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Breast dosimetry simulation using volumetric localization of dense breast tissue from breast tomosynthesis data – current status

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Objective

To get a more realistic dose estimation for the individual in breast tomosynthesis (BT).

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1. Investigate the local energy absorption in breasts with different amount and distribution of glandular tissue.

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1. Investigate the local energy absorption in breasts with different amount and distribution of glandular tissue.
2. Use a method for volumetric localization of glandular breast tissue from BT data to take the individual amount and distribution of glandular tissue into account.

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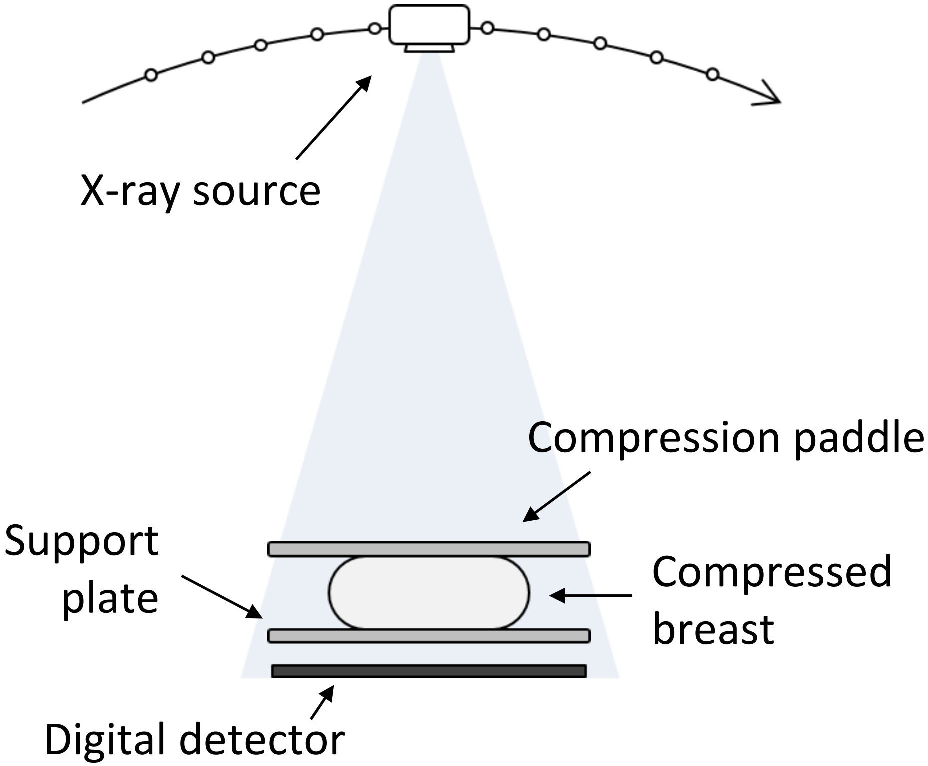
Breast tomosynthesis (BT)

Alternative or complement to mammography



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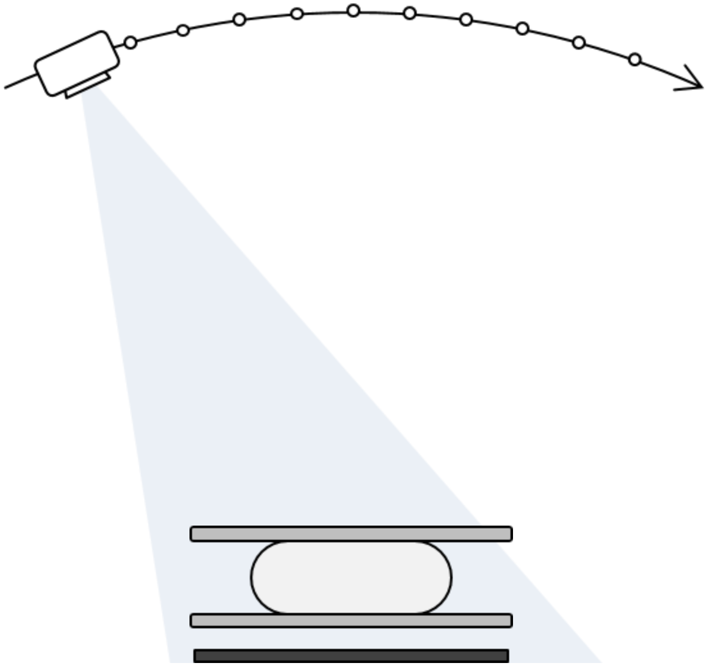

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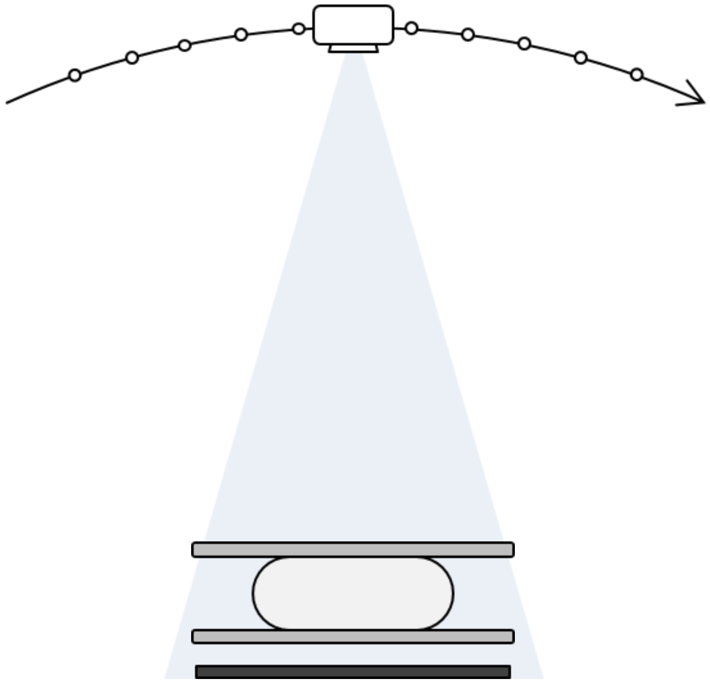

Breast tomosynthesis (BT)

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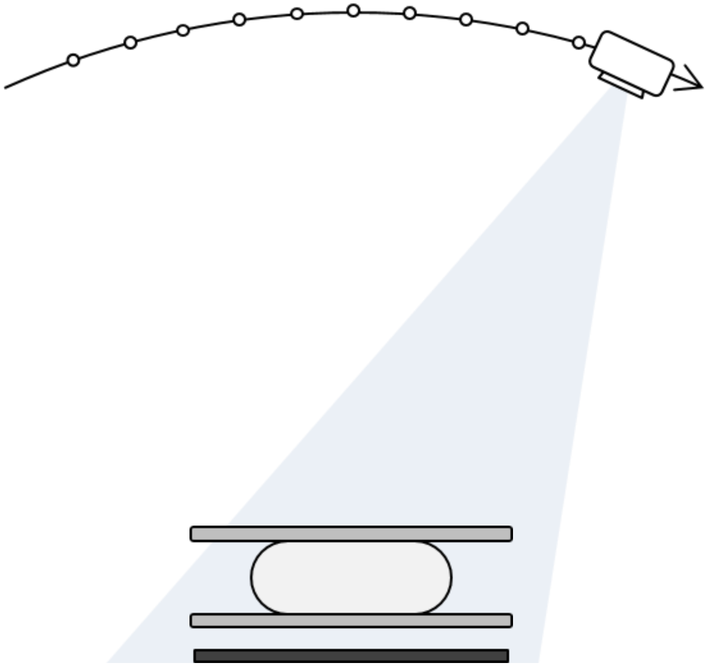

Breast tomosynthesis (BT)

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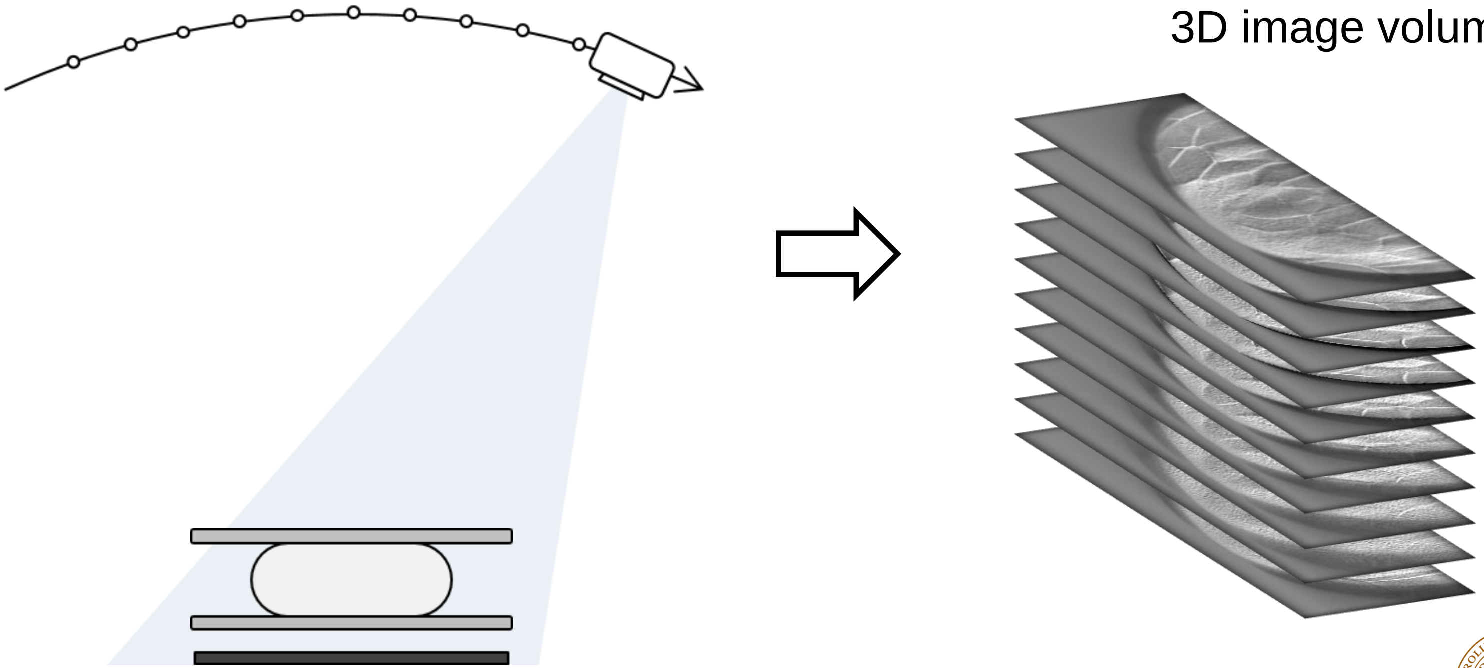

Mean/average glandular dose (MGD/AGD)

Dance, D. R. (1990)

Mean glandular dose to the standard breast:

$$D = K * g$$

- K – incident air kerma at the upper surface of the breast
- g – converts the incident air kerma to mean glandular dose for the standard breast

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- c – corrects for different breast composition (glandularity)
- s – corrects for different x-ray spectrum

Mean/average glandular dose (MGD/AGD)

Dance, D. R. *et al.* (2010)

Mean glandular dose to the standard breast for BT:

Single projection: $$D(\theta)= K * g * c * s * t(\theta)$$

- t(θ) – 'tomo' factor at projection angle θ

K measured at angle 0° but with the tube loading used at angle θ.

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Mean/average glandular dose (MGD/AGD)

Dance, D. R. *et al.* (2010)

Mean glandular dose to the standard breast for BT:

Single projection: $$D(\theta) = K * g * c * s * t(\theta)$$

Full scan: $$D_T = K_T * g * c * s * T$$

- $t(\theta)$ – 'tomo' factor at projection angle θ
- T – 'tomo' factor for complete examination

K measured at angle 0° but with the tube loading used at angle θ.

K_T measured at angle 0° but with the total mAs for the examination.

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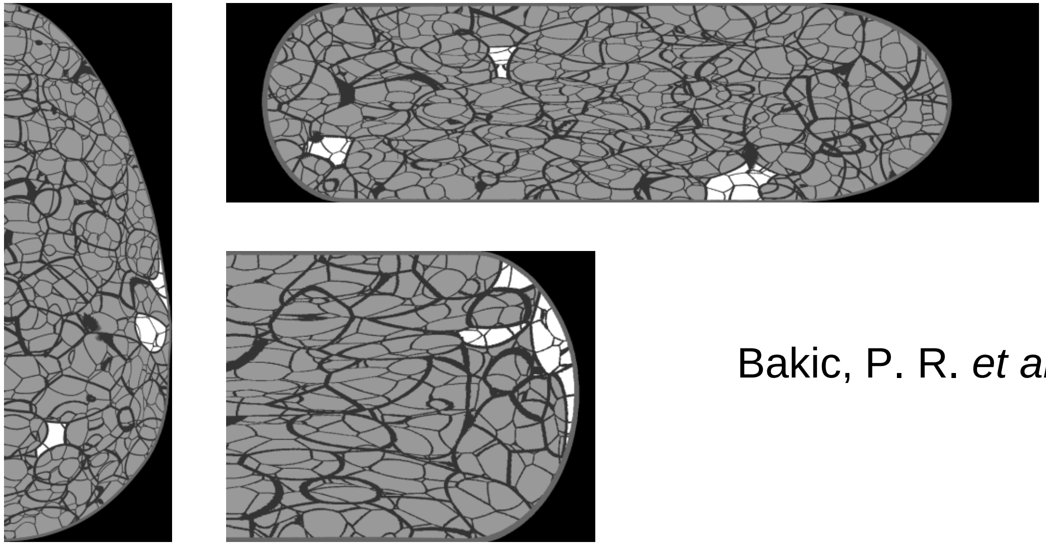
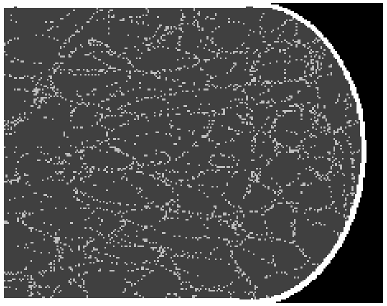
Software breast phantom

Software phantom in the form of a compressed breast developed at the University of Pennsylvania



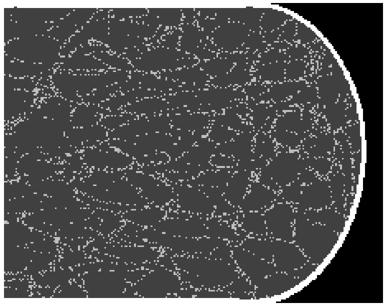
Bakic, P. R. *et al.* (2011)

7 modified phantoms



8 %: No glandular compartments, only ligaments as dense tissue

7 modified phantoms



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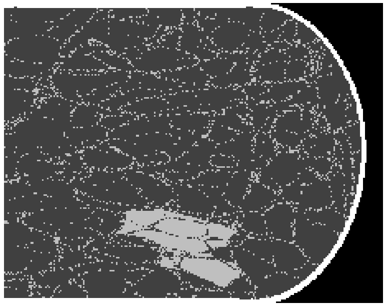
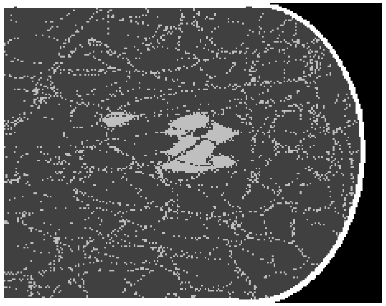
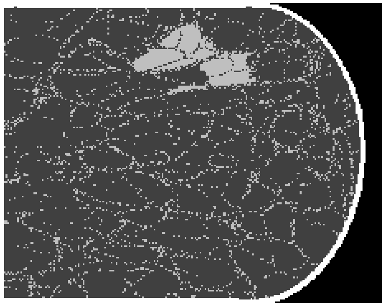
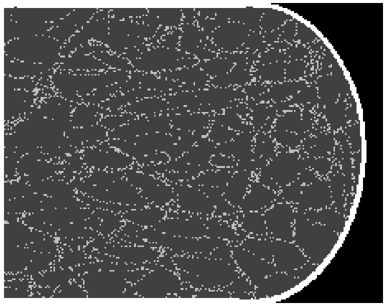




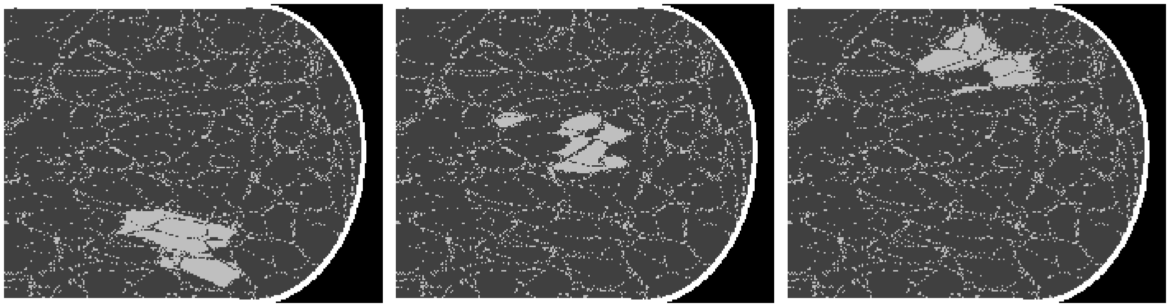


10 %: 3 different distributions

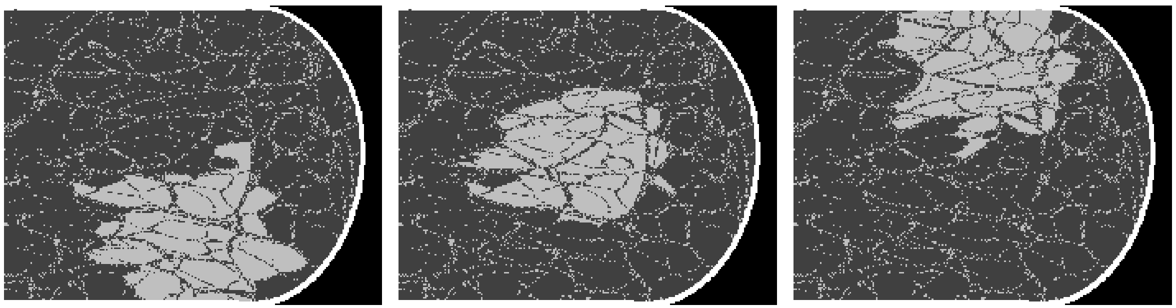
7 modified phantoms



8 %: No glandular compartments, only ligaments as dense tissue

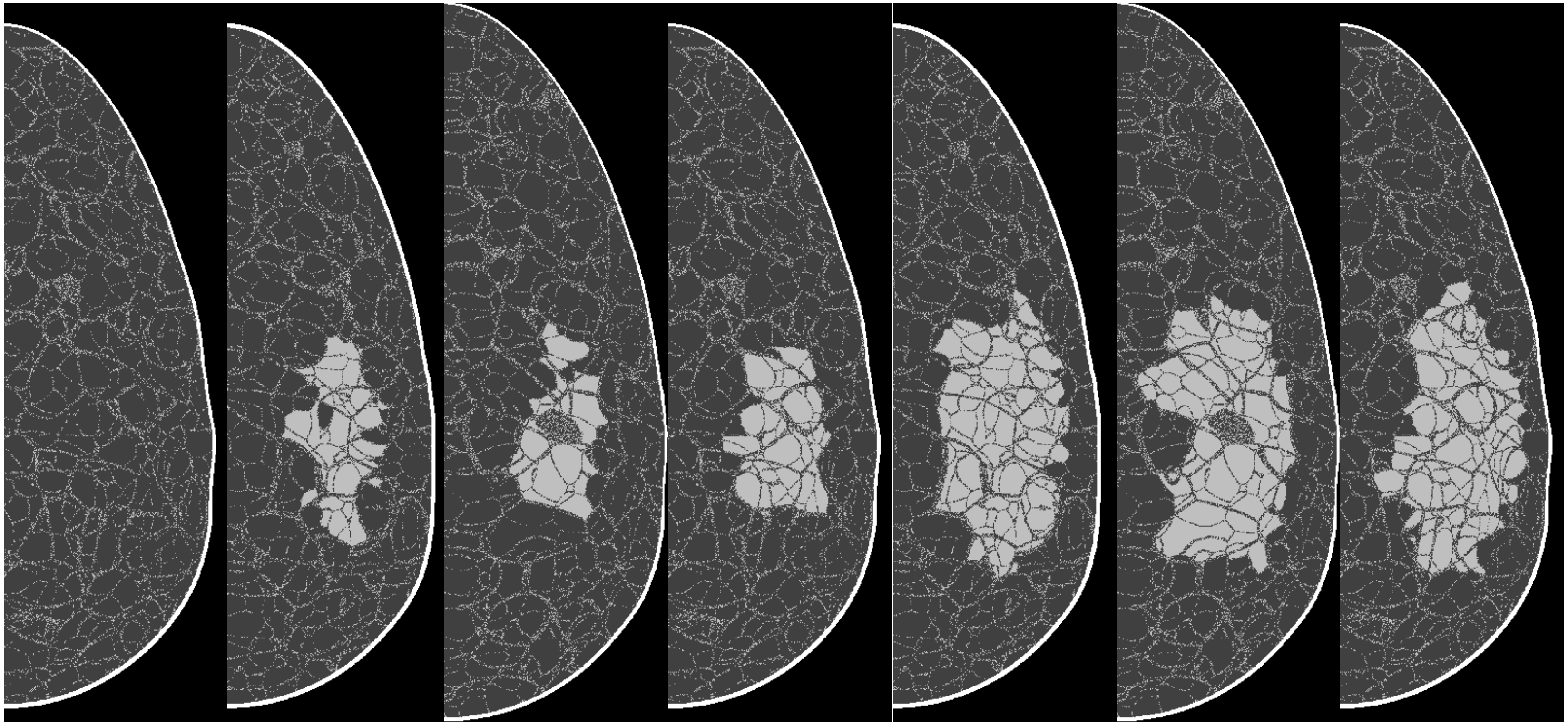


10 %: 3 different distributions



15 %: 3 different distributions

7 modified phantoms



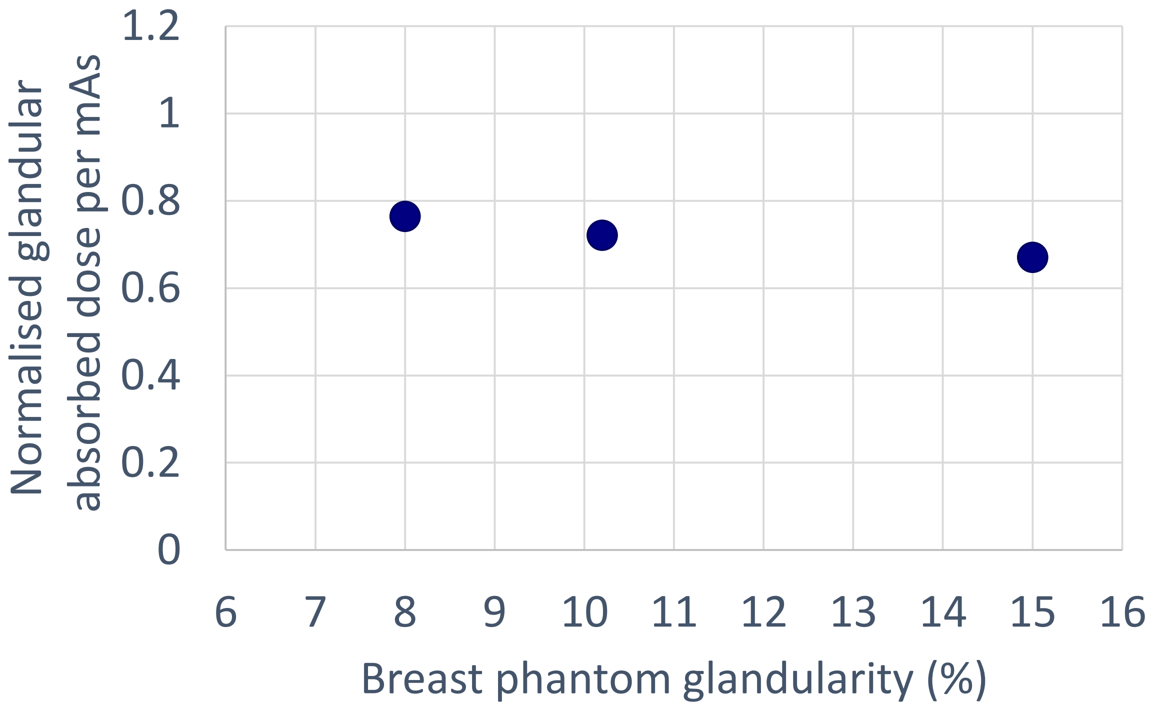
8 % 10 % 10.2 % 10 % 15 % 15 % 15 %

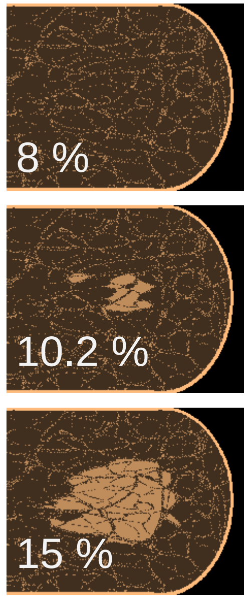
Monte Carlo simulations

- Projection images generated with PENELOPE
  - Breast thickness 6.4 cm, spectrum 30 kV
  - Primary images with analytical ray tracing
  - Scatter contribution with Monte Carlo

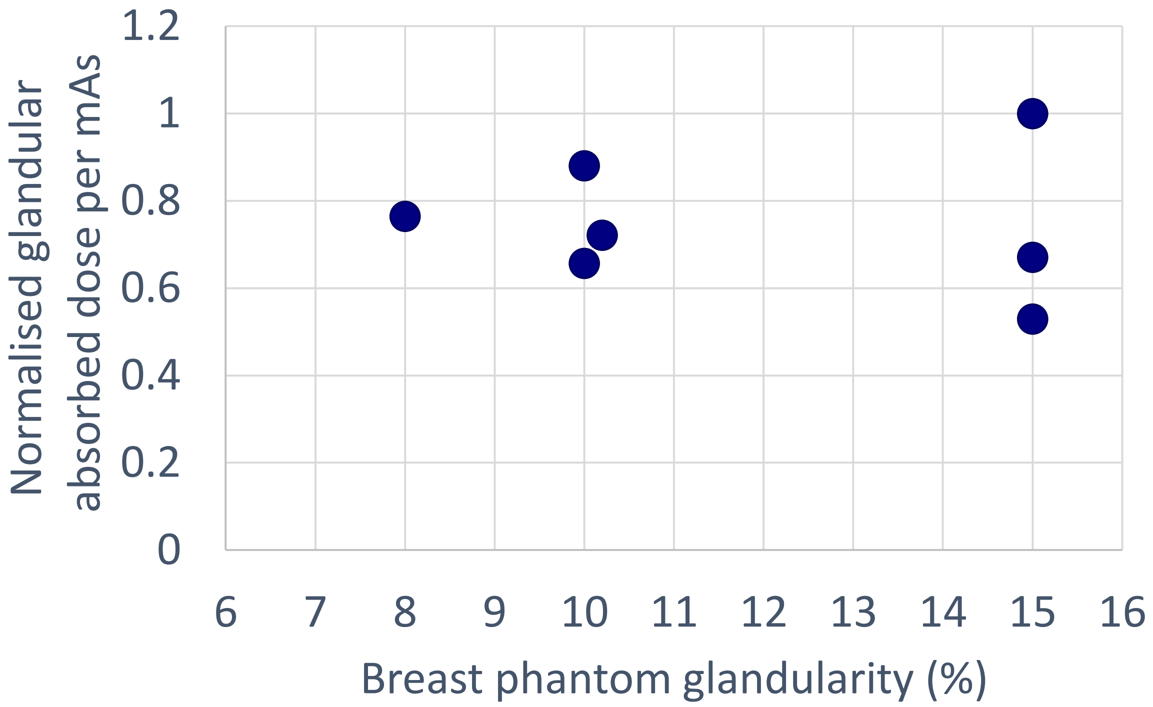
- Scoring of total energy deposition (eV) to glandular tissue

Glandular absorbed dos for 3 phantoms





Glandular absorbed dos for 7 phantoms



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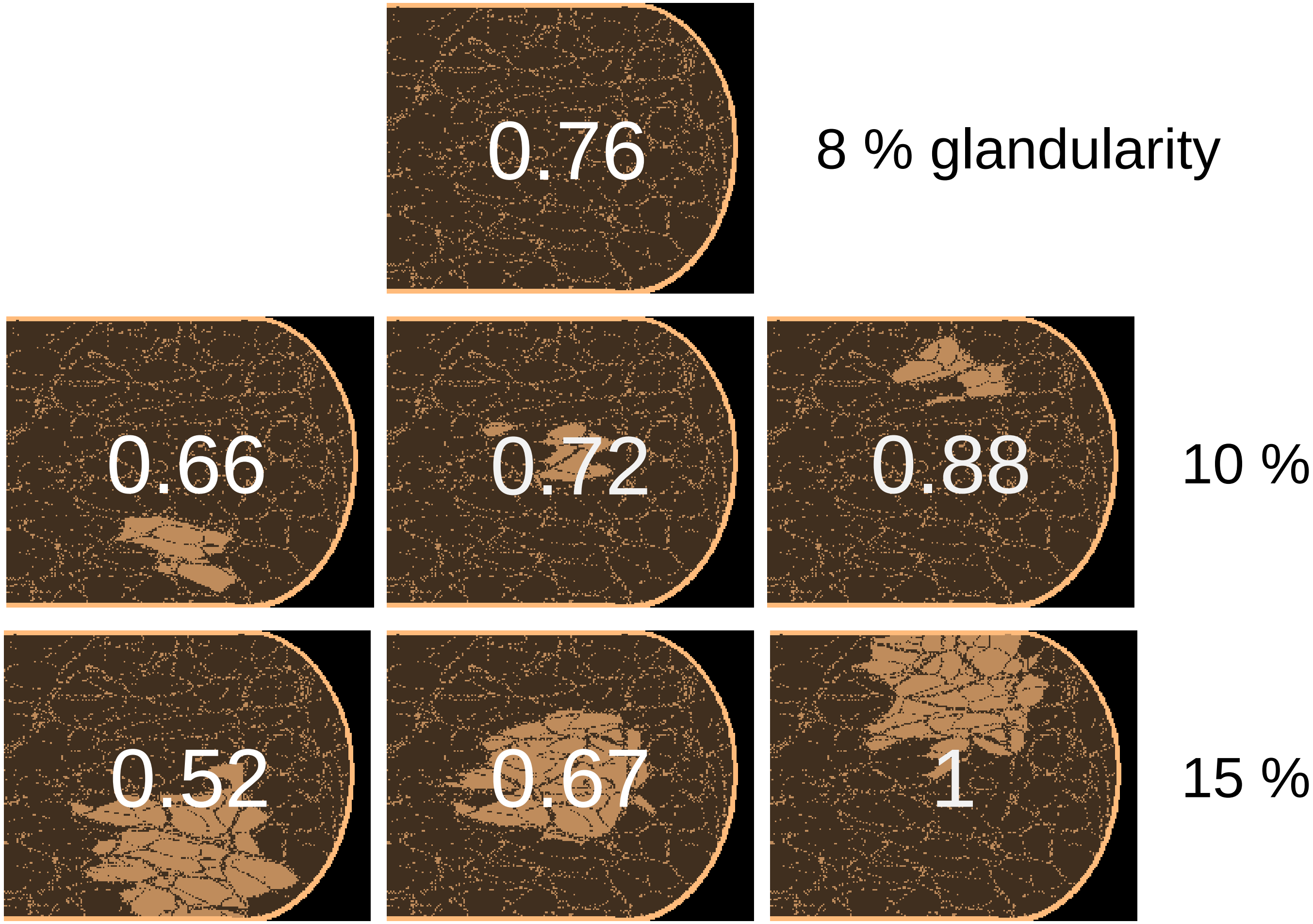
Relative glandular absorbed dose



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Mean/average glandular dose (MGD/AGD)

$$D_T = K_T * g * c * s * T$$

- same K_T (incident air kerma) per mAs

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- g – converts the incident air kerma to mean glandular dose for the standard breast
- s – corrects for different x-ray spectrum
- T – ’tomo’ factor for complete examination

g, *s* and *T*

Table 2. The conversion factor *g* which relates incident air kerma (without backscatter) to mean glandular dose for the 'standard' breast phantom.

HVL mm Al	g (mGy mGy^{-1}) for breast thicknesses of 2 cm	3 cm	4 cm	4.5 cm	5 cm	6 cm	7 cm	8 cm
0.25	0.339	0.234	0.174	0.155	0.137	0.112	0.094	0.081
0.30	0.390	0.274	0.207	0.183	0.164	0.135	0.114	0.098
0.35	0.433	0.309	0.235	0.208	0.187	0.154	0.130	0.112
0.40	0.473	0.342	0.261	0.232	0.209	0.172	0.145	0.126
0.45	0.509	0.374	0.289	0.258	0.232	0.192	0.163	0.140
0.50	0.543	0.406	0.318	0.285	0.258	0.214	0.177	0.154
0.55	0.573	0.437	0.346	0.311	0.287	0.236	0.202	0.175
0.60	0.587	0.466	0.374	0.339	0.310	0.261	0.224	0.195
0.65	0.622	0.491	0.399	0.363	0.332	0.282	0.244	0.212
0.70	0.644	0.514	0.421	0.384	0.352	0.300	0.259	0.227
0.80	0.682	0.555	0.460	0.422	0.389	0.333	0.289	0.254
0.90	0.721	0.592	0.500	0.473	0.430	0.378	0.327	0.293
1.00	0.733	0.623	0.534	0.497	0.464	0.407	0.360	0.321
1.20	0.777	0.675	0.588	0.550	0.516	0.456	0.406	0.364
1.40	0.813	0.717	0.632	0.594	0.559	0.497	0.444	0.399
1.60	0.842	0.753	0.670	0.632	0.596	0.533	0.479	0.432
1.80	0.865	0.783	0.704	0.666	0.631	0.567	0.511	0.463
2.00	0.886	0.810	0.734	0.696	0.660	0.596	0.540	0.490

Dance, D. R. (1990)

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g, s and T

Table 2. The conversion factor g which relates incident air kerma (without backscatter) to mean glandular dose for the 'standard' breast phantom.

g (mGy mGy^{-1}) for breast thicknesses of

							7 cm	8 cm
							0.094	0.081
							0.114	0.098
							0.130	0.112
							0.145	0.126
							0.163	0.140
							0.177	0.154
							0.202	0.175
							0.224	0.195
							0.244	0.212
							0.259	0.227
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Table 3. s-factors for clinically used spectra and maximum errors that can be incurred when they are used.

Spectrum	s-factor	Maximum error (%)
Mo/Mo	1.000	3.1
Mo/Rh	1.017	2.2
Rh/Rh	1.061	3.6
Rh/Al	1.044	2.4
W/Rh	1.042	2.1

Dance, D. R. *et al.* (2000)

Dance, D. R. (1990)

g, *s* and *T*

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g (mGy mGy^{-1}) for breast thicknesses of

		7 cm	8 cm
		0.094	0.081
1.00	0.73		
1.20	0.77		
1.40	0.81		
1.60	0.84		
1.80	0.86		
2.00	0.88		

Dance, D. R. (1990)

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Rh/Rh	1.061	3.6
Rh/Al	1.044	2.4
W/Rh	1.042	2.1

Table 9. *T*-factors for the Hologic Selenia Dimensions and Siemens Inspiration tomographic systems.

Breast thickness (mm)	T Hologic	T Siemens
20	0.997	0.980
30	0.996	0.974
40	0.996	0.971
50	0.995	0.968
60	0.994	0.966
70	0.994	0.965
80	0.993	0.964
90	0.992	0.962
100	0.993	0.961
110	0.992	0.960

Dance, D. R. *et al.* (2010)

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Mean/average glandular dose (MGD/AGD)

$$D_T = K_T * g * c * s * T$$

- same K_T (incident air kerma) per mAs
- same g (conversion factor)
- same s (spectrum correction)
- same T (‘tomo’ correction)

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→ D_T proportional to c (glandularity correction) for the 7 phantoms

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c (glandularity correction)

Table 7. *c*-factors for average breasts for women in age group 40 to 49.

Breast thickness (cm)	HVL (mm Al)						
	0.30	0.35	0.40	0.45	0.50	0.55	0.60
2	0.885	0.891	0.900	0.905	0.910	0.914	0.919
3	0.894	0.898	0.903	0.906	0.911	0.915	0.918
4	0.940	0.943	0.945	0.947	0.948	0.952	0.955
5	1.005	1.005	1.005	1.004	1.004	1.004	1.004
6	1.080	1.078	1.074	1.074	1.071	1.068	1.066
7	1.152	1.147	1.141	1.138	1.135	1.130	1.127
8	1.220	1.213	1.206	1.205	1.199	1.190	1.183
9	1.270	1.264	1.254	1.248	1.244	1.235	1.225
10	1.295	1.287	1.279	1.275	1.272	1.262	1.251
11	1.294	1.290	1.283	1.281	1.273	1.264	1.256

Table 8. *c*-factors for average breasts for women in age group 50 to 64.

Breast thickness (cm)	HVL (mm Al)						
	0.30	0.35	0.40	0.45	0.50	0.55	0.60
2	0.885	0.891	0.900	0.905	0.910	0.914	0.919
3	0.925	0.929	0.931	0.933	0.937	0.940	0.941
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.086	1.082	1.081	1.078	1.075	1.071	1.069
6	1.164	1.160	1.151	1.150	1.144	1.139	1.134
7	1.232	1.225	1.214	1.208	1.204	1.196	1.188
8	1.275	1.265	1.257	1.254	1.247	1.237	1.227
9	1.299	1.292	1.282	1.275	1.270	1.260	1.249
10	1.307	1.298	1.290	1.286	1.283	1.272	1.261
11	1.306	1.301	1.294	1.291	1.283	1.274	1.266

Dance, D. R. *et al.* (2000)

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Mean/average glandular dose (MGD/AGD)

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- same K_T (incident air kerma) per mAs
- same *g* (conversion factor)
- same *s* (spectrum correction)
- same *T* (‘tomo’ correction)
- *same c* (glandularity correction)

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- same *g* (conversion factor)
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- same *T* ('tomo' correction)
- *same c* (glandularity correction)

→ D_T same for the 7 phantoms

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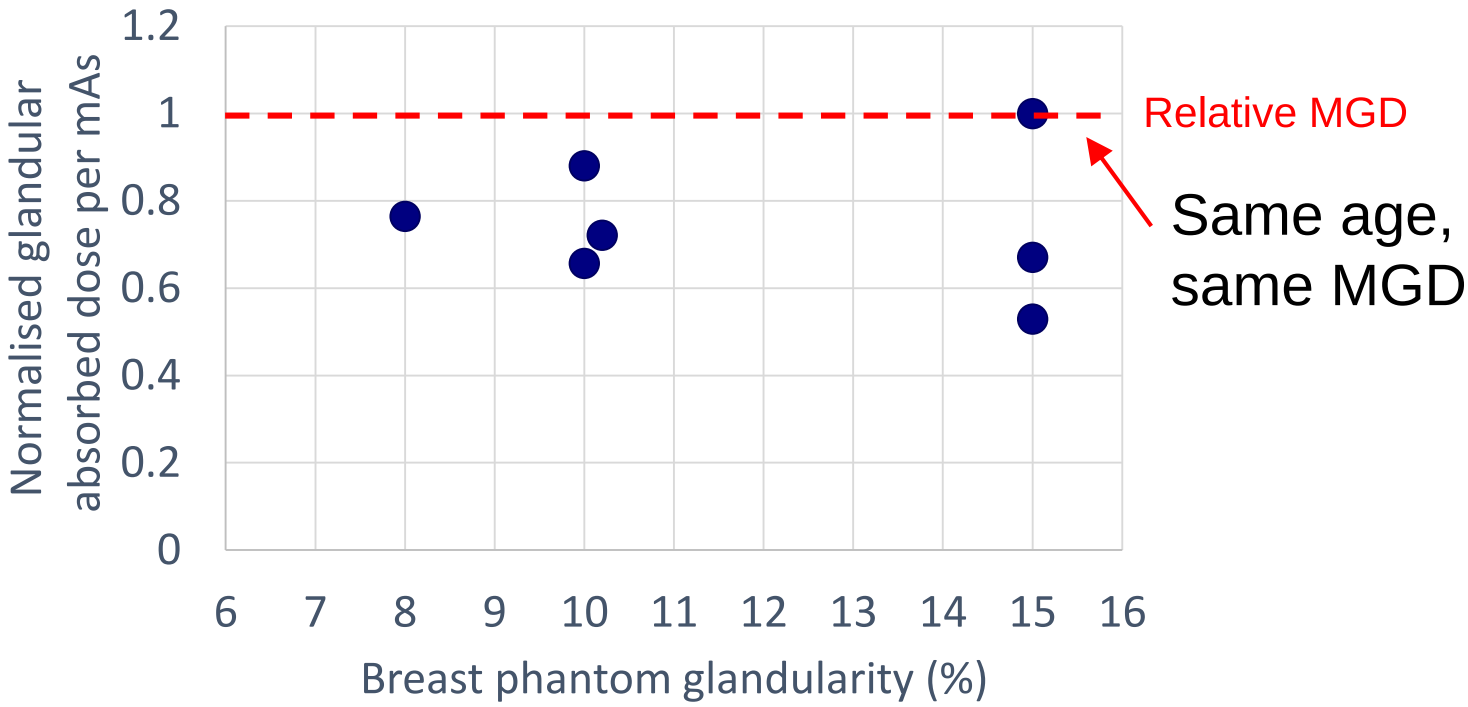
Glandular absorbed dos for 7 phantoms



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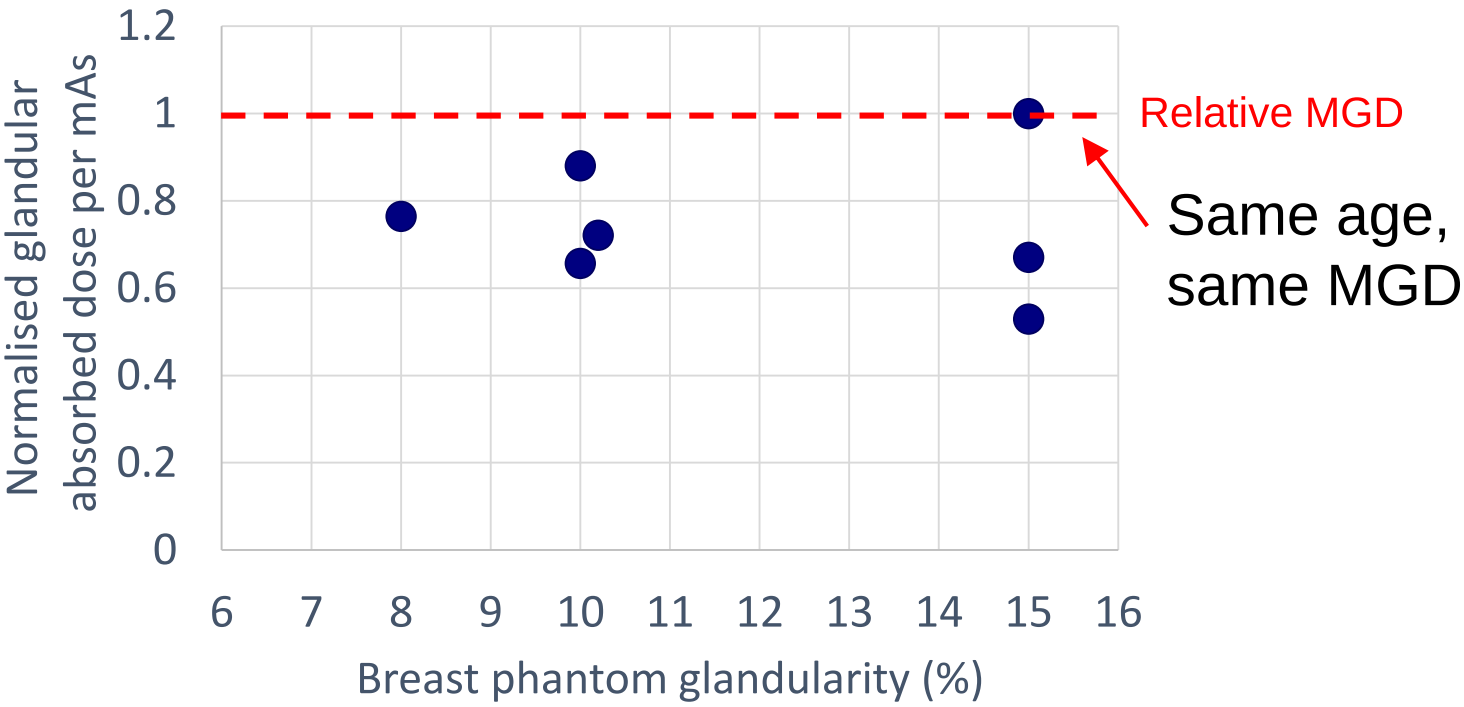

- No individual estimation of glandularity
- Maybe a large overestimation of glandularities
- No correction for glandular distribution

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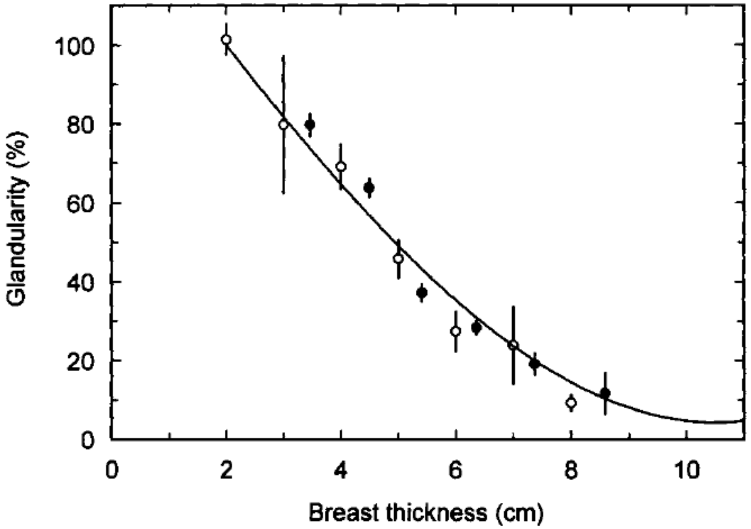
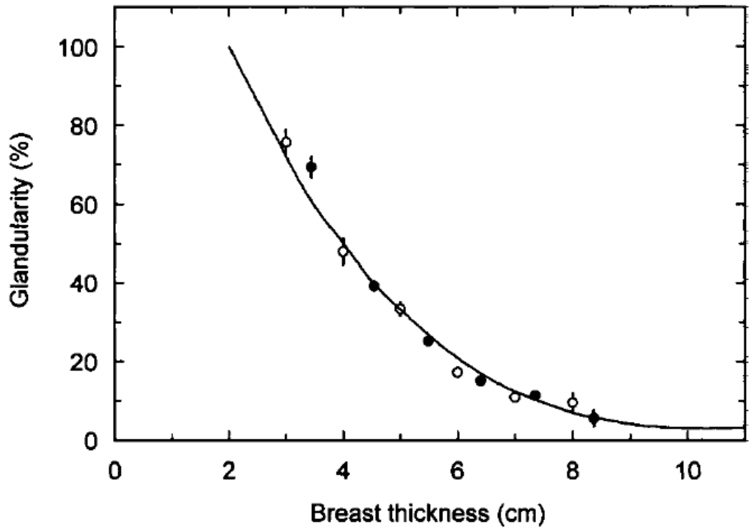
No individual estimation of glandularity

Glandularity 40 – 49 years



Glandularity 50 – 64 years



Dance, D. R. *et al.* (2000)

Maybe a large overestimation of glandularities

The myth of the 50-50 breast

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Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada

J. M. Boone and N. Packard
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O. Alonzo-Proulx

Results: Mean compositions, expressed as percent fibroglandular tissue (including the skin), varied from 13.7% to 25.6% among the groups with an overall mean of 19.3%. The mean compressed breast thickness for the mammograms was 5.9 cm (σ=1.6 cm). 80% of the women in our study had volumetric breast density less than 27% and 95% were below 45%.

University Health Network, University of Toronto, Toronto, Ontario M5G 2M9, Canada

(Received 30 April 2009; revised 23 September 2009; accepted for publication 29 September 2009; published 5 November 2009)

Purpose: For dosimetry and for work in optimization of x-ray imaging of the breast, it is commonly assumed that the breast is composed of 50% fibroglandular tissue and 50% fat. The purpose of this study was to assess whether this assumption was realistic.
Methods: First, data obtained from an experimental breast CT scanner were used to validate an algorithm that measures breast density from digitized film mammograms. Density results obtained from a total of 2831 women, including 191 women receiving CT and from mammograms of 2640 women from three other groups, were then used to estimate breast compositions.
Results: Mean compositions, expressed as percent fibroglandular tissue (including the skin), varied from 13.7% to 25.6% among the groups with an overall mean of 19.3%. The mean compressed breast thickness for the mammograms was 5.9 cm (σ=1.6 cm). 80% of the women in our study had volumetric breast density less than 27% and 95% were below 45%.
Conclusions: Based on the results obtained from the four groups of women in our study, the "50-50" breast is not a representative model of the breast composition. [DOI: 10.1118/1.3250863]

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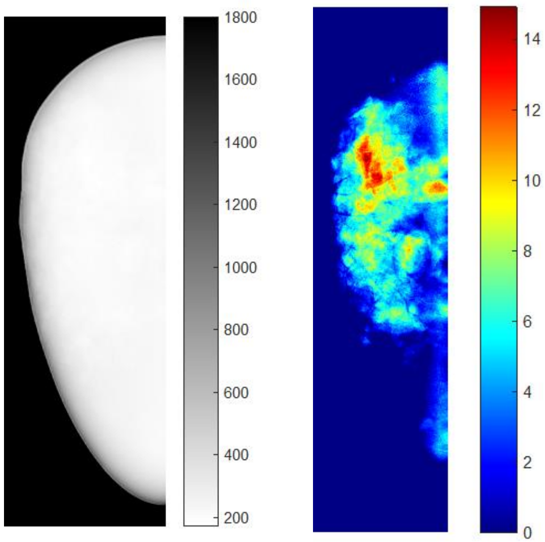
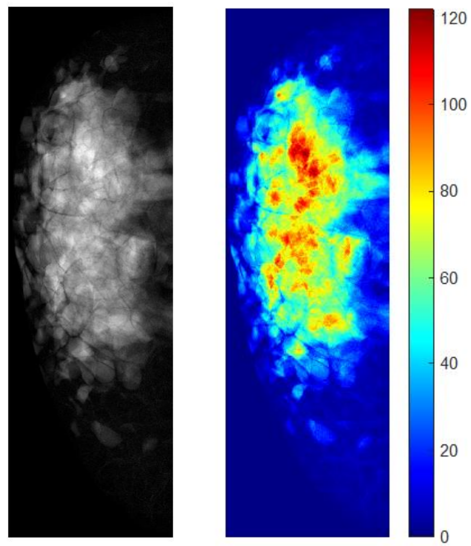
No correction for glandular distribution

Continuation of the project:

- Use a method for volumetric localization of glandular breast tissue from BT data to take the individual amount and distribution of glandular tissue into account.





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