AAPM 2016, Washington, D.C., August 3, 2016

Performance characteristics of photon-counting spiral breast CT

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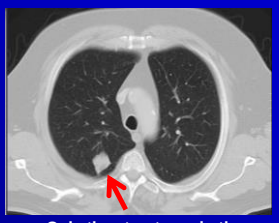
Why CT?

Projection image vs. spiral CT image

(in the same patient on the same day)

All structures along a ray are superpositioned and may obscure important details.



Only the structures in the section of interest are displayed.

Images: Courtesy of M. Lell, Erlangen

Dedicated Breast CT: Initial Clinical Experience[1]

Results: Overall, CT was equal to mammography for visualization of breast lesions. Breast CT was significantly better than mammography for visualization of masses (p<0.002); mammography outperformed CT for visualization of micro-calcifications (p<0.006). …

Conclusions: Some technical challenges remain, but breast CT is promising and may have potential clinical applications."

Lindfors KK, Boone JM et al. Radiology 2008; 246:725-733

AJR WOMEN'S IMAGING

MDCT of the Breast

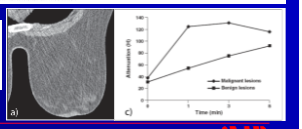
Anna Perrone[1]
Luigi Lo Mele[1]
Simona Sassi[1]
Marina Marini[1]
Lorenzo Testaverde[1]
Luciano Izzo[2]
Mario Marini[2]

OBJECTIVE. The purpose of this study was to evaluate retrospectively the accuracy of low-dose MDCT in the differentiation of breast lesions suspected on mammography and sonography.

MATERIALS AND METHODS. MDCT was performed on 61 patients with mammographic or sonographic findings suggestive of breast cancer who could not undergo MR mammography. For each lesion, morphologic features, attenuation, and time–attenuation curve pattern were evaluated. The 1-minute cut point of attenuation was analyzed on the images. CT findings were compared with histopathologic results, which were the reference standard.

RESULTS. Forty-seven of 61 patients underwent surgery, and the pathologic findings revealed 27 malignant and 20 benign lesions. With CT 25 of 27 malignant lesions and all 20 benign lesions were diagnosed correctly. CT had a sensitivity of 92.6%, specificity of 100%, positive predictive value of 100%, negative predictive value of 90.9%, and accuracy of 95.74%. The cutoff attenuation value, which had the best validity for differentiating malignant and benign lesions, was calculated to be 90 H on the 1-minute images.

CONCLUSION. Our results confirm and strengthen the importance of all imaging parameters and not one in particular. Dynamic MDCT can be used in the evaluation of selected patients with suspected breast tumors.



"Dynamic MDCT can be used in the evaluation of selected patients with suspected breast tumours."

Perrone A et al. AJR 2008; 190:1644-1651

Radiology

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

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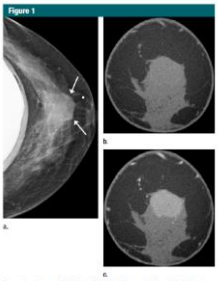
Karen K. Lindfors, MD
Shonket Ray, MS
Shih-Ying Huang, BS
Laurel A. Beckett, PhD
Wayne L. Monsky, MD, PhD
John M. Boone, PhD

Purpose: To quantify sions scanne phy (CT) an unenhanced

Materials and Methods: Approval of tion Use Co obtained for t



Conspicuity of malignant breast lesions, including ductal carcinoma in situ, is significantly improved at contrast-enhanced breast CT. Quantifying lesion enhancement may aid in the detection and diagnosis of breast cancer.

Prionas … Boone. Radiology 2010; 256:714-723

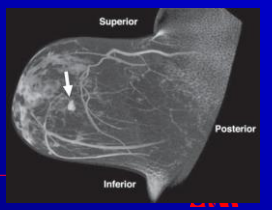
AJR WOMEN'S IMAGING

Cone-Beam CT for Breast Imaging: Radiation Dose, Breast Coverage, and Image Quality

Avice O'Connell[1]
David L. Conover[1]
Yan Zhang[1]
Posy Seifert[2]
Wende Logan-Young[2]
Chuen-Fu Linda Lin[1]
Lawrence Sahler[1]
Ruola Ning[1]

OBJECTIVE. The primary objectives of this pilot study were to evaluate the radiation dose, breast coverage, and image quality of cone-beam breast CT compared with a conventional mammographic examination. Image quality analysis was focused on the concordance of cone-beam breast CT with conventional mammography in terms of mammographic findings.

SUBJECTS AND METHODS. This prospective study was performed from July 2006 through August 2008. Twenty-three women were enrolled who met the inclusion criteria, which were age 40 years or older with final BI-RADS assessment category 1 or 2 lesions on conventional mammograms within the previous 6 months. The breasts were imaged with a flat-panel detector–based cone-beam CT system, and the images were reviewed with a 3D



Unenhanced breast CT exam

How about contrast-enhanced CT angiography?

O'Connell A et al. AJR 2010; 195:496-509

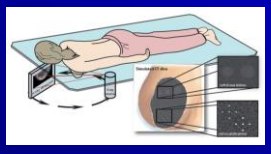
To improve diagnostics
breast CT scanners shall offer

- superposition-free imaging
- spatial resolution of about 100 µm in all 3 directions
- dynamic scanning for the differentiation of benign and malignant lesions
- dose levels similar to screening mammography
- integrated biopsy facility
- absence of painful compression

Breast CT scanner concept

Transition from

single-circle flat detector **to** Spiral CT with photon count. detector

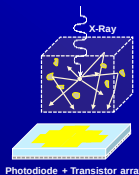


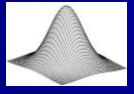
Photon-counting energy-discriminating CdTe detector
100 % geometrical and absorption efficiency

Kalender WA et al. Eur Radiol 2012; 22(1):1-8

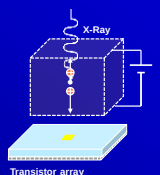
Detection principles

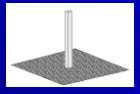
Scintillator





Direct converter, e.g. CdTe

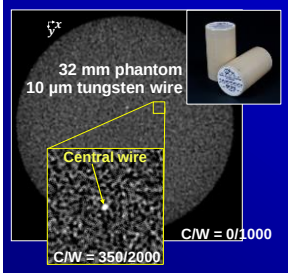


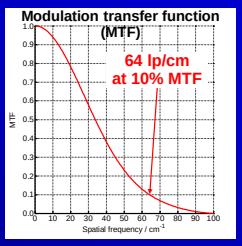


Point Spread Functions (PSF)

Measurements with a CdTe detector

(100 µm)² detector elements



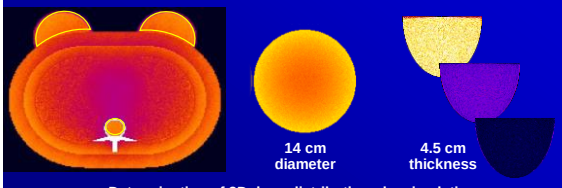


MTF measurement of a 10 µm wire reveals 64 lp/cm (80 µm detail) spatial resolution

1

Dose assessment by Monte Carlo methods

CT	Breast CT	Mammography
120 kV	60 kV	30 kV
	14 cm diameter	4.5 cm thickness



Determination of 3D dose distributions by simulations is established and confirmed by measurement. They apply to breast CT, mammography and tomosynthesis in equal manner.

BMBF booth at RSNA 2015

Dedicated breast CT at U of Erlangen & CT Imaging GmbH, spinoff founded by W. Kalender

Breast CT Scanner with CdTe detector

- 100 µm detector pitch
- 1000 frames/second
- 60 kV voltage
- 6-12 s spiral scans
- operating at screening dose levels

Clinical feasibility studies are planned for 2016 4th q. in Erlangen and Aachen supported by BMBF!

Materials and Methods

Test objects

- MTF phantom (10 µm tungsten wire)
- Ruby beads (130, 160, 250, 320, 400, 530 µm)
- 10 surgical resectates

Modalities

- Digital Mammography (DM)
  2 clinical systems of different manufacturers
- Breast Tomosynthesis (BT)
  2 clinical systems of different manufacturers
- Photon-counting Breast CT (pcBCT)
  Demonstrator with CdTe detector (100 µm)² pixels
  AGD < 5 mGy

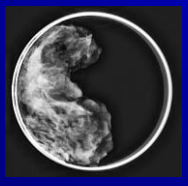
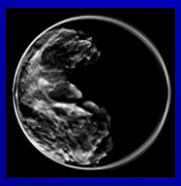
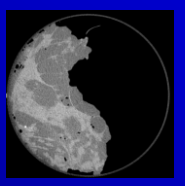
Prospects for breast CT in the future

- Breast CT offers excellent soft tissue and contrast-enhanced displays.
- Compared to mammography, it can offer superior 3D spatial and contrast resolution at similar dose levels.

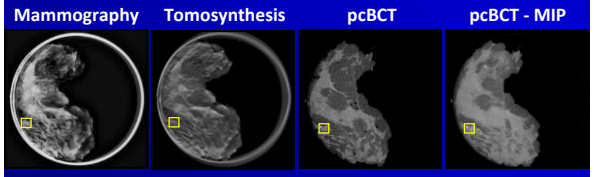
Parameter	UC Davis (Boone *)	Koning Corp. (Ning **)	CT Imaging (Kalender ***)
3D resolution MTF (10%),	2.00 lp/mm (250 µm)	1.56 lp/mm (320 µm)	6.50 lp/mm (80 µm)
AGD	4-16 mGy	7 mGy ± 20%	~ 5 mGy

* J Boone. Pers. Comm.; ** www.koningcorporation.com; *** W Kalender Eur Radiol

Measurements of a lumpectomy in direct comparison of

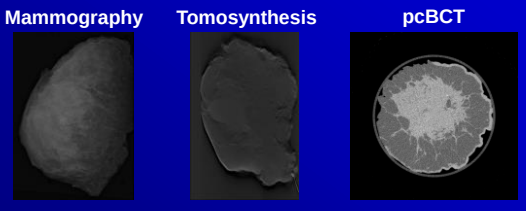
Mammography	Tomosynthesis	pcBCT
		
Projection image (20 mm thickness)	56 Tomo slices (? mm each)	133 CT slices (0.15 mm each)

Measurements of a lumpectomy in direct comparison of



Projection image	Position 10 mm	Position 10 mm	Position 10 mm
21 mm thickness	? mm slice thickness	0.15 mm slice thickness	3 mm slab thickness

Measurements of a mastectomy in direct comparison

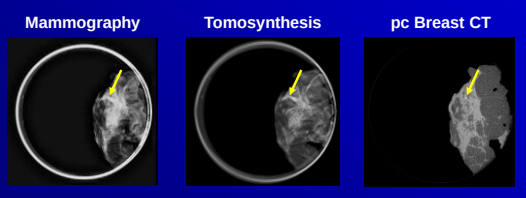


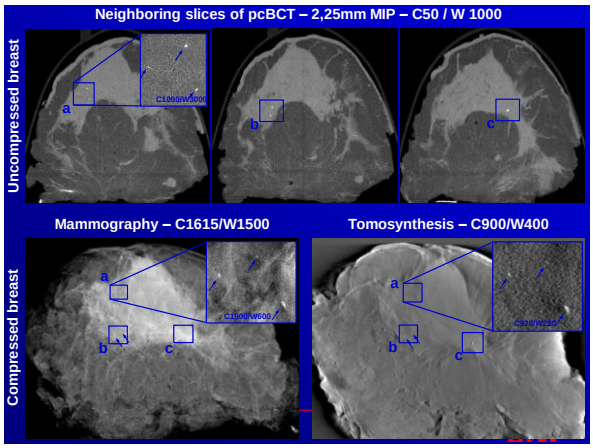
1 Projection image	33 Tomo slices	640 CT slices
33 mm thickness	33 mm thickness	140 mm diameter 95 mm height

Results

Comparison of imaging modalities

Detection rates for calcifications [%] (N = 10)		
Mammography	Tomosynthesis	pc Breast CT
73	70	100





Conclusions

Photon-counting breast CT based on CdTe detector technology can outperform mammography and tomosynthesis with respect to

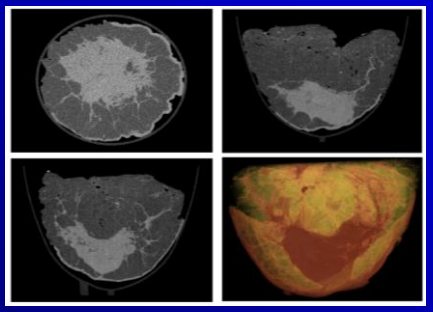
- 3D spatial resolution,
- detectability of calcifications,
- soft tissue delineation

at an AGD below 5 mGy!

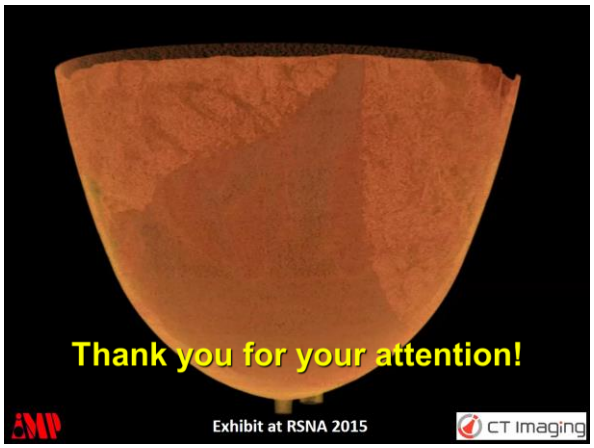
supported by gapless thin-slice low-scatter spiral scanning!

Measurements with a CdTe detector

Breast specimen, 12 s scan with 60 kV, 5 mGy AGD

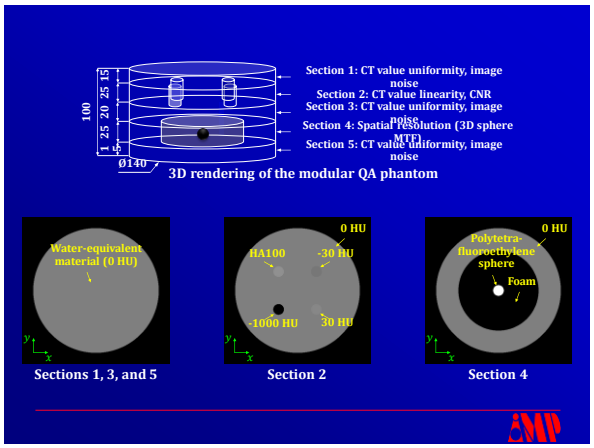


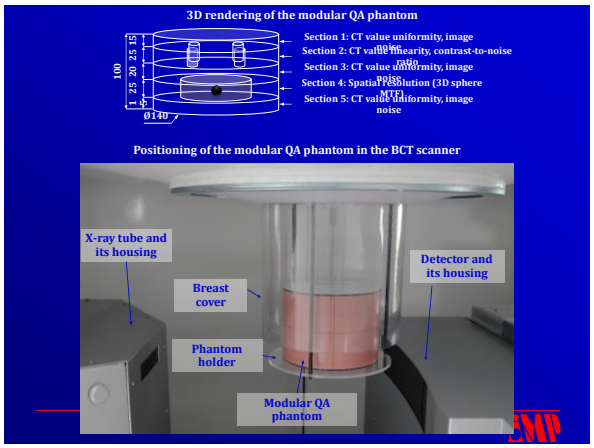
Kalender WA et al. Eur Radiol 2016; DOI 10.1007/s00330-016-4459-3



Acknowledgement of support

- **European Union FP7 program**
  "Dedicated CT of the female breast".
  1/2008-6/2010; PI: W.A. Kalender
- **German Science Foundation**
  "Multimodal Imaging for Preclinical Research",
  10/2009-9/2012; PI: W.A. Kalender
- **German Ministery of Education and Science**
  "Breast CT" 10/2010-4/2015; PI: W.A. Kalender
- **Special thanks** go to the Breast CT R&D teams at the IMP & CT Imaging GmbH in Erlangen





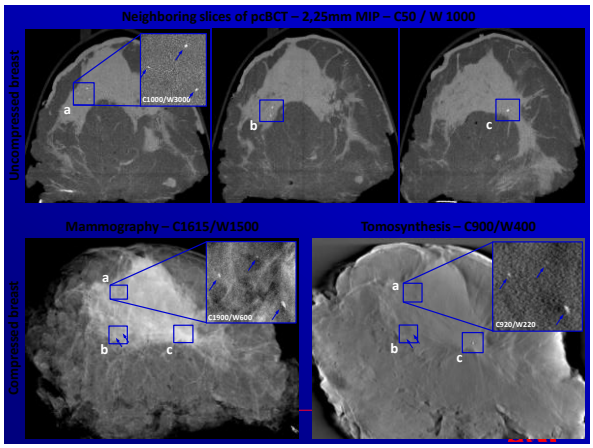
RSNA 2015, Chicago, Nov. 29, 2015

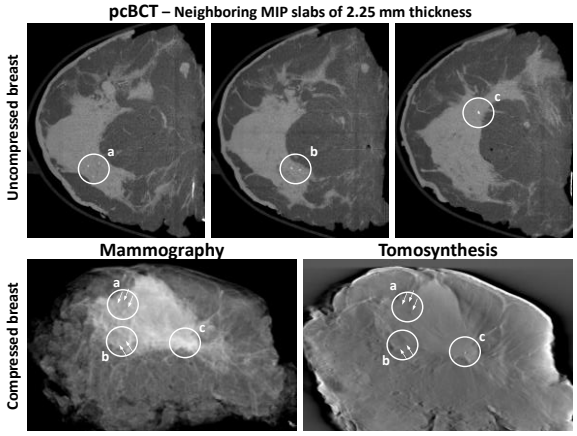
Dedicated high-resolution Breast CT

allows imaging micro-calcifications down to 130 µm at screening mammography dose levels

Willi A. Kalender [1,3], Daniel Kolditz [1,3], Ann-Christin Roessler [1], Evelyn Wenkel [2], Rüdiger Schultz-Wendtland [2], Peter Fasching [2]

[1)] Institute of Medical Physics
[2)] Institute of Radiology, University Hospital of Erlangen
[3)] CT Imaging GmbH, Erlangen, Germany


Neighboring slices of pcBCT – 2,25mm MIP – C50 / W 1000
Uncompressed breast
C1000/W3000
Mammography – C1615/W1500
Tomosynthesis – C900/W400
Compressed breast
C1500/W600
C920/W220


pcBCT – Neighboring MIP slabs of 2.25 mm thickness
Uncompressed breast
Mammography
Tomosynthesis
Compressed breast