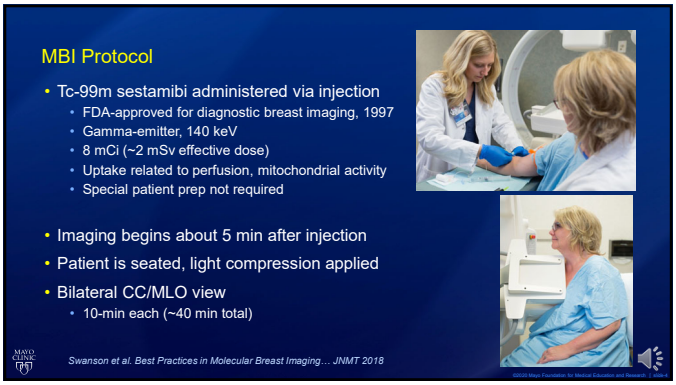
MBI Protocol
• Tc-99m sestamibi administered via injection
• FDA-approved for diagnostic breast imaging, 1997
• Gamma-emitter, 140 keV
• 8 mCi (~2 mSv effective dose)
• Uptake related to perfusion, mitochondrial activity
• Special patient prep not required
• Imaging begins about 5 min after injection
• Patient is seated, light compression applied
• Bilateral CC/MLO view
• 10-min each (~40 min total)
Swanson et al. Best Practices in Molecular Breast Imaging… JNMT 2018

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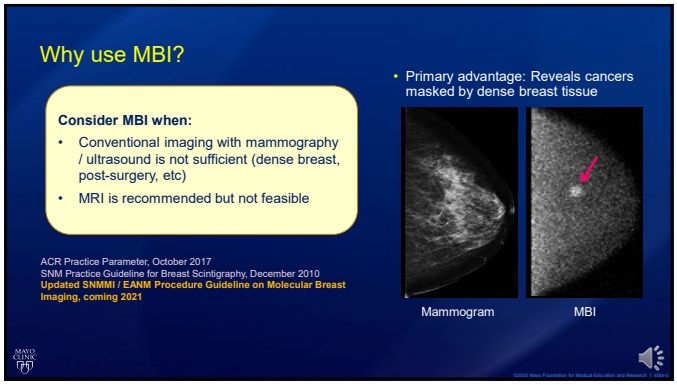
Why use MBI?
Consider MBI when:
• Conventional imaging with mammography / ultrasound is not sufficient (dense breast, post-surgery, etc)
• MRI is recommended but not feasible
ACR Practice Parameter, October 2017
SNM Practice Guideline for Breast Scintigraphy, December 2010
Updated SNMMI / EANM Procedure Guideline on Molecular Breast Imaging, coming 2021
• Primary advantage: Reveals cancers masked by dense breast tissue
Mammogram
MBI

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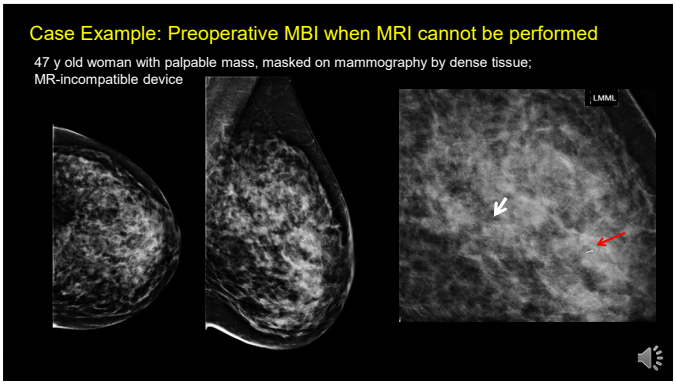
Case Example: Preoperative MBI when MRI cannot be performed
47 y old woman with palpable mass, masked on mammography by dense tissue;
MR-incompatible device
LMML

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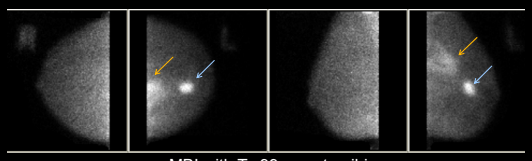
Case Example: Preoperative MBI when MRI cannot be performed



MBI with Tc-99m sestamibi

3.2 cm grade 3 IDC +
DCIS over total extent of 9 cm

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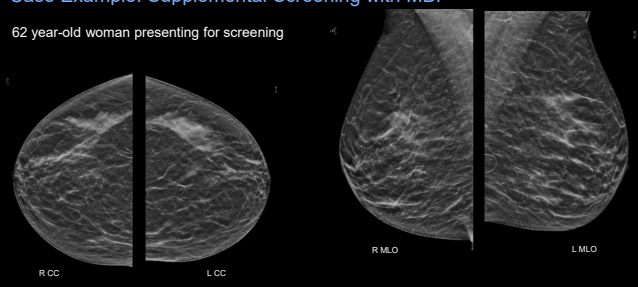
Case Example: Supplemental Screening with MBI

62 year-old woman presenting for screening



Screening DBT, Synthesized 2D shown: **BI-RADS 1 – Negative,** Heterogeneously dense

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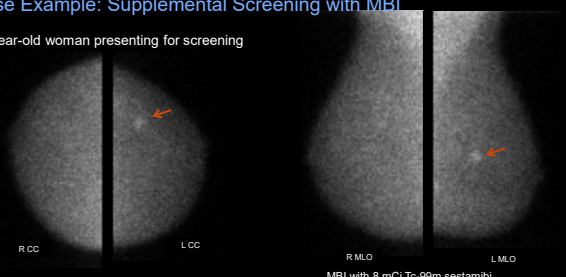
Case Example: Supplemental Screening with MBI

62 year-old woman presenting for screening



MBI with 8 mCi Tc-99m sestamibi
Focal area of moderate intensity uptake (arrows)

0.9 cm Grade 2, Invasive ductal carcinoma, Triple Negative, Node negative

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Comparison of Modalities in Supplemental Screening of Dense Breasts
beyond Mammography

Screening Modality	Total N	Incremental CDR per 1000	Incremental *Invasive* CDR per 1000	Recall Rate
DBT	103,245	1.7	1.4	-2%
Ultrasound	452,743	2.0 to 2.7	1.8 to 2.3	7.6% to 10.6%
MBI	4,277	8.1	6.2	6.7%
MBI, after DBT (prelim. results)	1,608	9.3	7.5	10.3%
MRI	9,256	16.0	12.1	10.4%
Abbreviated MRI, after DBT	1,444	9.7	6.9	21.5%
CEM *(retrospective analysis, women at increased risk)*	1,311	10.7	8.4	15.0%

Info from Berg et al. Screening Algorithms in Dense Breasts: AJR Expert Panel Narrative Review, August 2020

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Where is MBI?

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Commercial MBI Systems

Dilon / SmartBreast
a.k.a. Breast-specific gamma imaging (BSGI)
Single head NaI detector

Smart Breast/
GE Discovery NM 750b
Dual-head CZT detectors

CMR Naviscan
LumaGem
Dual-head CZT detectors

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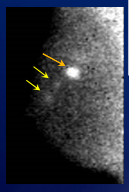
Conventional vs. Dedicated Systems

General purpose gamma camera

"Scintimammography"

Dedicated gamma camera

MBI



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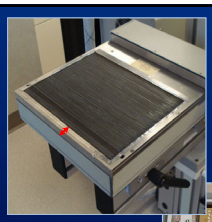
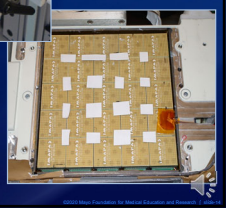
Deadspace

General purpose gamma camera



Dedicated detector



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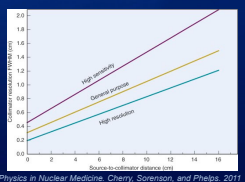
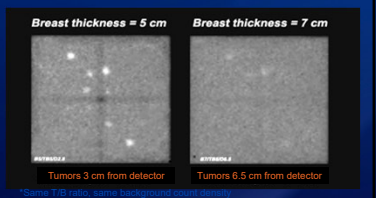
Distance

- Spatial resolution degrades with increasing distance from the detector



Physics in Nuclear Medicine. Cherry, Sorenson, and Phelps. 2011



*Same T/B ratio, same background count density

Mueller B et al. J Nucl Med, 2003; 44: 602-609.

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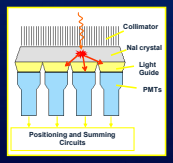
Scintillating vs. Semiconductor Detectors

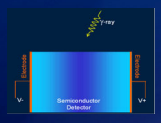
General-purpose Scintillator (NaI)

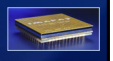
- Converts gamma ray photons to light
- Photomultiplier tubes (PMT) converts light to electrons

Semiconductor (CZT)

- Direct conversion: gamma rays to electrons







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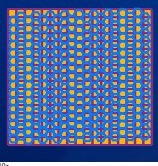
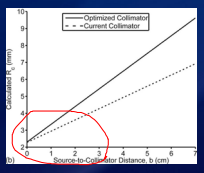
Collimator Optimization for MBI

- Hexagonal holes changed to square registered holes
  - Improves active area, count sensitivity
- Shorten bore
  - More count sensitive but give up resolution
- Dual-detector design
  - 5 mm resolution maintained throughout 6-cm breast





Weinmann et al. Medical Physics 2009; 36: 845-856.

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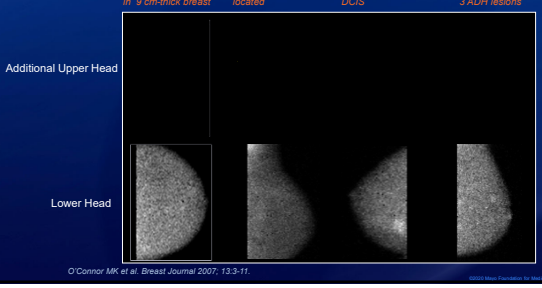
Dual-head MBI: Additional Lesions Detected



O'Connor MK et al. Breast Journal 2007; 13:3-11.

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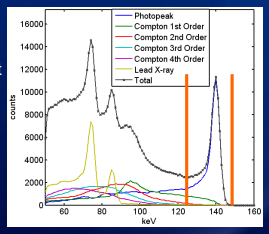
MBI Energy Acceptance Window

- Tailing Effect in CZT:
  - "Good" photopeak events mis-registered at lower energies
  - Due to incomplete charge trapping in semiconductor



Hruska et al. IEEE Trans Nuc Sci. 2008; 55:491-500.
O'Connor et al. Proceedings of SPIE 2010; vol 7806

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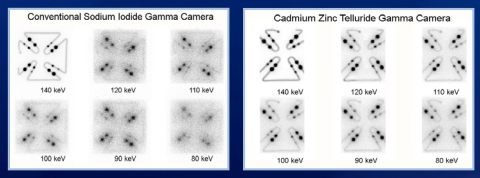
MBI Energy Acceptance Window



O'Connor et al. Proceedings of SPIE 2010; vol 7806

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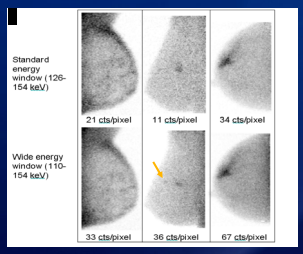
MBI Energy Acceptance Window

- MBI performed with conventional and widened energy window
- ~1.4 gain in counts



O'Connor et al. Proceedings of SPIE 2010; vol 7806

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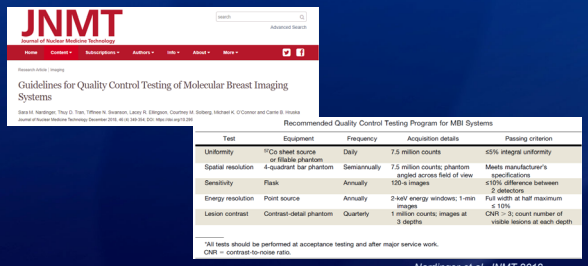
QC Testing for MBI Cameras



Nardinger et al. JNMT 2018

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Uniformity Testing

$$\text{Integral uniformity (\%)} = 100 \times \frac{max.pixel\ count - min.pixel\ count}{max.pixel\ count + min.pixel\ count}$$

- Routine daily test, before patients
- Ensure a uniform response to radiation across the detector (< 5% integral uniformity)
- Typically, extrinsic measure (collimators may not be easily removed)
- Source placed directly on camera, acquire both heads simultaneously

Small sheet source (Co-57)

Fillable source (Tc-99m pertechnetate)

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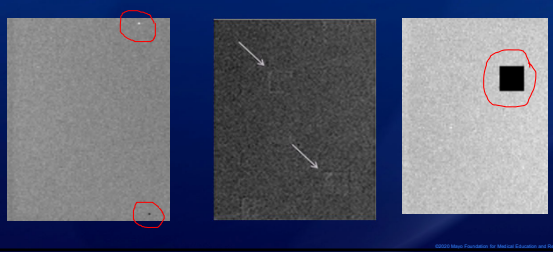
Uniformity Testing
Considerations for MBI Systems

- Non-uniformities will be individual pixels or blocks of pixels (no PMTs)



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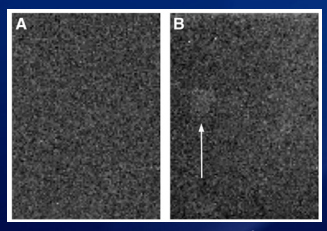
Uniformity Testing
Considerations for MBI Systems

- MBI systems designed for high sensitivity
- More susceptible to high energy contaminants from Co-57 uniformity maps



Co-57 uniformity

Tc-99m uniformity using Co-57 map

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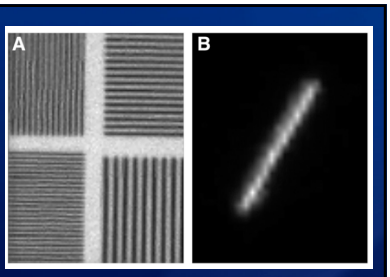
Spatial Resolution

- Spatial resolution of MBI system (pixelated detectors) doesn't change over time
- Small bar phantom is easy to use
- Line source is difficult to obtain consistent results



Performance characteristics of a new pixelated portable gamma camera

W. Siman and S. Cheenu Kappadath[a)]
Department of Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas 77030

(Received 15 December 2011; revised 24 April 2012; accepted for publication 26 April 2012; published 25 May 2012)

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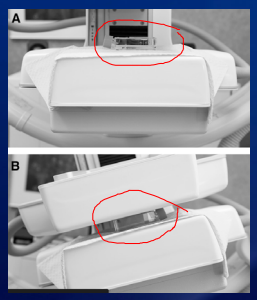
Sensitivity

- Flask with known amount of activity and thin layer of water, imaged for 2 min
- Modified to fill entire flask for dual-head
  - (if detectors cannot be rotated all the way around)



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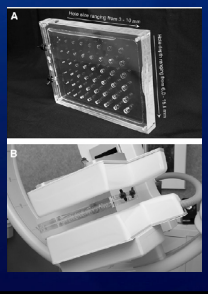
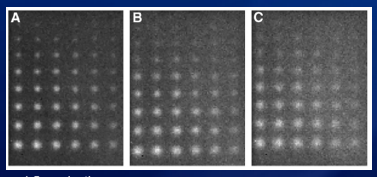
Contrast Phantom





1.5 cm depth | 3 cm depth | 4.5 cm depth

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Today we reviewed…

- MBI protocol
- Clinical applications
- Equipment
- QC Testing

Acknowledgements

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