dosimetry in the (Dutch) Breast Cancer screening

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- Introduction
- Breast dosimetry model
- Implementation in Breast Cancer Screening
- Quality control, limiting values
- Patient dosimetry
- Risk analysis

Introduction

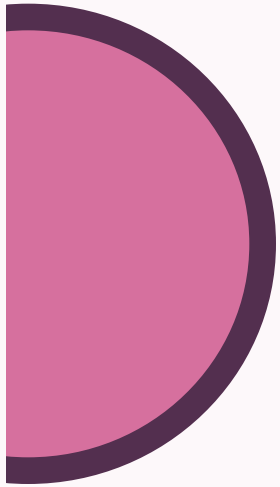
- To understand the dosimetry model: chronological explanation
- Risk assessment:

  - Absorbed energy in glandular tissue
- Mean Glandular Dose (MGD) cannot be measured directly
- Entrance Surface Air Kerma is measured
- Using a model of the breast the MGD is estimated for a population

Hammerstein (1979)

Breast model (Hammerstein 1979)

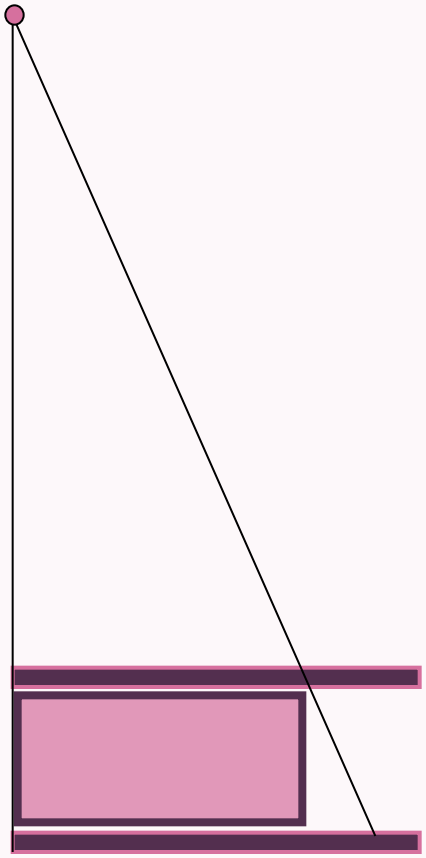
- 5 mm skin (fatty tissue)
- Core: homogeneous mixture of glandular and fatty tissue
- 50/50% glandular/fatty tissue



CC projection

Side view

Dance (1990)



Configuration:

- Hammerstein breast model
- Compression paddle present
- Bucky table present
- Mo/Mo target/filter combination

Dance (1990)

$MGD = K_{air} \cdot g$

g-factor: fraction of energy absorbed in glandular tissue of breast

K_{air}: Entrance Surface Air Kerma

g-factor: determined using Monte Carlo simulations
→ tabulated against HVL

(IPSM Report 59 1989, European Protocol 1996)

Dance (1990)

g-factor							
PMMA Thickness (mm)	HVL (mm Al)						
	0.3	0.35	0.4	0.45	0.5	0.55	0.6
2	0.378	0.421	0.460	0.496	0.529	0.559	0.575
3	0.261	0.294	0.326	0.357	0.388	0.419	0.448
4	0.183	0.208	0.232	0.258	0.285	0.311	0.339
4.5	0.155	0.177	0.198	0.220	0.245	0.272	0.295
5	0.135	0.154	0.172	0.192	0.214	0.236	0.261
6	0.106	0.121	0.136	0.152	0.166	0.189	0.210
7	0.086	0.098	0.111	0.123	0.136	0.154	0.172
8	0.074	0.085	0.096	0.106	0.117	0.133	0.149

Dance (2000)

Developments since 1990:

- Additional X-ray spectra are used:

  - Mo/Rh, Rh/Rh

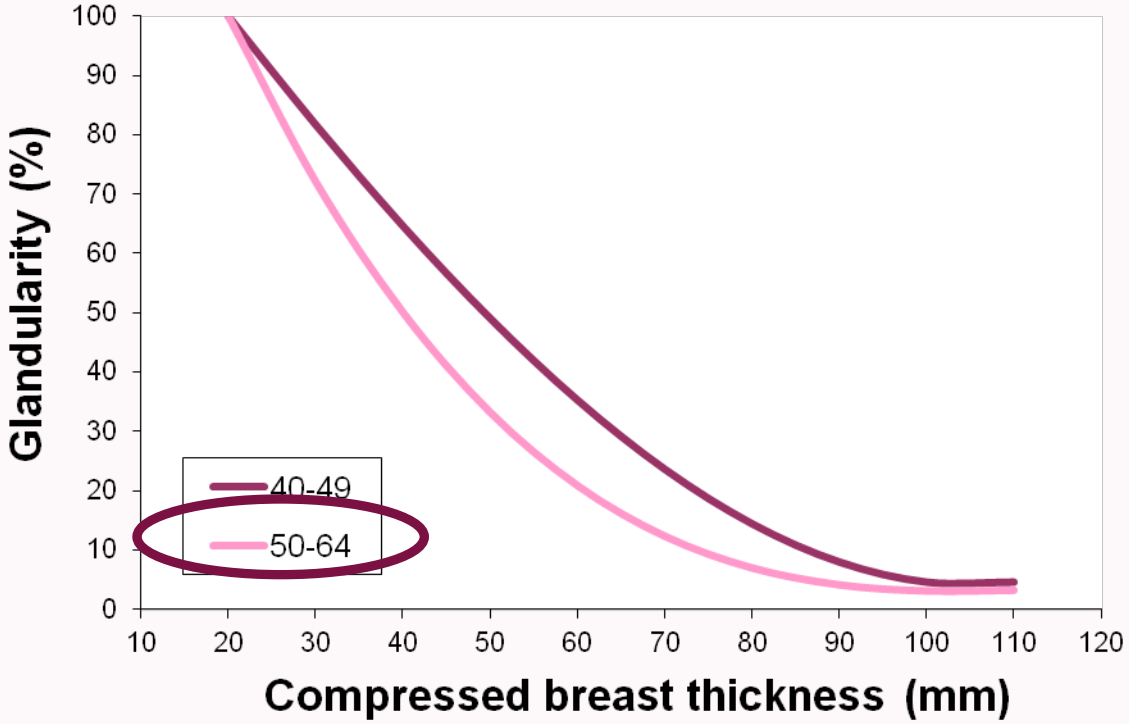
  The g-factor was based on Mo/Mo

- Correction on g-factor for other X-ray spectra

  -> s-factor

Dance (2000)

- Breast composition assumption (50% glandularity) is a simplification



Dance (2000)

-> Introduction of c-factor,

correction of g factor for differences in breast composition

(other than 50% glandular/50% fatty tissue)

discussion in USA:

“the myth of the 50-50 breast”

Dance (2000)

$MGD = K_{air} \cdot g \cdot c \cdot s$

g-factor: fraction of energy absorbed in glandular tissue

K_{air} entrance Surface Air Kerma

c-factor: correction for breast composition

s-factor: correction X-ray spectrum

(Dance 2000)

c-factor								
PMMA thickness [cm]		HVL [mm Al]						
		0.30	0.35	0.40	0.45	0.50	0.55	0.60
2.0		0.889	0.895	0.903	0.908	0.913	0.917	0.921
3.0		0.940	0.943	0.945	0.946	0.950	0.952	0.953
4.0		1.043	1.041	1.041	1.039	1.038	1.036	1.035
5.0		1.164	1.160	1.151	1.150	1.144	1.139	1.134
6.0		1.254	1.245	1.236	1.231	1.226	1.217	1.208
7.0		1.299	1.292	1.282	1.275	1.270	1.260	1.249
8.0		1.307	1.299	1.291	1.288	1.283	1.273	1.263

s-factor	
Mo/Mo	1.000
Mo/Rh	1.017
Rh/Rh	1.061
W/Rh	1.042

Dance (2009)

- Digital mammography has been introduced
- New target/filter combinations:

  - W/Ag (thickness between 50 -75 μm)

  - W/Al (0.5 mm thickness)

Dance (2009)

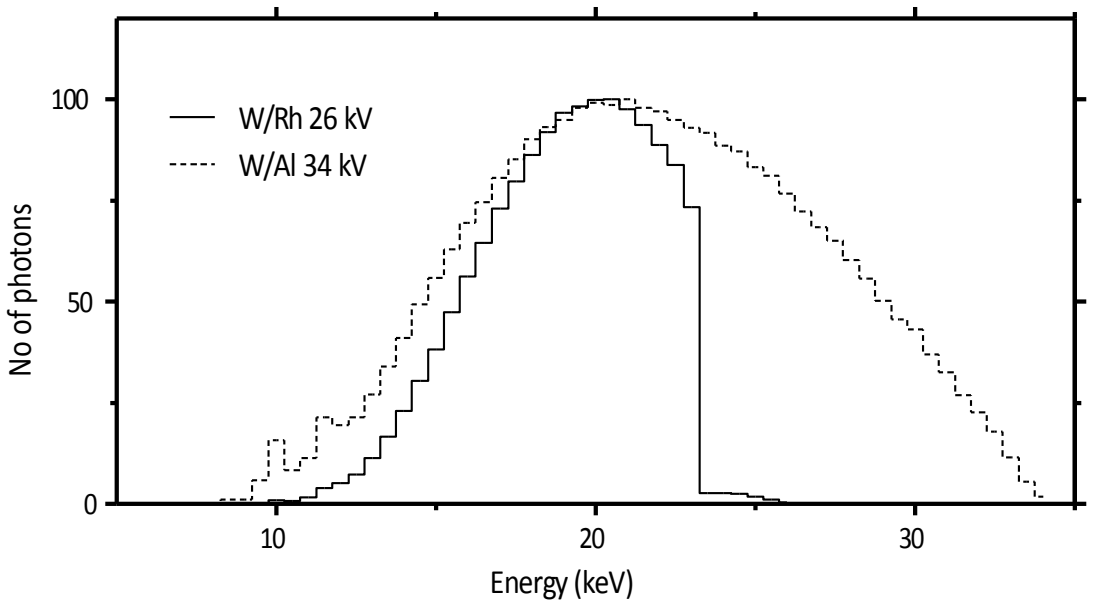
- W/Ag target/filter combinations:

Target	Filter	kV range (kV)	s-factor using Boone spectra	Maximum error %
W	50 μm Ag	25-40	1.063	2.6
W	55 μm Ag	25-40	1.054	2.6
W	60 μm Ag	25-40	1.048	2.9
W	65 μm Ag	25-40	1.043	3.1
W	75 μm Ag	25-40	1.037	4.1
W	50-75 μm Ag	25-40	1.042	4.6

- One s-factor for W/Ag

Dance (2009)

- W target combined with 0.5 mm Al filter:
- Broad X-ray spectrum



Dance (2009)

- It is not possible to use one s-factor for W/ 0.5 mm Al

PMMA thickness (mm)	Equiv breast thickness (mm)	s-factor
20	21	1.075
30	32	1.104
40	45	1.134
45	53	1.149
50	60	1.160
60	75	1.181
70	90	1.198
80	103	1.208

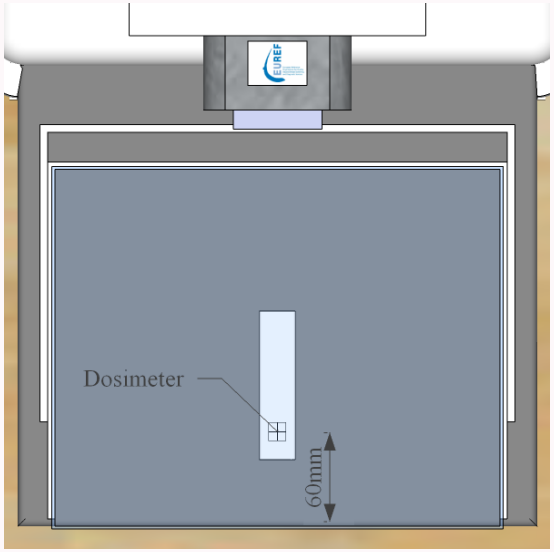
Dance (2009)

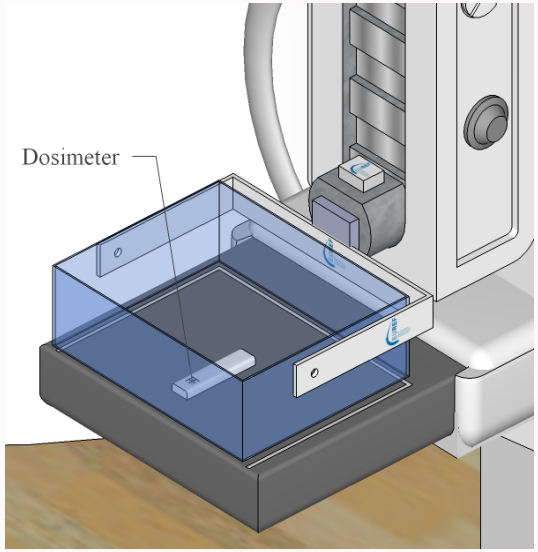
- 1990: Scatter free
- 2000: dose meter in contact with compression paddle
- 2009:

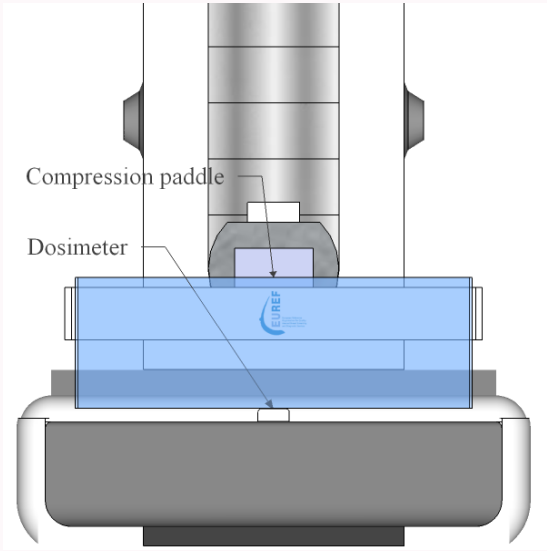
Calculation geometry	Relative value of incident air kerma
Chamber in contact with compression paddle	1.000
Compression paddle raised 50 mm above chamber	0.968
Scatter free measurement	0.929

- 2012: EU Guidelines: measuring device in contact with paddle

European Guidelines 2012







Position dosemeter: on bucky in contact with compression paddle

European Guidelines 2012

- S-factor for W/0.7 mm Al

PMMA thickness (mm)	Equiv breast thickness (mm)	s-factor
20	21	1.052
30	32	1.060
40	45	1.076
50	60	1.087
60	75	1.105
70	90	1.121
80	103	1.129

- Additional c- and g-factors for HVL up to 0.8 mm Al

Implementation of Dance model

- European Guidelines,
  Fourth edition (2006),
  Supplement (2012)
- MGD calculated in QC
- Limits on MGD and
  image quality
- Distinction between:
  - acceptable (limit)
  - achievable values
- DRN

Implementation of Dance model

PMMA thickness	*Eq.Breast th.*	*Mean Glandular dose*	
		acceptable	*achievable level*
[cm]	*[cm]*	*[mGy]*	*[mGy]*
2.0	*2.1*	*< 1.0*	*< 0.6*
3.0	*3.2*	*< 1.5*	*< 1.0*
4.0	*4.5*	*< 2.0*	*< 1.6*
4.5	*5.3*	*< 2.5*	*< 2.0*
5.0	*6.0*	*< 3.0*	*< 2.4*
6.0	*7.5*	*< 4.5*	*< 3.6*
7.0	*9.0*	*< 6.5*	*< 5.1*

- Limits derived from screen-film mammography
- Basic principle: digital should be equal or better

Implementation of Dance model

How have the limiting values been derived?

- For 5 cm PMMA existing limit on Entrance Kerma
- MGD calculated using a standard spectrum (appr. 3 mGy)
- Limits should be extended to other thicknesses
- Relationship between PMMA thickness and MGD in screen-film mammography determined
- Resulting curve scaled to 3 mGy

Dose level 2009

PMMA thickness (cm)	Equivalent breast thickness (cm)	MGD screen-film (2007) (mGy)	MGD digital (2009) (mGy)	Difference (mGy)
2	2.1	0.36	0.76	0.40
3	3.2	0.57	1.10	0.53
4	4.5	1.02	1.50	0.48
5	6	1.69	1.66	-0.04
6	7.5	2.93	2.23	-0.70
7	9	4.81	2.12	-2.68

Note: Before introduction of W-target in digital mammography

Dose level 2012

PMMA Thickness (cm)	Equivalent breast thickness (cm)	MGD digital (2009) (mGy)	MGD digital (2012) (mGy)	Difference (mGy)
2	2.1	0.76	0.57	-0.19
3	3.2	1.10	0.82	-0.28
4	4.5	1.50	1.15	-0.35
5	6	1.66	1.39	-0.27
6	7.5	2.23	1.80	-0.43
7	9	2.12	1.79	-0.33

In practice

In practice:

- Most DR systems: Using “**achievable**” dose level, “**achievable**” image quality is obtained
- Most CR systems: Using “**acceptable**” dose level, “**acceptable**” image quality is obtained

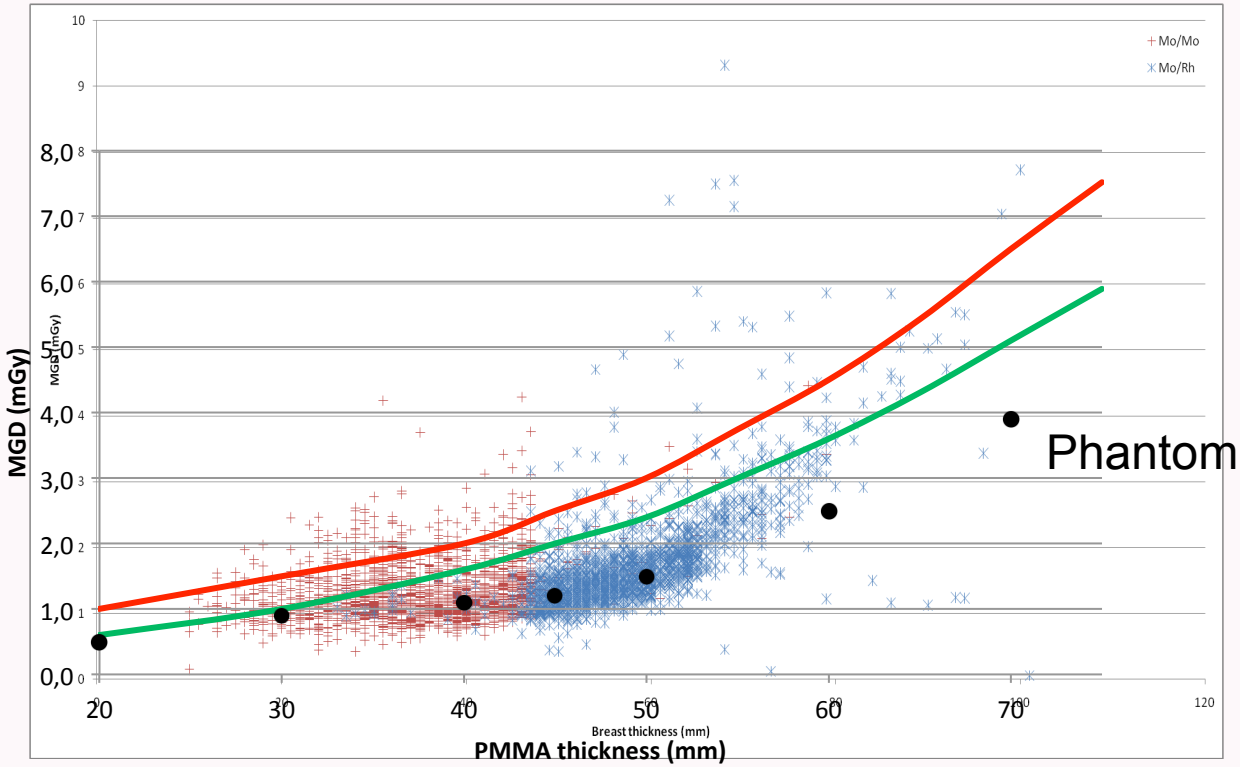
(comparison for single sided CR plates)

DRN

- CR systemen hebben meer dosis nodig om dezelfde kwaliteit te bereiken
- Onderscheid tussen dosis referentieniveau van DR en CR
- CR: DRN is “acceptable” waarde uit EU richtlijn
- DR: DRN is “achievable” waarde uit EU richtlijn
- Alleen 3, 5 en 7 cm in DRN

Patient dosimetry

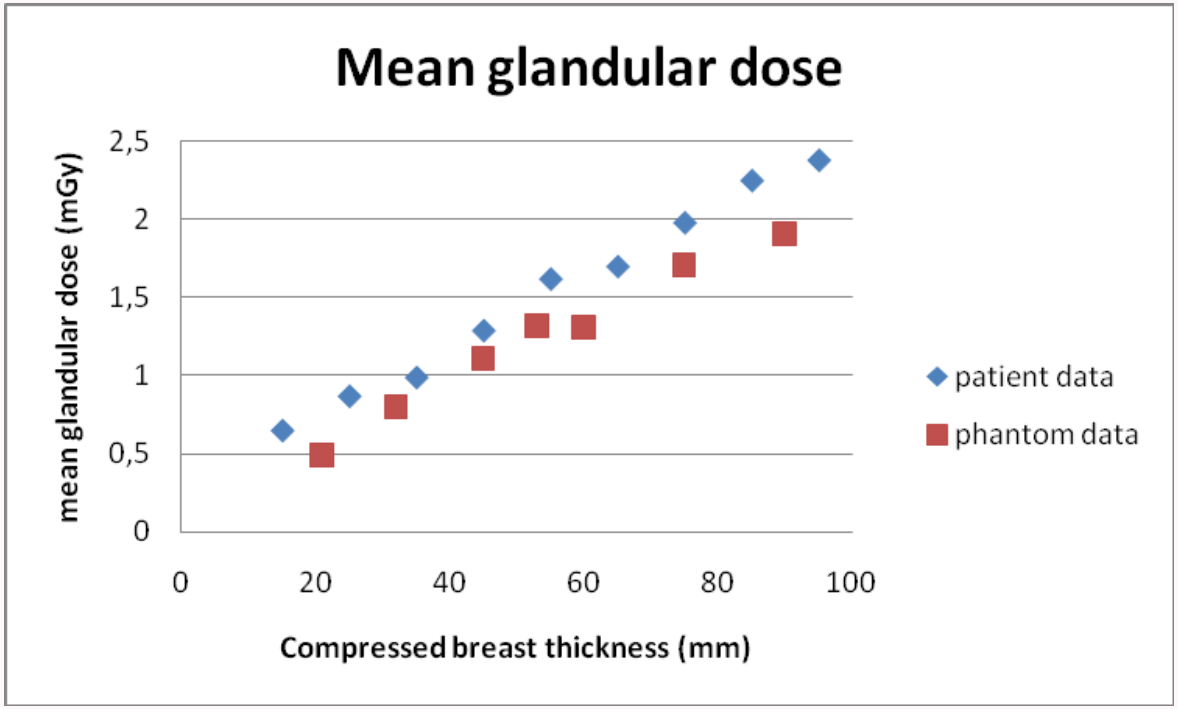
- Data from 4923 exposures



Phantom measurements

Patient dosimetry

- Some differences exist:
  - Breast model is not a real breast
  - Workings of Automatic Exposure Control



Risk assessment

- Patient dosimetry data is used for calculating the risk-benefit of mammography screening
- Latest data (Yaffe et al. 2010):

100 000 women (MGD 3.7 mGy),screened annually (40 - 55 year) and biennially (55 - 74 year)

136 woman-years would be lost
10 670 woman-years would be saved by early detection by screening.

Conclusion: “For the mammographic screening regimens considered that begin at age 40 years, this risk is small compared with the expected mortality reduction achievable through screening. The risk of radiation-induced breast cancer should not be a deterrent from mammographic screening of women over the age of 40 years. “

- Thank you for your attention