#### Quantitative Dynamic Contrast Enhanced Breast Tomosynthesis: How Do We Get There?

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#### **Disclosures**

Research Agreements S C S

Siemens Healthineers Canon Medical Systems ScreenPoint

Speaking Agreement Siemens Healthineers



#### LET'S START FROM THE BEGINNING...





#### **Digital Mammography Improvements**

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Detection in some patient subgroups (DMIST)

## 

#### **Towards Tomographic Breast Imaging**

2 D	2+ D	2.2 D	3 D
Standard Mammography	Stereoscopic Mammography	Digital Tomosynthesis	Dedicated Breast CT



29% of cancers missed by "overlying tissue"



Birdwell et al, Radiology 219, 192-202 (2001).

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#### **DIGITAL BREAST TOMOSYNTHESIS**

















#### **Benefits**

Mammography++ System Workflow Interpretation Dose

...but with **some** discrimination of vertical position!













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Chang et al, Scientific Reports, Vol. 7, 9746 (2017)

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#### **CONTRAST-ENHANCED TOMO**







Chou et al., Eur J Radiol. 84(12), 2501







#### Spatial(-temporal) characterization

Cellular density Vascular access Molecular profiles Genetic characteristics

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# Can we make DBT quantitative?

7/17/2019





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well, I don't know how to...

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## Can we make CE-DBT quantitative?

**Calibration-based quantitative accuracy** 



Hill et al., IWDM Malmö. 645-653, 2016

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Lesion diameter (mm)	[I] <sub>calib</sub> (mg/ml)		
	0.5 mg/ml	1.0 mg/ml	1.5 mg/ml
9.5	(0.44, 0.69)	(1.01, 1.35)	(1.42, 1.86)
7.4	(0.32, 0.63)	(0.85, 1.20)	(1.15, 1.62)
5.0	(0.23, 0.66)	(0.73, 1.15)	(0.93, 1.49)
4.0	(0.28, 0.83)	(0.53, 1.12)	(0.98,1.72)

(95 % confidence intervals)

Hill et al., IWDM Malmö. 645-653, 2016



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## X-ray spectra Volume of support X-ray scatter Limited angle

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X-ray spectra Volume of support X-ray scatter Limited angle

## Polychromatic forward model

$$\hat{y}_i(\vec{w}) = \sum_e b_{ie} \exp\left(-\sum_a \mu_a^{(e)} \sum_j l_{ij} w_{aj}\right)$$

Bustamonte et al., SIAMJ. Sci. Comput. 35(5), 2013.

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$$\underbrace{\overline{j_i(w)}}_e = \sum_e b_{ie} \exp\left(-\sum_a \mu_a^{(e)} \sum_j l_{ij} w_{aj}\right)$$

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$$\hat{y}_{i}(\vec{w}) = \sum_{e} b_{ie} \exp\left(-\sum_{a} \mu_{a}^{(e)} \sum_{j} l_{ij} w_{aj}\right)$$









#### **Spectral Reconstruction**

Beam hardening included

eixt

## **Spectral Reconstruction**

Material decomposition

(iodine map w/out subtraction)

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## X-ray spectra Volume of support X-ray scatter Limited angle

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Michielsen et al, CT Meeting 2018

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Agasthya et al, AAPM 2015 Rodriguez-Ruiz et al, PMB, 2017 Radboudumc



http://www.david-3d.com/?section=Gallery



Rodriguez-Ruiz et al, PMB, 2017

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## Results





Michielsen et al, CT Meeting 2018

### Results



Michielsen et al, CT Meeting 2018

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## **Quantitative Evaluation**



Michielsen et al, CT Meeting 2018







## X-ray spectra Volume of support **X-ray scatter** Limited angle

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Rodriguez-Ruizet al, ECR 2019





#### **Modified u-net**





200 phantoms x 15 projections
= 3,000 scatter fraction images

Patient-base	ed split:	
Training	2400	
Validation	300	
Testing	300	
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## Mean absolute error

All images:	0.9%
Only area inside breast:	0.4%
Only breasts > 60 mm thick:	1.0%

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## X-ray spectra Volume of support X-ray scatter Limited angle



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 $\mathbf{2}^{nd}$  pass recon with lesion volume constrain

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...need to segment the (true) enhancing lesion







Michielsen et al, CT Meeting 2018

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#### **First Pass Reconstruction**





Michielsen et al, CT Meeting 2018



## **Feasibility Experiment**

Lesion location: 50% central / 50% lateral



Michielsen et al, CT Meeting 2018

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#### **Feasibility Experiment**

Enhancement type: 50% rim / 50% homogeneous





#### **Feasibility Experiment**

4500 total cases simulated



Michielsen et al, CT Meeting 2018

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#### **OF COURSE...**

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Erhard et al, Investigative Radiology, 2016

#### A lot of work left...

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3D cases Additional lesions Real patient images What level of accuracy is needed?

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#### A lot of work left...

What biomarkers for tumor status/response/recurrence can we discover from QDCE-DBT?





