

Medical Physics 2.0 Mammography 2.0

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University of Rochester

- Avice O'Connell, MD

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Objectives

1. Current role of the Medical Physicist in mammography.
2. Accomplishments and problems in current practice.
3. It is more than mammography, it is Breast Imaging.
4. Evolution of mammography: tomosynthesis and other techniques.
5. Responsibilities beyond equipment surveys.
6. Expanding role of the Medical Physicist.
7. Operationally engaged.

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Historical note

- The Mammography Quality Standards Act and Program (MQSA) was enacted by the United States Congress in 1992 to regulate the quality of care in mammography. The act was officially effective in 1994, and was extended in 2004. The U.S. Food and Drug Administration (FDA) began inspections of mammography facilities to ensure compliance in 1995. In 1997, more comprehensive regulation was added and became effective in 1999¹.
- Prior to MQSA the American College of Radiology (ACR) had established a rigorous mammography accreditation program.

Reference: 1. http://en.wikipedia.org/wiki/Mammography_Quality_Standards_Act

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Historical note

- ACR and MQSA requirements represent landmark initiatives defining the role and responsibilities of the Medical Physicist at the national level.
- Some local jurisdictions had certain requirements for medical physics services prior to ACR and MQSA.

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Developments since MQSA implementation

FDA Approved

- ✓ Digital mammography
 - Flat panel
 - Computed radiography
 - Photon counting
 - Digital stereotactic imaging
- ✓ Digital readout of "dose"
- ✓ Computer assisted diagnosis and detection
- ✓ Quantitative density evaluation
- ✓ Digital Breast Tomosynthesis
- ✓ Reconstruction of planar view from tomosynthesis acquisition.
- ✓ Contrast mammography
- ✓ MRI
- ✓ Whole breast ultrasound

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Developments since MQSA implementation

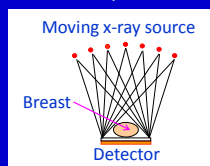
Under development (not FDA approved)

- ✓ Dedicated breast CT (CE Mark approval in Europe and approved in Canada)
- ✓ Contrast tomosynthesis
- ✓ Nuclear medicine imaging (breast specific gamma imaging)

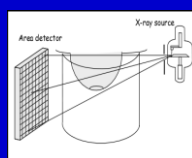
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Tomographic Imaging of the Breast Tomosynthesis vs. Dedicated Breast CT

Tomosynthesis



Dedicated breast CT



From lab notes on file dated 3-6-1996
Andrew Karellas

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Current status

- The medical physicist is largely viewed as a person who conducts QA on equipment.
- Many medical physicists are not afforded the opportunity to spend enough time with technologists and radiologists.
- Phantom images are very useful but they may not represent all aspects of image quality.

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Current status

- The medical physicist rarely deals with dose issues relating to a specific patient. Frequently patients who inquire about radiation dose and risk may not be given factual information.
- In spite of the recognized need for medical physics expertise in breast imaging, advances in professional medical physics services tend to lag the technology.
- Technologies may be deployed in the clinic but medical physicists have limited information on initial acceptance and periodic QA (rely mostly on manufacturer's QA recommendations).

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Current status - Confidence in medical physics support *

<u>Modality</u>	<u>Confidence</u>
✓ Digital mammography	High
- Flat panel	High
- Computed radiography	High
- Digital stereotactic imaging	High
- Photon counting	Low
✓ Digital readout of "dose"	Low
✓ Computer assisted diagnosis and detection	Low
✓ Quantitative density evaluation	Low
✓ Digital Breast Tomosynthesis	Moderate
✓ Reconstruction of planar view from tomosynthesis	Low
✓ Contrast mammography	Low
✓ MRI	Moderate
✓ Whole breast ultrasound	Low

*All FDA approved modalities

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Questions we need to ask and our vision for the role of the Medical Physicist

- Is what we measure all we should be measuring in routine QA?
- How does a small drift in kVp can affect the AEC?
- Are x-ray spectra important and under what circumstances?
- Is “disk” contrast or contrast-to-noise a sufficient measurement?
- Does anyone measure radiation waveform?
- Is the dose we measure with the phantom in place meaningful for patient dosimetry?

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Questions we need to ask and our vision for the role of the Medical Physicist

- Can we provide the average glandular dose for a given patient?
- How do we know the selected mammographic technique is optimal for a given breast size and composition? How do we evaluate this?
- Are we prepared to discuss radiation risks in view of the potential benefit from mammography (screening or diagnostic) with an inquiring physician or with a concerned patient?
- Do all medical physicists fully appreciate the difference between screening and diagnostic mammography?

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Radiation dose

Medical physicists must:

- ✓ Become familiar with emerging developments in patient specific dosimetry in mammography.
New models are emerging on dose estimation in mammography and tomosynthesis. These new models take into account the size and revised composition of the breast.
- ✓ Investigate methods for testing the accuracy and reproducibility of dose estimation models.
- ✓ Expand the dose reporting from simple phantom to various scenarios of breast size and composition.

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Radiation dose

- ✓ Provide input on the dose from diagnostic mammography.
- ✓ Be prepared to answer questions about the radiation dose to other parts of the body from mammography or digital breast tomosynthesis.
- ✓ Be prepared to answer questions about radiation and allay any fears in situations where the risk is very small in view of the potential benefit.
- ✓ Adapt to translating this knowledge to emerging imaging approaches such as dedicated breast CT*.

* Not FDA approved in the US. CE Mark approval in Europe and approved in Canada.

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Radiation dose

J O P Pinar et al. Physics in Medicine and Biology
Phys. Med. Biol. 58 (2013) 7921–7936
doi:10.1088/0031-9155/58/22/7921

Personalized estimates of radiation dose from dedicated breast CT in a diagnostic population and comparison with diagnostic mammography

Srinivasan Vedantham^{1,2}, Linxi Shi¹, Andrew Kareklas¹,
 Arlene M O'Connell² and David L. Comover²

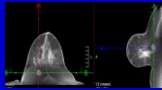
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² Department of Radiology, University of Rochester Medical Center, Rochester, NY 14642, USA
³ Koning Corporation, West Henrietta, NY 14586, USA

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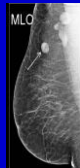
Received 31 May 2013, in final form 14 August 2013
 Published 29 October 2013
 Online at stacks.iop.org/PMB/58/7921

Abstract
 This study retrospectively analyzed the mean glandular dose (MGD) to 133 breasts from 132 subjects, all women, who participated in a clinical trial evaluating dedicated breast CT in a diagnostic population. The clinical trial was conducted in adherence to a protocol approved by institutional review

Dedicated breast CT



Digital mammography



.....The median Mean Glandular Dose from dedicated breast CT was equivalent to 4–5 diagnostic mammography views....

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Knowledge learned from emerging modalities that is applicable to mammography and digital breast tomosynthesis dosimetry

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Radiation Dose

Average Glandular Dose ~ 1.2 mGy (2D mode)

Average Glandular Dose ~ 1.4 mGy (Tomosynthesis mode)

With ACR recommended accreditation phantom. For individual breasts, the radiation dose will vary depending on compressed breast thickness, selected technique factors and breast composition.

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Mammography dose

- Measure exposure (air kerma) at skin entrance
- Measure kVp / HVL
- Use DgN conversion factors that were derived from Monte Carlo simulations
 - Monte Carlo simulations assumed 4 mm thick skin and 50% fibroglandular breast

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Breast skin thickness

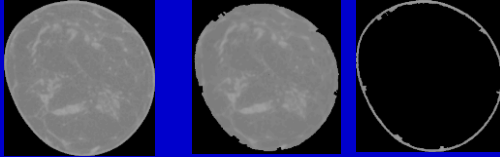
- Subcutaneous fat may provide additional shielding, its thickness affects the dose calculation.
- More importantly, radiosensitive ductal epithelium and fibrous attachment are present within subcutaneous fat¹
- Should we use 1.45 mm skin layer for estimating DgN coefficients to provide a more accurate estimate of radiation risk?

¹ Kopans DB. Breast Imaging. Second ed. Philadelphia, PA: Lippincott-Raven Publishers; 1997

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Breast skin thickness

Determination of the mean and range of location-averaged breast skin thickness for use in Monte Carlo-based estimation of normalized glandular dose coefficients. The study found that 1.45 mm thick skin layer comprising the epidermis and the dermis for breast dosimetry is appropriate.



Shi et al., Med Phys 2013, 40(3): 031913

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Breast skin thickness

Study	Number of breasts	Mean $\pm$ Inter-breast SD	Range
Shi et al ¹	137	1.44 $\pm$ 0.25 mm	0.9 – 2.3 mm
Huang et al ²	100	1.45 $\pm$ 0.3 mm	0.9 – 2.3 mm

Measured skin thickness corresponds to the combined thickness of epidermis and dermis

¹ Shi et al., Med Phys 2013, 40(3): 031913

² Huang et al., Med Phys 2013, 40(3): 031913

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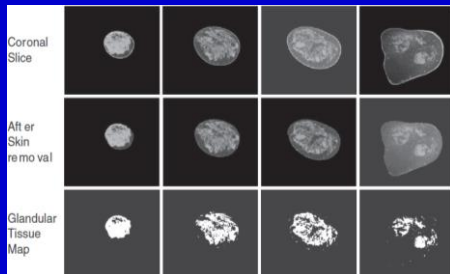
Fibroglandular fraction

- ❑ Should we use 15% fibroglandular breast instead of 50% fibroglandular breast for estimating dose?
- ❑ Should we calculate the fibroglandular fraction for each breast (Quantra, Volpara, Cumulus, etc.) and use appropriate DgN coefficients?
- ❑ How do we determine if the fibroglandular fraction provided by these tools are accurate?
- ❑ Need for structured phantoms with different compositions.

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Fibroglandular fraction

Mean and range of volumetric glandular fraction (VGF) of the breast in a diagnostic population using a high-resolution flat-panel cone-beam dedicated breast CT system. **Important for Monte Carlo-based estimation** of normalized glandular dose coefficients and for investigating the dependence of VGF.



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Fibroglandular fraction

- Several studies have reported on the fibroglandular fraction

Study	Modality	Mean
Vedantham et al ¹	BCT	15.8 ± 13%
Yaffe et al ²	BCT	14.3 ± 10%
	Mammography+ BCT	14.3 ± 11%
Nelson et al ³	BCT	17.1 ± 15%

¹ Vedantham et al., *Med Phys* 2012; 39:7317-7328

² Yaffe et al., *Med Phys* 2009; 36:5437-5443

³ Nelson et al., *Med Phys* 2008; 35:1078-1086

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Radiation dose (the physicist's role)

The Medical Physicist's input must be expanded in:

- ✓ Dealing with dose issues in tomographic imaging of the breast (tomosynthesis at present and eventually in dedicated breast CT).
- ✓ Optimization of acquisition protocols (tomosynthesis with planar views combination versus synthesized planar view from tomosynthesis projections). Image quality and dose considerations.
Radiation dose optimization in tomographic imaging of the breast presents significant challenges.

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Operationally engaged to meet future challenges

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Stationary Digital Breast Tomosynthesis



LEFT: Hologic Selenia Dimensions Unit. Digital Breast Tomosynthesis system with single rotating x-ray source
RIGHT: Stationary digital breast tomosynthesis system with integrated CNT x-ray source array (XinRay Systems Inc. Research Triangle Park, NC). There are 31 x-ray generating focal spots; each x-ray beam can be electronically controlled to turn on/off instantaneously.

Tucker AW, Lu J, Zhou O. Med Phys. 2013 Mar;40(3):031917.
 Courtesy of Dr. Otto Zhou, University of North Carolina

Investigational device.
 Limited by Federal law
 to investigational use.
 Not FDA approved

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Stationary Digital Breast Tomosynthesis

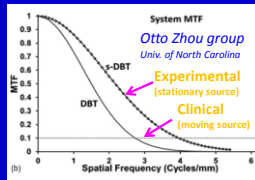


Courtesy of Dr. Otto Zhou, University of North Carolina
 Investigational device. Limited by Federal law to investigational use.
 Not FDA approved

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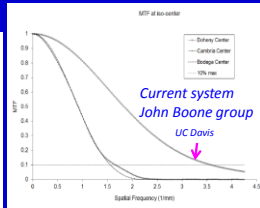
System MTF obtained after reconstruction

Digital Breast Tomosynthesis
(moving versus stationary x-ray sources)



Source: Qian et al., Med Phys 2014; 39(4): 2090-99

Dedicated Breast CT



Source: Gazi et al., Proc. SPIE 2014; 9033: 903348-3

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Dedicated Breast CT

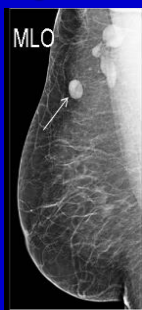
At the University of Massachusetts Medical School



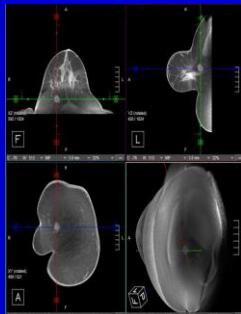
Manufacturer: Koning Corporation
Investigational device. Limited by Federal law to investigational use.
Not FDA approved

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Digital MLO



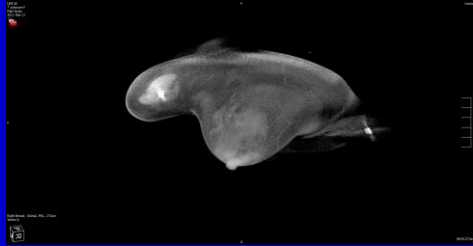
Dedicated Breast CT



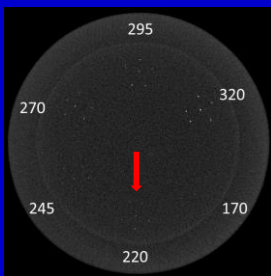
University of Massachusetts Medical School
– University of Rochester study

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A 3D demonstration for one out of the 150 clinical cases with calcification as well as calcified tissue at posterior breast (complete coverage)



Dedicated breast CT QC with calcification phantom - UMass prototype



CaCO₃ specks size in microns

- 13 cm diameter phantom
- 15% fibroglandular (fg) composition
- Ramp filtered FBP
- Voxel size: 0.155 mm
- AGD: matched to diagnostic mammography¹ (4.5 views, 12 mGy)
- CaCO₃ specks

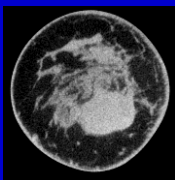
Note: ACR mammography accreditation phantom uses Al₂O₃ specks. For CT, this phantom may not represent the best choice for image quality evaluation.

¹ Vedantham et al., *Phys Med Biol* 2013; 58:7921-7936

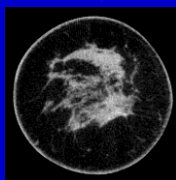
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Neoadjuvant treatment Monitoring response

Before treatment

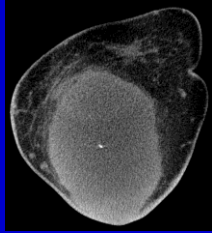


After treatment
Tumor regression

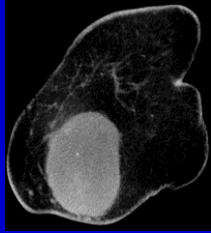


Collaboration between Avrice O'Connell, MD and UMass Medical School team.

Neoadjuvant treatment: Monitoring response Before and after treatment: tumor size change



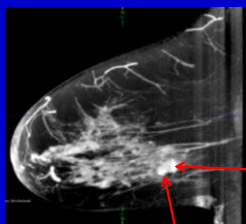
Before treatment



After treatment

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Are we ready for contrast enhancement studies ? Contrast enhanced Breast CT

Biopsy
clip

Index lesion (ILC)

UMass Lobular Carcinoma study (UMLC03)

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Algorithms / Segmentation routines.



Ductaloma

Segmentation routines/algorithms for tumor volume (size) estimation:

- Should Physicists be involved in verifying its accuracy?
 - Can provide a perspective on issues due to dose, contrast, CNR and artifacts
- Do we have the necessary tools?

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Today's research is tomorrow's practice "Operational engagement in the clinical environment"

- ✓ Medical physicists are "Scientists in Medicine" and they are expected to function as objective evaluators and innovators.
- ✓ The evaluation of the performance of imaging equipment and practices must be based on sound scientific principles.
- ✓ Published research serves as the basis for maintaining the validity of existing tests and for implementing new tests.

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Conclusions

Today's research is tomorrow's practice "Operational engagement"

- ✓ Medical physicists must be willing to discontinue tests that are deemed not helpful and replace them with new more effective tests where appropriate.
- ✓ Medical physicists must continue to play an important role in the evolution of existing and implementation of new standards. They must continue to present and publish their scientific results.
- ✓ Medical Physicists must be active as reviewers of journal scientific manuscripts, peer review panels, and as authors in high quality review publications (such as book chapters).

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Thank you

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