Joint ICTP-IAEA Workshop on Establishment and Utilization of
Diagnostic Reference Levels in Medical Imaging (smr3333)
18-22 November 2019, Trieste, Italy

Establishing and using DRLs for optimization in mammography

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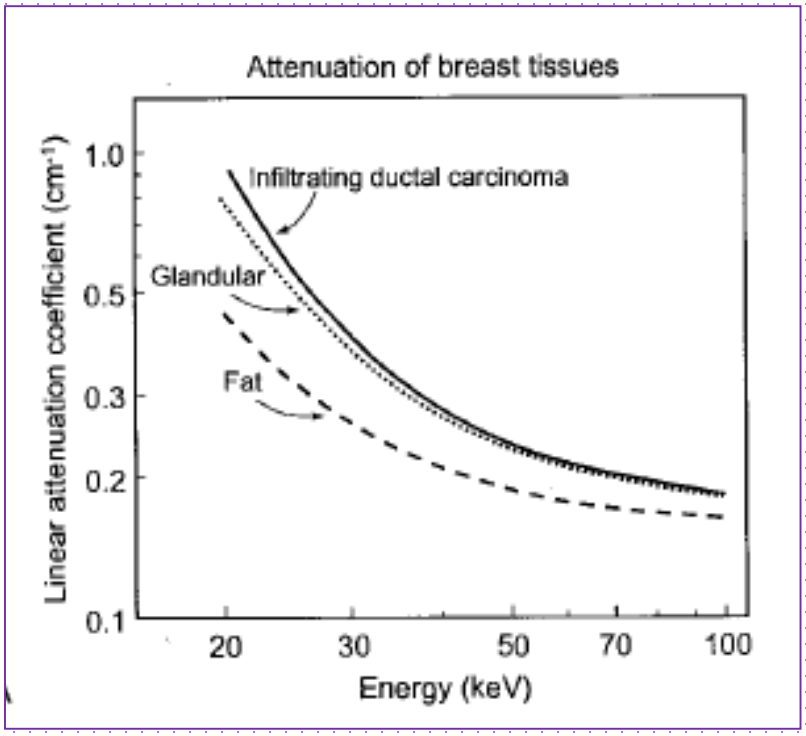
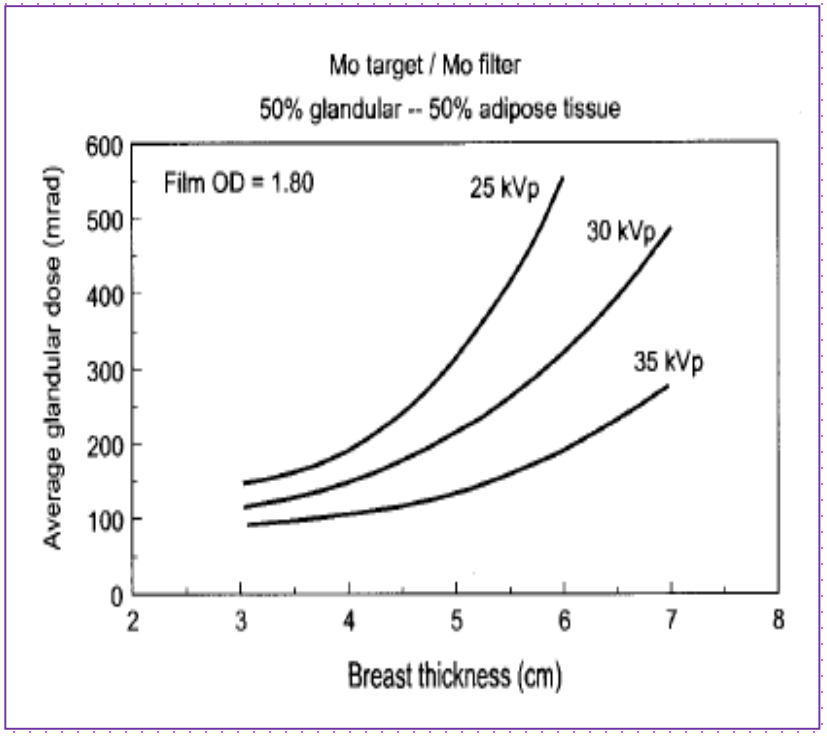
Objectives

To understand

- Why the DRLs are needed in mammography
- What dose metrics should be used for DRLs in mammography
- How to collects data and establish and use DRLs in mammography

Mammography





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Mammography

- Tube potentials between 25 kV and 38 kV
  - Specially designed meters are used for radiation output measurements
  - Require specific calibration with an X ray spectrum in the range used for mammography
- The only part of the body that receives a significant dose is the breast

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Mammography examinations, their relative frequencies and contribution to collective effective dose

Examination	Percentage of total frequency of all radiography examinations (%)	Percentage contribution to collective dose (%)
Mammography	0.3-15	0.6-4.7

EC, 2008. European Guidance on Estimating Population Doses from Medical X-ray Procedures. Radiation Protection No. 154 . European Commission, Directorate-General for Energy and Transport, Luxembourg. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/154.zip (last accessed 10 August 2017).

Why dosimetry in mammography?

- Evaluation of Risk to the Patient
- Comparison of Techniques
  - Screen/Film
  - New Image Receptors
- Equipment Performance Evaluation
- Information to Patient
- Regulations and Guidelines
- Optimisation

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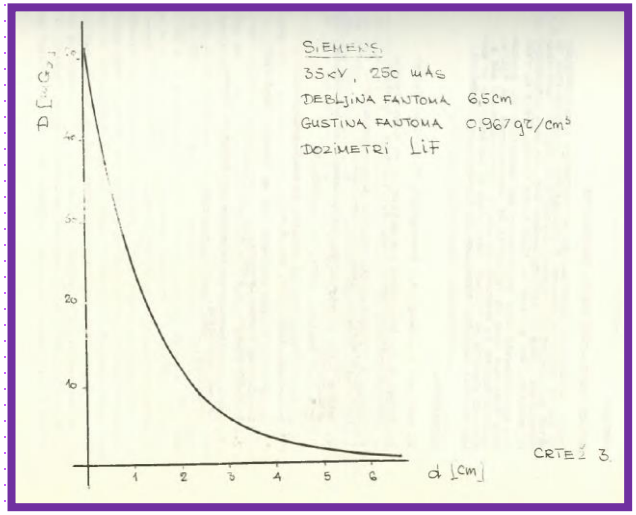
Development of mammography dosimetry

- US, survey in 1976 (Bent,1978)
- UK, TLD on top of 5 cm phantom (Fitzgerald, 1981)
- ESD is not an adequate measure of risk as dose decrease rapidly with depth



Ozračenost dojki pri mamografiji autora *Tomašević i sardanika* (1983)

- **ICRP, MGD/AGD (ICRP, 1987)**

Breast size and composition

- Breast thickness: 5 mm-117 mm (Kelaranta, et al 2015)
- 4 major tissues (skin, adipose, fibro-glandular, pectoral muscle)
- Amount of FG tissues=glandularity
- Breast models
  - Simple
  - Realistic (dedicated breast CT)

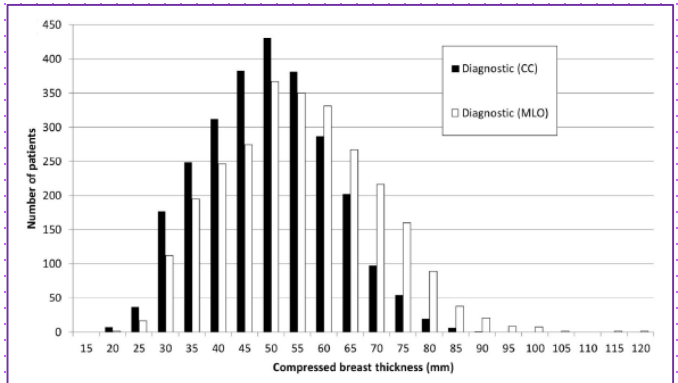


Figure 1. Typical distributions of compressed breast thickness for CC and MLO views. The data are for women attending for a diagnostic examination. Figure from Kelaranta *et al* (2015) and reproduced by permission of Oxford University Press.

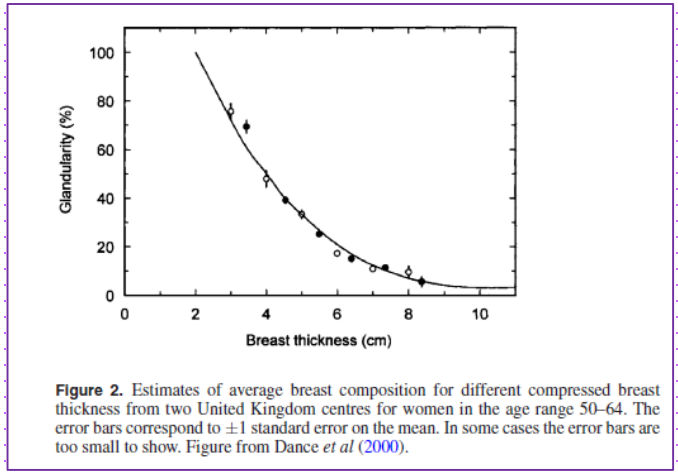
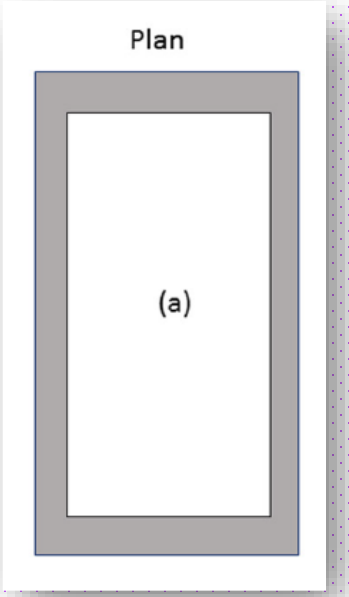


Figure 2. Estimates of average breast composition for different compressed breast thickness from two United Kingdom centres for women in the age range 50–64. The error bars correspond to ±1 standard error on the mean. In some cases the error bars are too small to show. Figure from Dance *et al* (2000).

Dance, PMB, 2016

European models (Dance et al)

- Used in the United Kingdom (IPEM 2005), European (EC 2013) and IAEA (2007)
- Simple model, a cylinder of fixed semi-circular cross section of diameter 160 mm
- Typical glandularities for women of age groups 40–49 and 50–64 (figure 2) were provided (Dance *et al* 2000)
- Tormalism used to calculate **MGD: D=Kgcs**



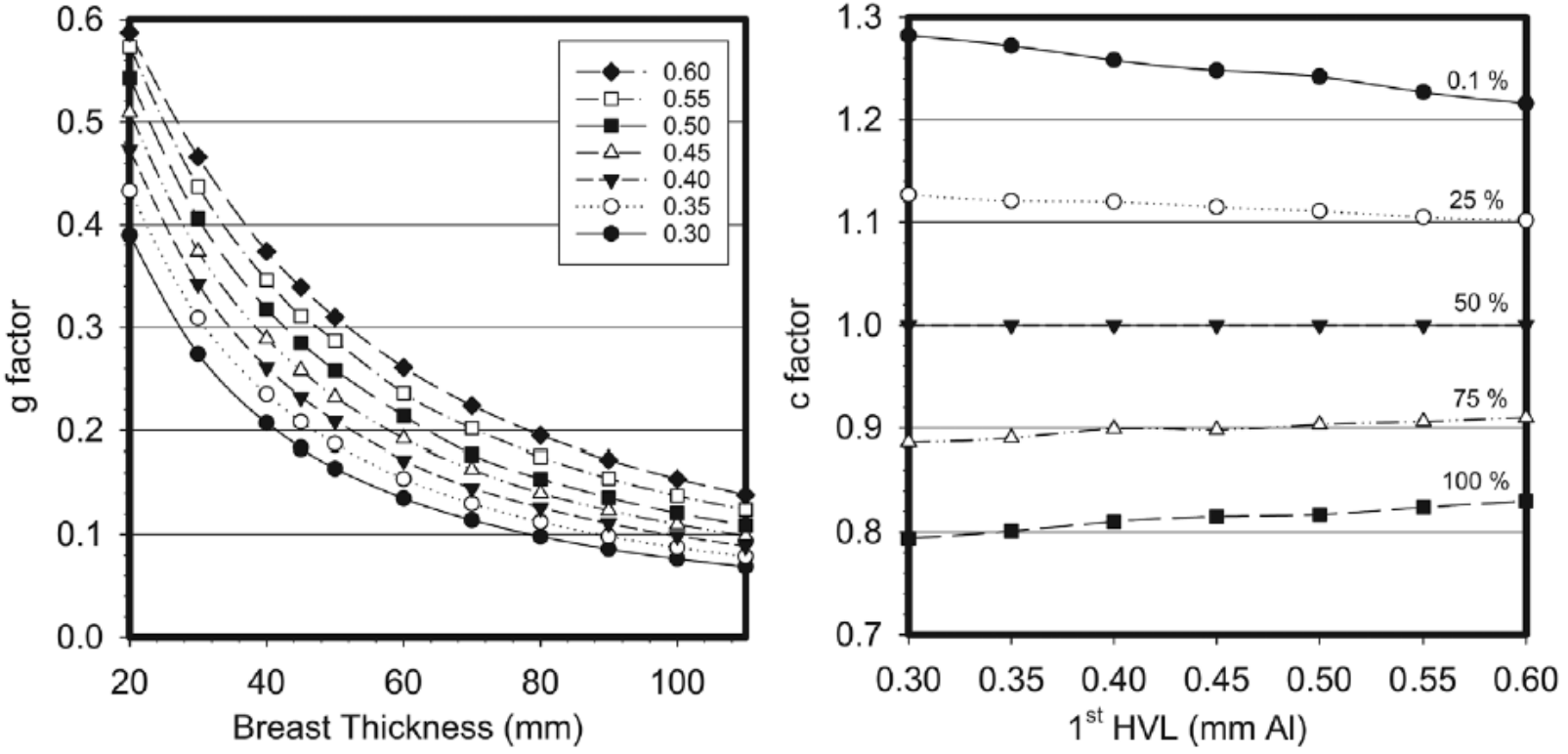
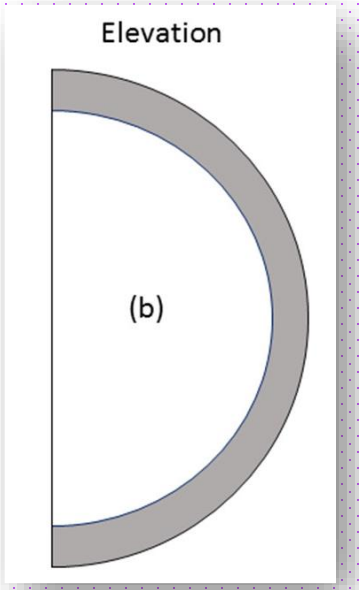


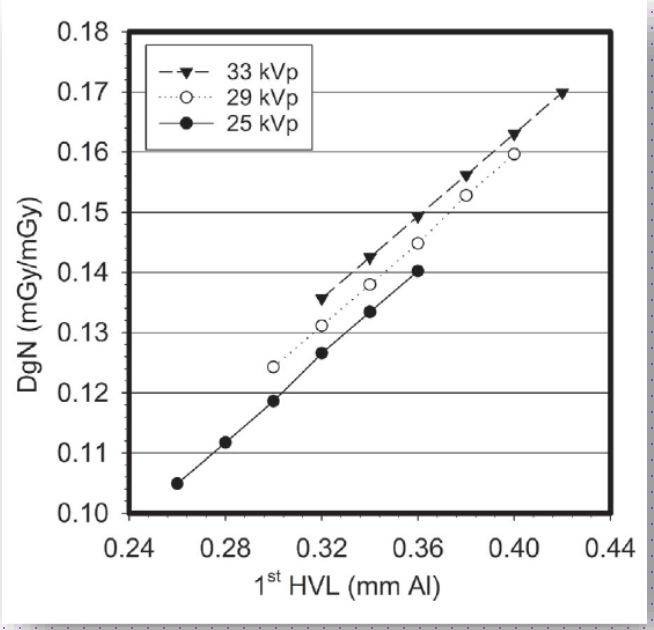
Figure 5. (Left) The *g* factor for varying breast thickness and 1st HVL. (Right) *c* factors for a 5 cm compressed breast thickness for varying breast glandularity and 1st HVL. Data taken from Dance *et al* (2000).

Dance, PMB, 2016

US models (Wu, et al)

- Wu *et al* (1991, 1994)
- Cylinder model with a semi-elliptical cross-section
- Dosimetry formalism: D=KDgN
- DgN=normalized average glandular dose

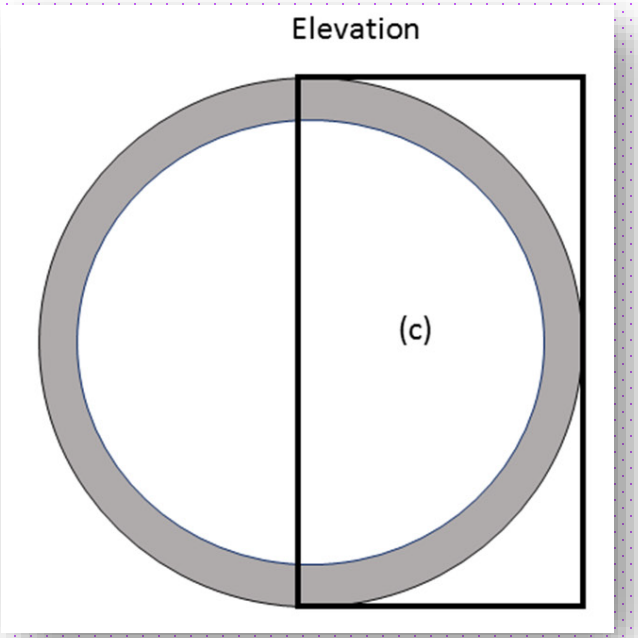




Dance, PMB, 2016

US models (Boone, et al)

- Extended model of Wu *et al*
- Mono-energetic x-rays up to 120 keV (Boone 1999)
- More T/F combinations
- DgN=normalized average glandular dose
- Better explanation of energy absorbtion in the central homogeneous region of the breastbetween the adipose and glandular tissues



Dance, PMB, 2016

IOP Publishing | Institute of Physics and Engineering in Medicine
Physics in Medicine & Biology
Phys. Med. Biol. **61** (2016) R271–R304
doi:10.1088/0031-9155/61/19/R271

Topical Review

Dosimetry in x-ray-based breast imaging

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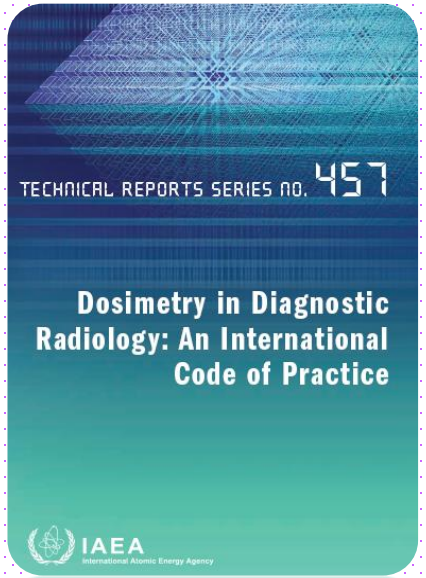
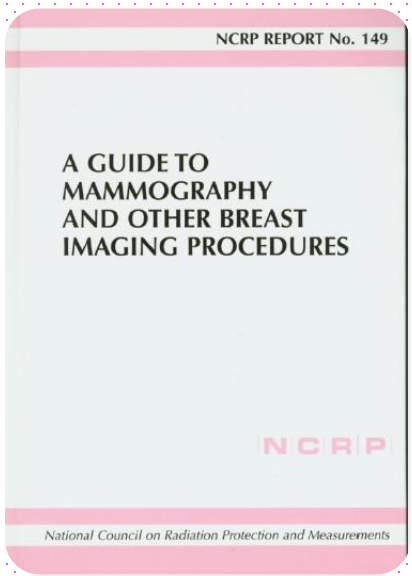
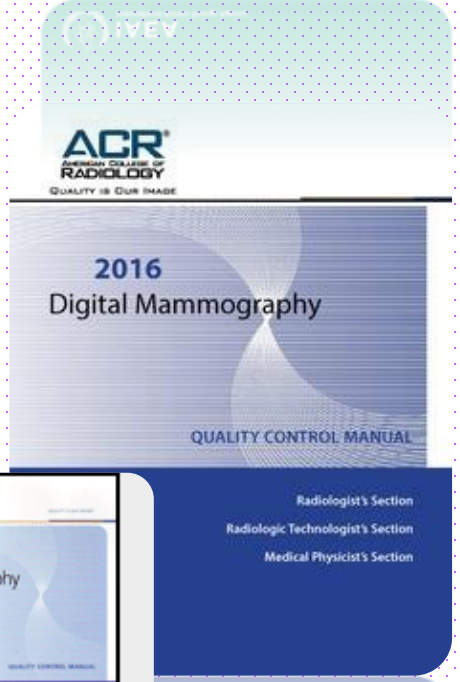
Received 16 March 2016, revised 16 May 2016
Accepted for publication 22 June 2016
Published 12 September 2016

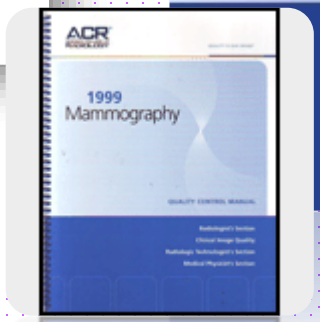
Abstract

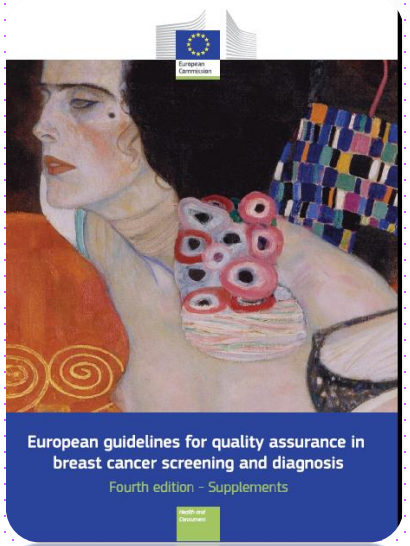
The estimation of the mean glandular dose to the breast (MGD) for x-ray based imaging modalities forms an essential part of quality control and is needed for risk estimation and for system design and optimisation. This review considers the development of methods for estimating the MGD for mammography, digital breast tomosynthesis (DBT) and dedicated breast CT (DBCT). Almost all of the methodology used employs Monte Carlo calculated conversion factors to relate the measurable quantity, generally the incident air kerma, to the MGD. After a review of the size and composition of the female breast, the various mathematical models used are discussed, with particular emphasis on models for mammography. These range from simple geometrical shapes, to the more recent complex models based on patient DBCT examinations. The possibility of patient-specific dose estimates is considered as well as special diagnostic views and the effect of breast implants. Calculations using the complex models show that the MGD for mammography is overestimated by about 30% when the simple models are used. The design and uses of breast-simulating test phantoms for measuring incident air kerma are outlined and comparisons











DRL quantity for mammography

Modality	DRL quantity	Unit
Mammography	$K_{a,e}$	mGy
	$K_{a,i}$	mGy
	D_G	mGy

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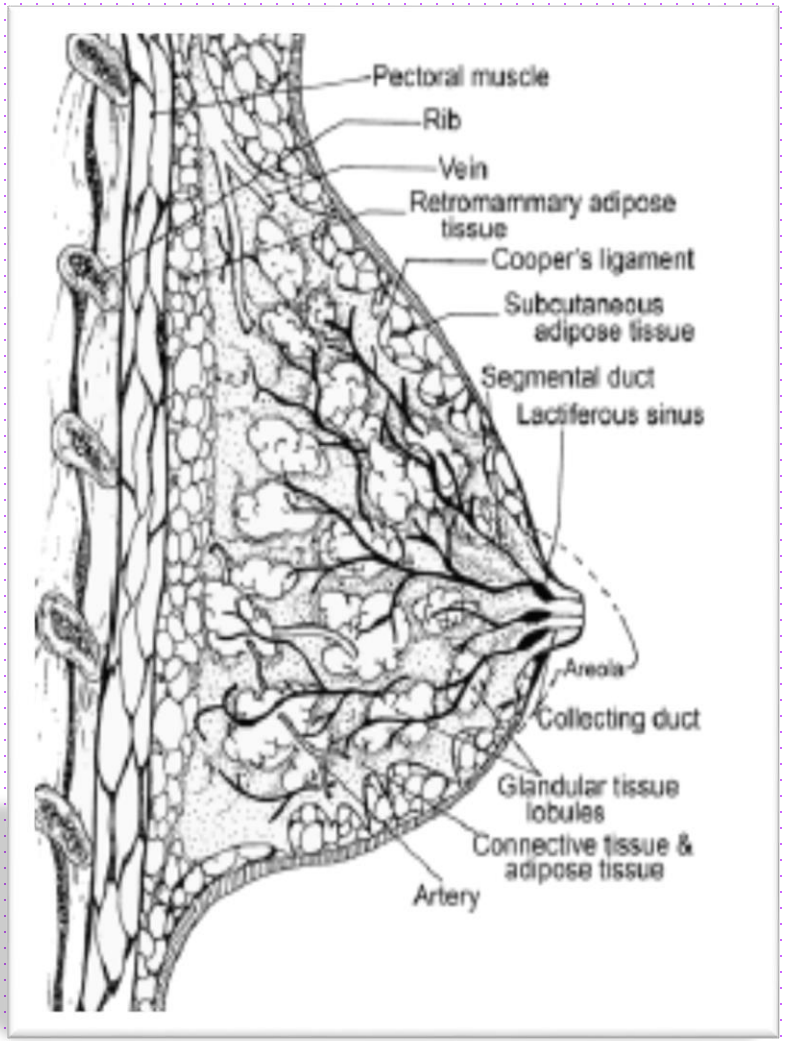
Air kerma

- Easy to measure
- Useful for quick comparisons
- Non-additive
- Not representative of risk

Mean/Average Glandular Dose

- Can not be measured directly
- Most representative of risk
- Calculated from simple measurements and lookup tables



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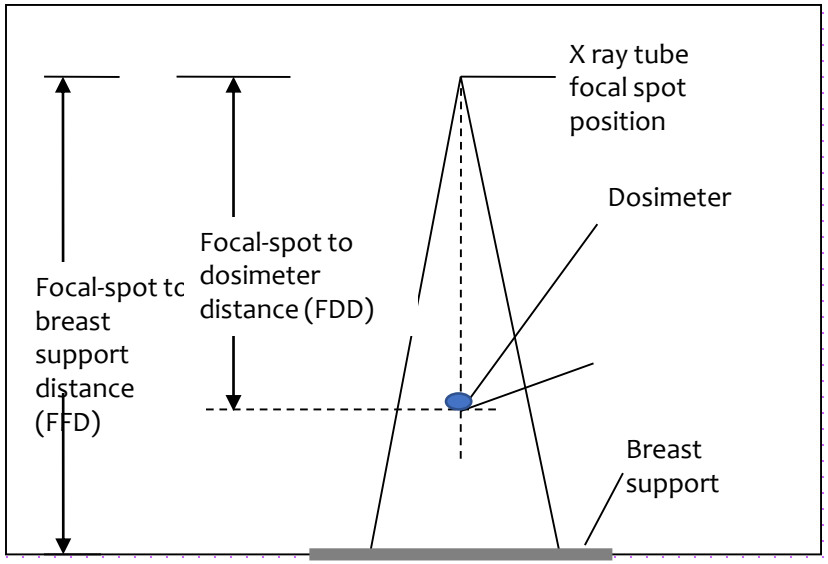
Assumptions

- Firm Compression
- Uniform Cross Section
- Adipose / Gland Mix:
  - 100% / 0%
  - 50% / 50%
  - 0% / 100%
  - …

Incident air kerma

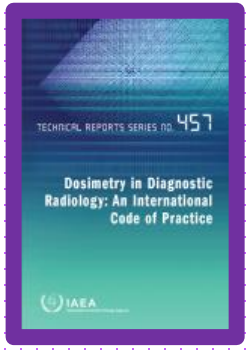


$$K_{a,i}(FDD) = M \cdot N_K \cdot k_Q$$

Incident air kerma

$$Y(U_0, FDD) = K_{a,i} / It_0$$

X ray tube output



For detailed information, please refer to IAEA TRS 457, https://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf

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Mean glandular dose

Incident air kerma

$$K_i = Y_{ref}\left(\frac{d_P - d_{ref}}{d_P - d_B}\right)^2 P_{It,pat}$$

d_P is the distance from the tube focus to the top of the breast support platform
d_{ref} and d_B are the distances from this platform to the reference point and the top of the breast (the breast thickness), respectively
$P_{It,pat}$ is the recorded tube loading for the patient exposure

Mean glandular dose

$$D_G = c_{D_{G50},K_i} c_{D_{Gg},D_{G50}} sK_i$$

Conversion of the incident air kerma to the mean glandular dose for a breast of 50% glandularity

Conversion of the mean glandular dose for a breast of 50% glandularity to that for a breast of glandularity

Spectral correction factor

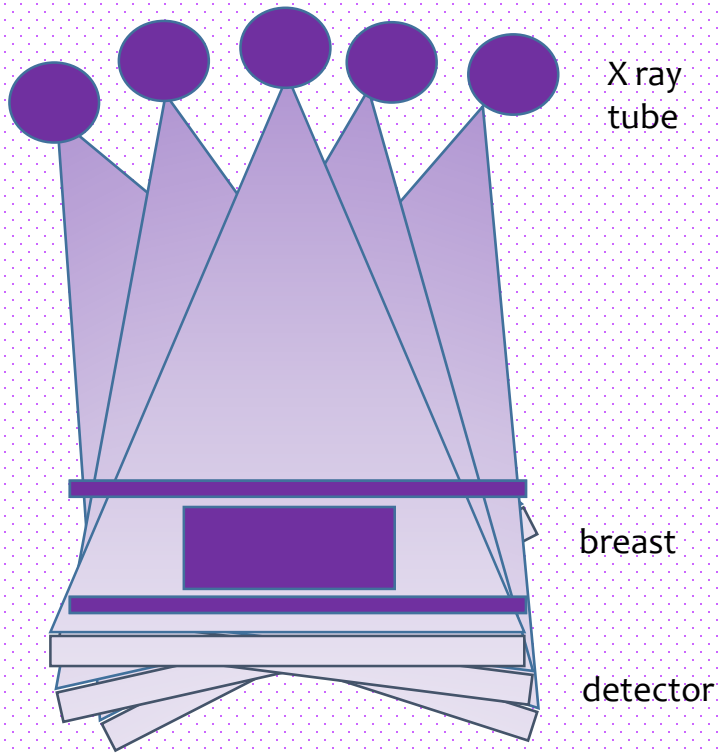
Dance DR, Sechopoulos I. Dosimetry in x-ray-based breast imaging. Phys Med Biol. 2016 Oct 7;61(19):R271-R304

DRLs for clinical and screening mammography

- For the same views (craniocaudal, mediolateral), use the **same DRL values** for screening programmes and for examinations of patients with clinical symptoms

Digital breast tomosynthesis (DBT)

- Uses multiple X ray exposures of the breast from many angles
- Multiple image asepect
- DRL quantity: Ka,e, Ka,i, or D_G (as for mammography)
- DRL value: differs from mammography



Dance DR, Sechopoulos I. Dosimetry in x-ray-based breast imaging. Phys Med Biol. 2016 Oct 7;61(19):R271-R304

Dosimetry for DBT

- Sechopoulos *et al* (2007a)
- Extend the mammography model by adding relative glandular dose (RGD(α))
- Accounts for the variation in the *DgN*

$$D_g = X_{CR} D_g N_0 \sum_{\alpha=\alpha_{min}}^{\alpha_{max}} RGD(\alpha)$$

- Dance et al (2011)
- *t*(θ) factor
- system-specific, *T* factor

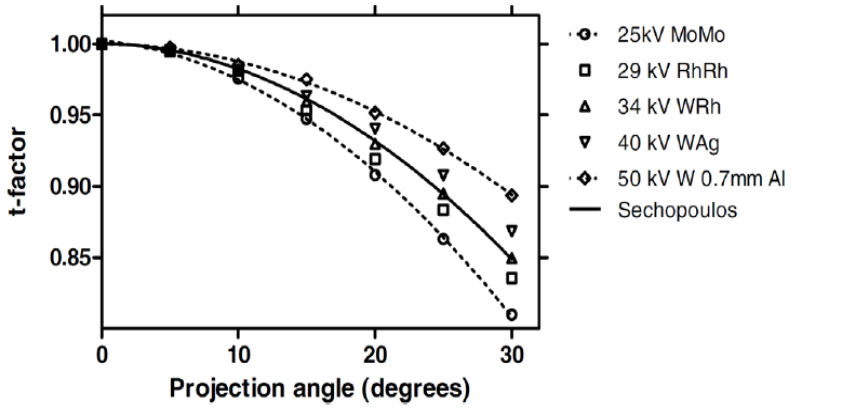


Figure 9. Comparison of Dance *et al's* t factors with Sechopoulos *et al*'s RGD(α), showing the expected similarity given their equivalent definition. Figure from Dance *et al* (2011).

Dance, PMB, 2016

Dosimetry for DBT (Dance, et al. 2011)

$D(\vartheta)$ – dose for a single projection at angle ϑ
$t(\vartheta)$ - 'tomo' factor at that angle

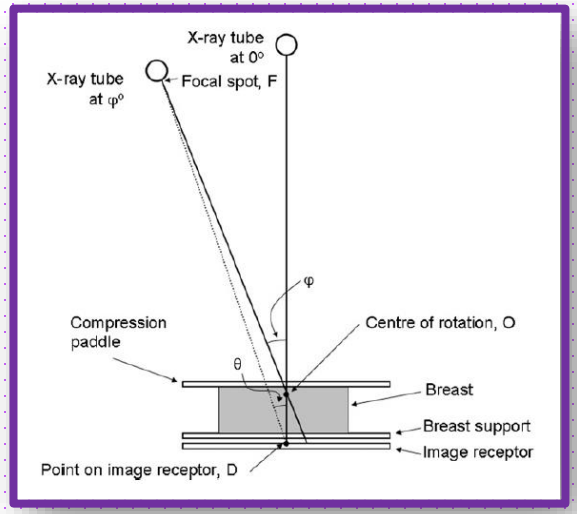
$$D(\theta) = K g c s \, t(\theta)$$

In the 0◦ projection the dose, $D(o)$ is the same as that for conventional mammography

$$t(\theta) = \frac{D(\theta)}{D(0)}$$

For a complete examination the 3D breast dose

$$D_T = K_T g c s T \qquad \text{with} \qquad T = \sum_i \alpha_i t(\theta_i).$$



i-summation is over the *N* projections for the examination
αi give the partition of the total tube loading for the examination between the different projections

Incident air kerma *KT* is again measured in the 'straight through' position, for total mAs

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Phantoms or patients?

- Phantoms can be useful for checking the performance of mammography units
- Phantom measurements as standard dose comparator
- Patient survey to set DRL

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Example: DRLs for phantoms and patients

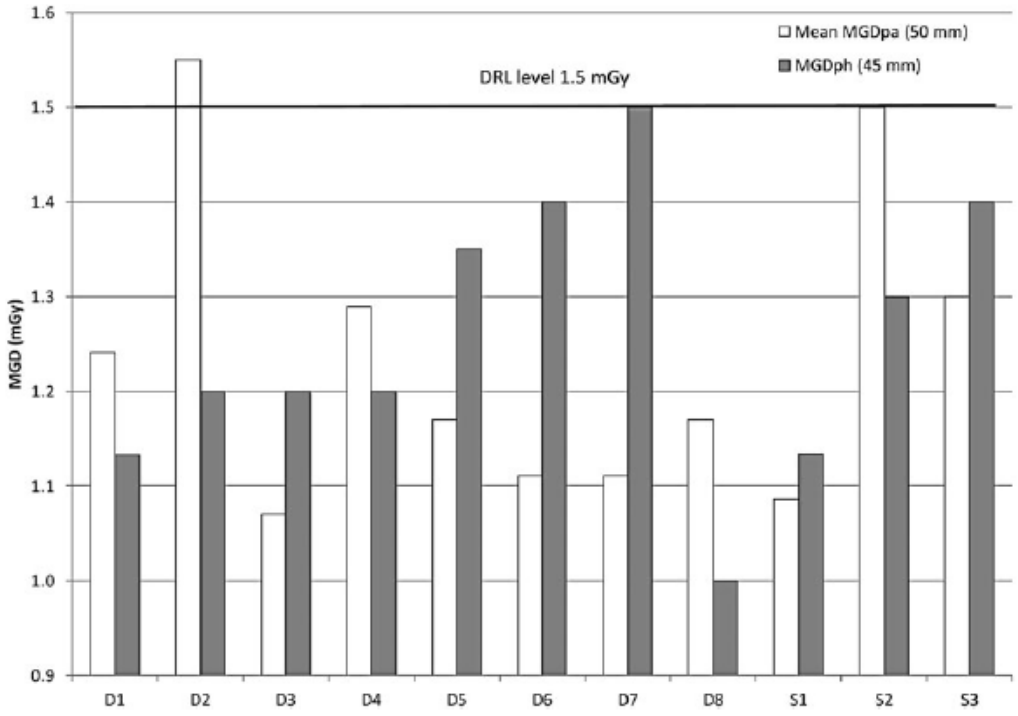

Figure 3. Comparison of MGD based on standard phantom exposures, MGD_{ph} (45 mm), and patient exposures, mean MGD_{pa} (50 mm), for systems D2–D8 and S2–S3. For D1 and S1, the calculated values with $c = 1$ are shown.

Kelaranta A, et al. Conformance of mean glandular dose from phantom and patient data in mammography. Radiat Prot Dosimetry. 2015 Apr;164(3):342-53.

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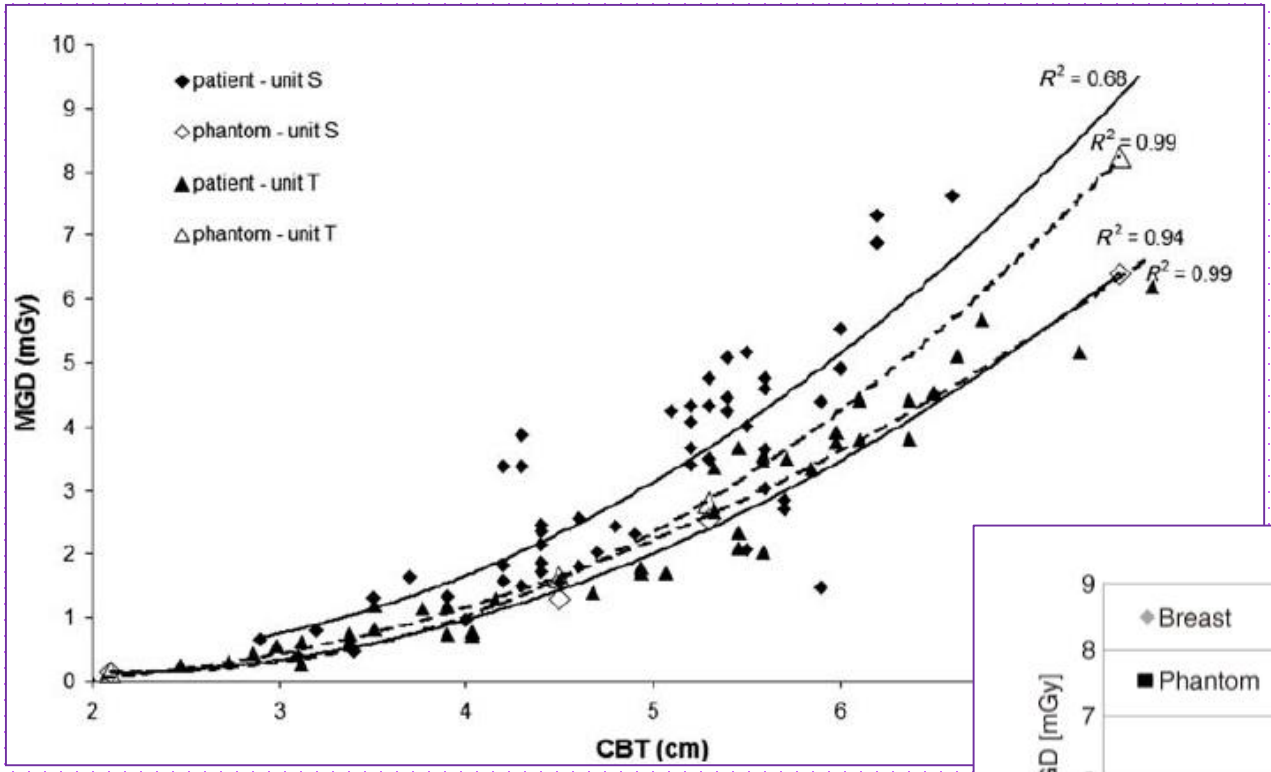

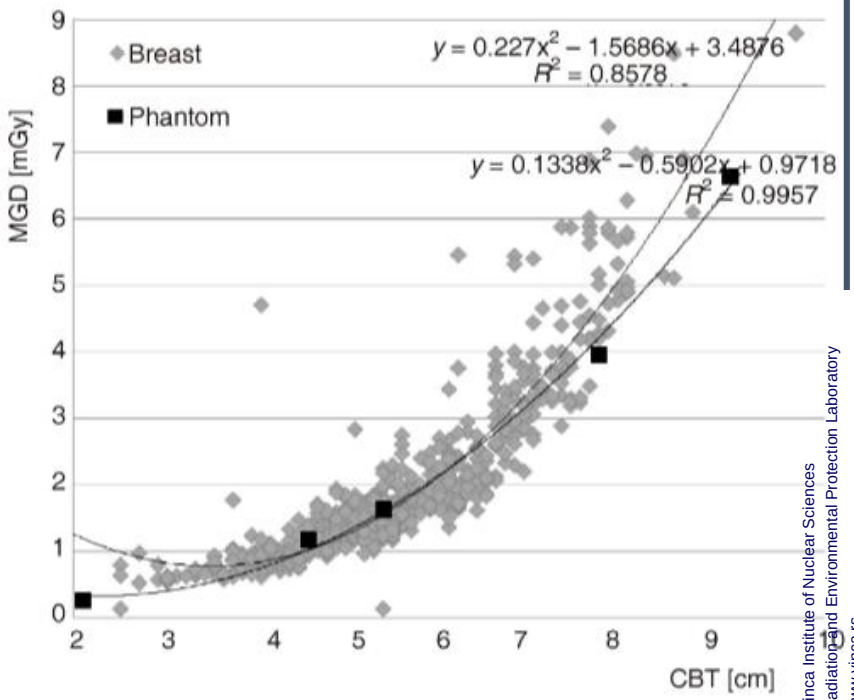

Figure 2. Correlation of mean glandular dose (M
and compressed breast thickness (CBT) for patient
phantom dose measurements at FFDM unit

Ciraj-Bjelac et al, RPD (2010), Vol. 140, pp. 75–80
Statntic ste al, NTRP, 2013

Dose to typical breasts simulated with PMMA

$D = K_{gcs}$

Dose levels for typical breasts simulated with PMMA

Thickness of PMMA (mm)	Equivalent breast thickness (mm)	Maximum average glandular dose to equivalent breasts (mGy)	
		Acceptable level	Achievable level
20	21	≤ 1.0	≤ 0.6
30	32	≤ 1.5	≤ 1.0
40	45	≤ 2.0	≤ 1.6
45	53	≤ 2.5	≤ 2.0
50	60	≤ 3.0	≤ 2.4
0	75	≤ 4.5	≤ 3.6
0	90	≤ 6.5	≤ 5.1

Figure 1.7: Position of dosimeter to estimate incident air kerma for dose estimation, top view and 3D view

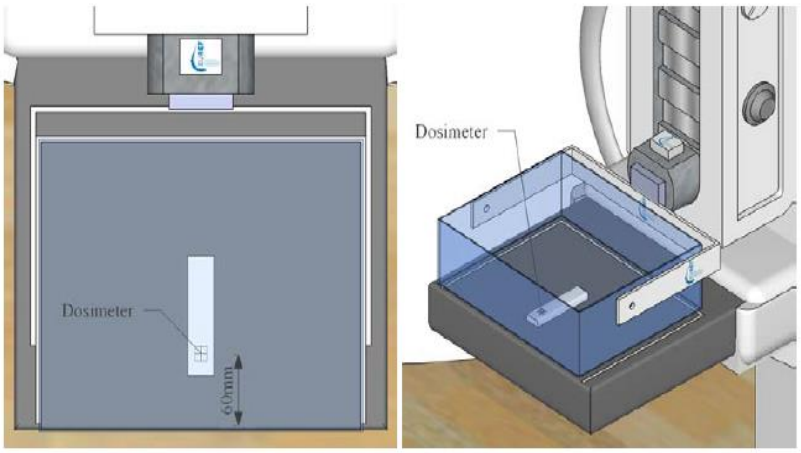

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Table A5.1: g-Factors for breasts simulated with PMMA

PMMA thickness (mm)	Equivalent breast thickness (mm)	Glandularity of equivalent breast (%)	g-factor (mGy/mGy) HVL (mm Al) 0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
20	21	97	0.378	0.421	0.460	0.496	0.529	0.559	0.585	0.609	0.631	0.650	0.669
30	32	67	0.261	0.294	0.326	0.357	0.388	0.419	0.448	0.473	0.495	0.516	0.536
40	45	41	0.183	0.208	0.232	0.258	0.285	0.311	0.339	0.366	0.387	0.406	0.425
45	53	29	0.155	0.177	0.198	0.220	0.245	0.272	0.295	0.317	0.336	0.354	0.372
50	60	20	0.135	0.154	0.172	0.192	0.214	0.236	0.261	0.282	0.300	0.317	0.333
60	75	9	0.106	0.121	0.136	0.152	0.166	0.189	0.210	0.228	0.243	0.257	0.272
70	90	4	0.086	0.098	0.111	0.123	0.136	0.154	0.172	0.188	0.202	0.214	0.227
80	103	3	0.074	0.085	0.096	0.106	0.117	0.133	0.149	0.163	0.176	0.187	0.199

Table A5.2: c-Factors for breasts simulated with PMMA

PMMA thickness (mm)	Equivalent breast thickness (mm)	Glandularity of equivalent breast (%)	c-factor* HVL (mm Al) 0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
20	21	97	0.889	0.895	0.903	0.908	0.912	0.917	0.921	0.924	0.928	0.933	0.937
30	32	67	0.940	0.943	0.945	0.946	0.949	0.952	0.953	0.956	0.959	0.961	0.964
40	45	41	1.043	1.041	1.040	1.039	1.037	1.035	1.034	1.032	1.030	1.028	1.026
45	53	29	1.109	1.105	1.102	1.099	1.096	1.091	1.088	1.082	1.078	1.073	1.068
50	60	20	1.164	1.160	1.151	1.150	1.144	1.139	1.134	1.124	1.117	1.111	1.103
60	75	9	1.254	1.245	1.235	1.231	1.225	1.217	1.207	1.196	1.186	1.175	1.164
70	90	4	1.299	1.292	1.282	1.275	1.270	1.260	1.249	1.236	1.225	1.213	1.200
80	103	3	1.307	1.299	1.292	1.287	1.283	1.273	1.262	1.249	1.238	1.226	1.213

* for typical breasts for women in the age group 50–64

Clinical breast doses

- Measurement of incident air kerma
- Measurement of compressed breast thickness

$$D = K_{gcs}$$

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Table A5.5: Additional g-factors

HVL (mm Al)	Breast thickness (mm) 20	30	40	50	60	70	80	90	100	110
0.30	0.390	0.274	0.207	0.164	0.135	0.114	0.098	0.0859	0.0763	0.0687
0.35	0.433	0.309	0.235	0.187	0.154	0.13	0.112	0.0981	0.0873	0.0786
0.40	0.473	0.342	0.261	0.209	0.172	0.145	0.126	0.1106	0.0986	0.0887
0.45	0.509	0.374	0.289	0.232	0.192	0.163	0.14	0.1233	0.1096	0.0988
0.50	0.543	0.406	0.318	0.258	0.214	0.177	0.154	0.1357	0.1207	0.1088
0.55	0.573	0.437	0.346	0.287	0.236	0.202	0.175	0.1543	0.1375	0.1240
0.60	0.587	0.466	0.374	0.31	0.261	0.224	0.195	0.1723	0.1540	0.1385
0.65	0.622	0.491	0.399	0.332	0.282	0.244	0.212	0.1879	0.1682	0.1520
0.70	0.644	0.514	0.421	0.352	0.300	0.259	0.227	0.2017	0.1809	0.1638
0.75	0.663									
0.80	0.682									

Table A5.6: Additional c-factors for average breasts for women in the age group 50–64

Breast thickn. (mm)	Gland. (%)	HVL (mm Al) 0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
20	100	0.885	0.891	0.9	0.905	0.91	0.914	0.919	0.923	0.928	0.932	0.936
30	72	0.925	0.929	0.931	0.933	0.937	0.94	0.941	0.947	0.950	0.953	0.956
40	50	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
50	33	1.086	1.082	1.081	1.078	1.075	1.071	1.069	1.064	1.060	1.057	1.053
60	21	1.164	1.160	1.151	1.15	1.144	1.139	1.134	1.124	1.117	1.111	1.103
70	12	1.232	1.225	1.214	1.208	1.204	1.196	1.188	1.176	1.167	1.157	1.147
80	7	1.275	1.26									
90	4	1.299	1.29									
100	3	1.307	1.29									
110	3	1.306	1.30									

Additions to the table in Dance

Table A5.7: Additional c-factors for average breasts for women in the age group 40–49

Breast thickn. (mm)	Gland. (%)	HVL (mm Al) 0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
20	100	0.885	0.891	0.9	0.905	0.91	0.914	0.919	0.923	0.928	0.932	0.936
30	82	0.894	0.898	0.903	0.906	0.911	0.915	0.918	0.924	0.928	0.933	0.937
40	65	0.940	0.943	0.945	0.947	0.948	0.952	0.955	0.956	0.959	0.961	0.964
50	49	1.005	1.005	1.005	1.004	1.004	1.004	1.004	1.004	1.003	1.003	1.003
60	35	1.080	1.078	1.074	1.074	1.071	1.068	1.066	1.061	1.058	1.055	1.051
70	24	1.152	1.147	1.141	1.138	1.135	1.130	1.127	1.117	1.111	1.105	1.098
80	14	1.220	1.213	1.206	1.205	1.199	1.190	1.183	1.172	1.163	1.154	1.145
90	8	1.270	1.264	1.254	1.248	1.244	1.235	1.225	1.214	1.204	1.193	1.181
100	5	1.295	1.287	1.279	1.275	1.272	1.262	1.251	1.238	1.227	1.215	1.20
110	5	1.294	1.290	1.283	1.281	1.273	1.264	1.256	1.242	1.232	1.220	1.20

Additions to the table in Dance et al. (2000) are highlighted in grey.

EUREF, 2013

S-factors

Target material	Filter material	Filter thickness (µm)	s-factor
Mo	Mo	30	1.000
Mo	Rh	25	1.017
Rh	Rh	25	1.061
W	Rh	50–60	1.042
W	Ag	50–75	

Table A5.4d: s-Factors for a tungsten target filtered by 0.5

Breast thickness (mm)	Glandularity range (%)	Typical glandularity, age 50–64 (%)	Typical glandularity, age 40–49 (%)		
20	80–100	100	100		
30	62–82	72	82		
40	40–65	50	65		
50	23–49	33	49		
60	11–35	21	35		
70	2–24	12	24		
80	0.1–17	7	14	30–40	1.187
90	0.1–14	4	8	30–40	1.198
100	0.1–13	3	5	30–40	1.206
110	0.1–13	3	5	30–40	1.212

Table A5.4e: s-Factors for a tungsten target filtered by 0.7 mm aluminium

Breast thickness (mm)	Glandularity range (%)	Typical glandularity, age 50–64 (%)	Typical glandularity, age 40–49 (%)	kV range (kV)	s-factor
20	80–100	100	100	25–50	1.052
30	62–82	72	82	25–50	1.060
40	40–65	50	65	25–50	1.076
50	23–49	33	49	25–50	1.087
60	11–35	21	35	25–50	1.105
70	2–24	12	24	28–50	1.121
80	0.1–17	7	14	28–50	1.129
90	0.1–14	4	8	28–50	1.136
100	0.1–13	3	5	28–50	1.140
110	0.1–13	3	5	28–50	1.144

Mammography

Data collection form for phantom measurements

Phantom No	Data of examination		Radiographic technique					Detector		Exposure data										
		thnikness	breast support (cm)	ntiscattering	ter comination	ot (Large /	of exposure rs (select from	n)	m)			time (ms)	e layer (mm	phantom distance	e output (U, 1 m) s)*	air kerma (mGy)			(see table)	ndular dose
1	2015.04.23																			
2																				
3																				
4																				
5																				

OPTION 1:Calculation of x-ray tube output from measurements

Note: this worksheet can be used a s a template, yellow fields are to be updated with actual data and green fields are calculated automatically

Date:	
Hospital:	
Room:	
Dosimeter:	

FDD =	60	cm
Nk =	1	
kq =	1	

No	Uo[kV]	Ito[mAs]	M [mGy]	Ka [mGy]	Y [µGy/mAs] at 1 m
1	25	20	2.10	2.10	38

$$K_a(FDD) = M \cdot N_K \cdot k_Q$$

$$Y(U_0, FDD) = K_a / It_0$$

ASSESSMENT OF MEAN GLANDULAR DOSE FOR PHANTOMS AND PATIENTS

The mean glandular dose is derived from measurements of the incident air kerma (without backscatter) at the surface of the phantom and of the half value layer (HVL), using tabulated conversion coefficients. The incident air kerma may be obtained by measuring the air kerma in the absence of the phantom using a suitable ionization chamber and electrometer or semiconductor dosimeter. For detailed information, please refer to IAEA TRS 457, http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf.

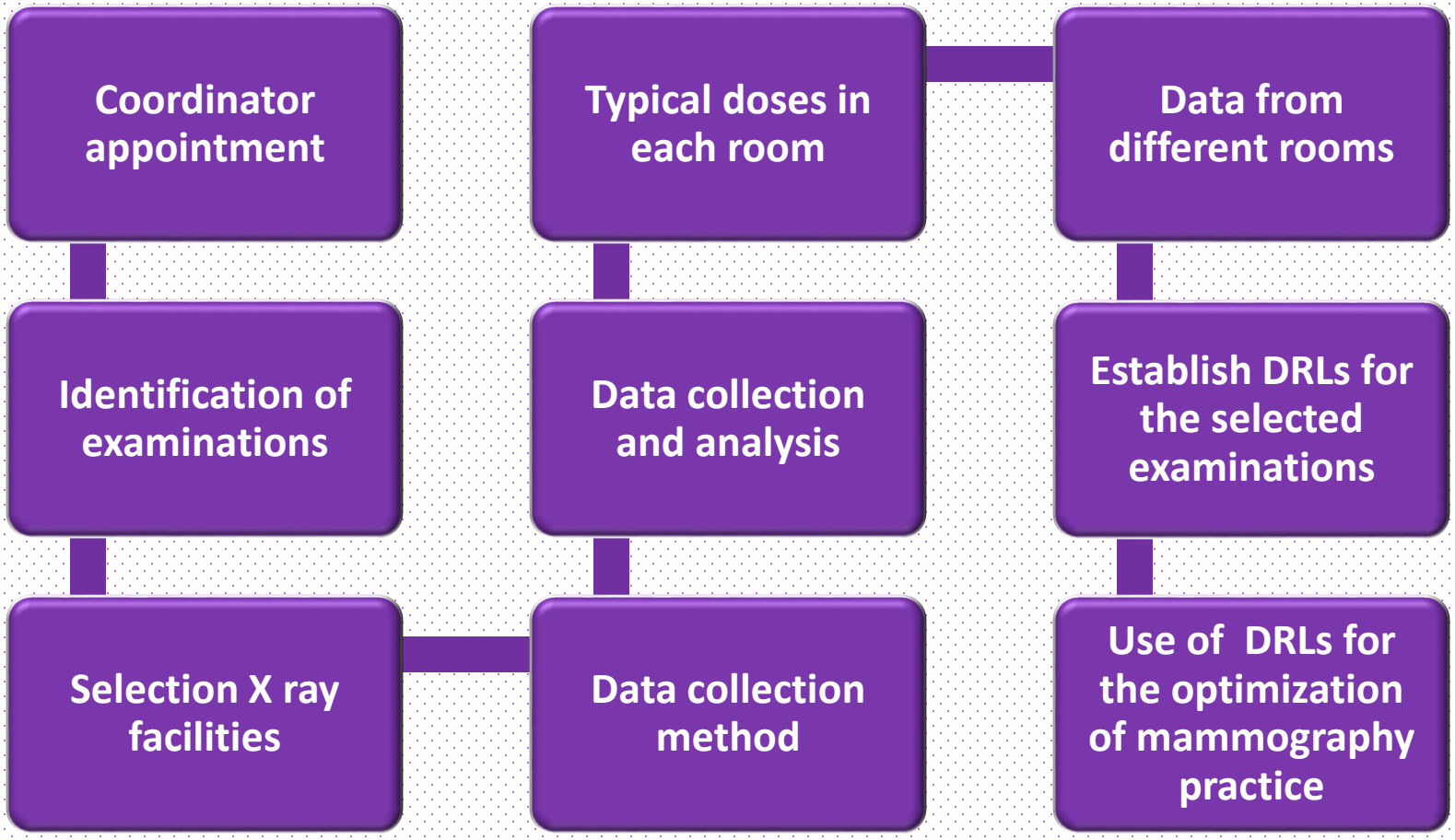
The conversion coefficients used to estimate the mean glandular dose from the incident air kerma are quality dependent. It is necessary therefore to note the target/filter combination and tube voltage used and to measure the HVL of the X ray unit. Data in the tables in worksheet for dose calculation are provided for situations where measured values of the HVL are not available.

Some X ray equipment uses the thickness of the compressed breast as an aid to the selection of tube voltage and target/filter combination. As the thickness of the phantom will be less than the thickness of the breast being simulated, the user can consider adding an appropriate thickness of a low density material (spacers) such as expanded polystyrene to the top of the phantom so that the overall thickness is then correct. The polystyrene should be cut away so that it does not cover the AEC system.

Determination of tube loading for phantoms and patients

Clinical exposures are terminated automatically, but the tube voltage and in some cases the materials of the target and filter have to be selected. For some

Towards DRLs in mammography



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Steps to establish DRLs

Decide the examinations for which DRLs are to be established

- Consider national or regional resources
- Discuss with radiologists:
  - *Class (or code) of the examination (the clinical description)*
  - *Clinical indication of the mammography examination*
- Data that comes from procedures has to be similar across all participating facilities

Note: For the same views (i.e. craniocaudal, mediolateral), screening programmes for asymptomatic individuals should use the same DRL values as examinations performed to investigate patients with clinical symptoms

Steps to establish DRLs

Decide on the methodology

Patients

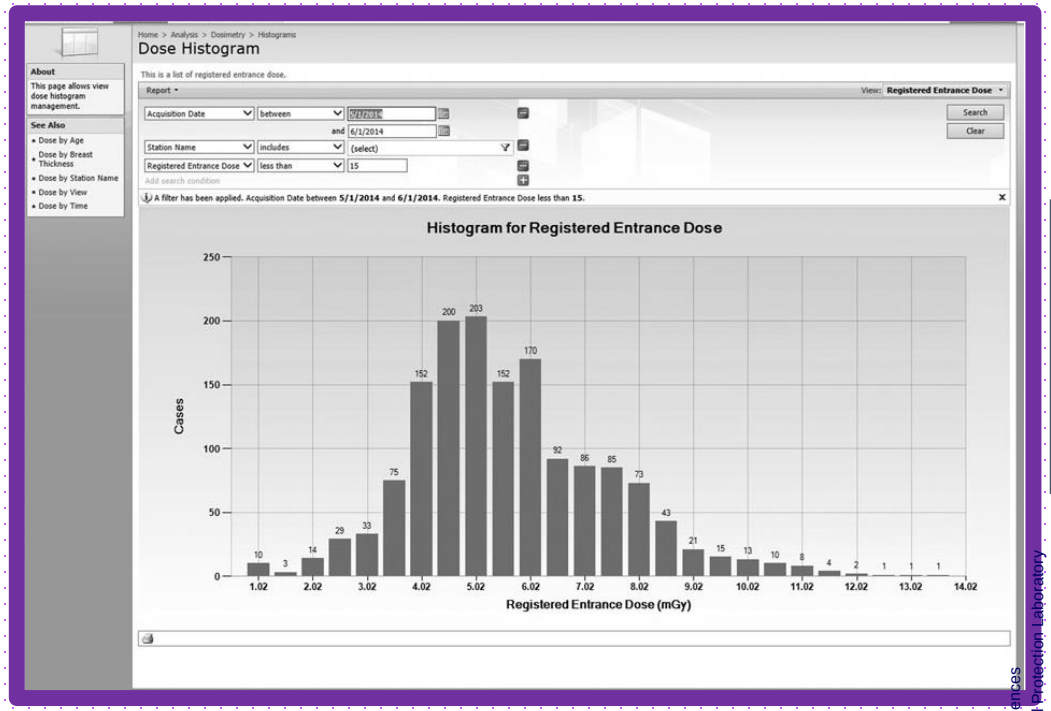
- At least 50 patients in each room
- Possibly with restriction f the range of breast thicknesses

Phantoms

- Phantoms can be helpful in assessing the performance of mammography units
- They should not replace surveys of actual patient examinations
- Example: PMMA plates of various specified thicknesses, a semi-circular PMMA phantom, 160 mm in diameter and 45 mm thick, or similar

Example: Automatic dose registry

- DICOM images are automatically routed from the PACS to the MammoQA System that reads the DICOM header
- The dose quantities: entrance surface air kerma and the mean glandular dose



Ten JI, et al. Automatic patient dose registry and clinical audit on line for mammography. Radiat Prot Dosimetry. 2015 Jul;165(1-4):346-9.

Example: Automatic dose registry

Table 1. Statistics for kVp, exposure, breast thickness, ESAK (registered and calculated) and AGD (registered and calculated) group by target/filter combination for cranio-caudal (CC) and mediolateral oblique (MLO) views.

Target/filter (% of cases)	View (cases)	kVp ± SD	Exposure ± SD (mAs)	Breast Thickn. ± SD (mm)	ESAK ± SD (mGy)		AGD ± SD (mGy)	
					Registered	Calculated	Registered	Calculated
Mo/Mo	CC (8682)	27.6 ± 0.8	51.2 ± 16.3	37 ± 11	4.30 ± 1.4	4.6 ± 1.7	1.02 ± 0.3	1.10 ± 0.3
(21.2%)	MLO (5445)	27.7 ± 0.9	52.8 ± 18.0	37 ± 11	4.44 ± 1.5	4.8 ± 1.9	1.04 ± 0.3	1.20 ± 0.3
Mo/Rh	CC (15880)	28.0 ± 1.0	78.2 ± 12.8	51 ± 8	5.86 ± 1.3	6.0 ± 1.4	1.32 ± 0.2	1.40 ± 0.2
(44.0%)	MLO (13580)	28.1 ± 1.0	79.7 ± 13.8	52 ± 9	6.10 ± 1.5	6.2 ± 1.7	1.36 ± 0.3	1.40 ± 0.3
Rh/Rh	CC (10010)	29.5 ± 1.3	74.8 ± 17.2	58 ± 10	6.92 ± 2.3	7.1 ± 2.6	1.43 ± 0.4	1.50 ± 0.4
(34.8%)	MLO (13236)	29.7 ± 1.3	79.9 ± 21.0	62 ± 12	7.70 ± 2.9	7.8 ± 3.3	1.54 ± 0.5	1.60 ± 0.5

Ten JI, et al. Automatic patient dose registry and clinical audit on line for mammography. Radiat Prot Dosimetry. 2015 Jul;165(1-4):346-9.

Patient specific dose estimates

- Errors in standardized dosimetry (Secopulouus, et al, 2012)
- Reflects the average (and spread) of the true patient breast MGD distribution
- DBT and DBCT provides images that have at least partial tomographic information on the internal structure of the breast

Pat

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  tor
  bre

Figure 15. Screen capture of mammographic patient dose monitoring using TQM software (Qaelum NV, Leuven, Belgium) at the University of Leuven. Image courtesy of Hilde Bosmans.

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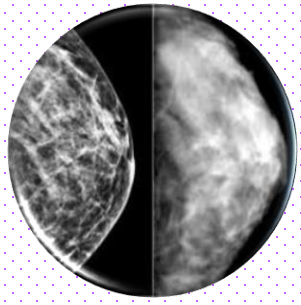
Steps to establish DRLs

Decide DRL quantity

- Modality based, e.g. mammography
- Available dosimetry systems and other resources

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Steps to establish DRLs

Data recording and collection

Recording

A process of documenting patient exposure data manually or electronically

Collecting

A process of gathering patient exposure data into a common system. The term can be used synonymously as recording and collecting together

Analyzing

Statistics, trending, tracking of individual or collective stored data

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Steps to establish DRLs

Data recording and collection

Level 1
Minimal requirements

- Data relevant to characterize the exposure and contain information that can be easily derived from the patient and exam records in the RIS and dosimetric quantities that the equipment can provide (calculated or measured)

Level 2
Standard requirements

- Data for the single irradiation events are included for every modality. Scope of this set of data is to refine the exposure conditions in order to estimate single patient dose. The level of accuracy in the calculations depends on the amount of information collected

Level 3
Advanced requirements

- Data is used for the optimization, includes derived dosimetric data

Data to be recorded in mammography

Level 1

Patient and examination information

- Patient identification (name, hospital ID,…)
- Procedure type (including indication)
- Equipment
- Date
- Time
- Age
- Gender

Mammography

- Number and type of views (e.g. CC/MLO…) (incl. rejected), laterality, breast thickness, source-detector distance
- Per projection: MGD value
- If MGD not available: kV, mAs, tube output

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Data to be recorded in mammography

Level 1

Level 2

Patient and examination information	Mammography
• Weight/CBT	• kV, mAs, exposure time, incident air kerma, anode, filter • Detector type

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Data to be recorded in mammography

Level 1

Level 2

Level 3

Patient and examination information

- Height
- BMI

Mammography

- Focal spot size, compression force
- Post-processing settings, AEC (Y/N; chamber location)
- Matrix size, pixel size, image quality
- Tomosynthesis parameters

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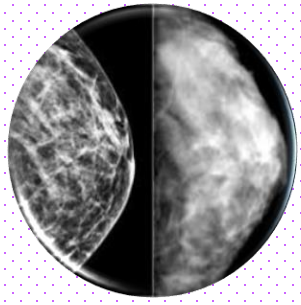
Steps to establish DRLs

Collect data in a particular mammography room

Collect only dose data for procedures where the image quality was confirmed as adequate for the clinical purpose.

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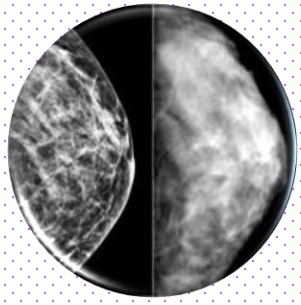
Data collection

Examination parameters

- Procedure (mammography)
- Sub-procedure (MLO view),
- Clinical indication targeted for the examination (identified breast lump)

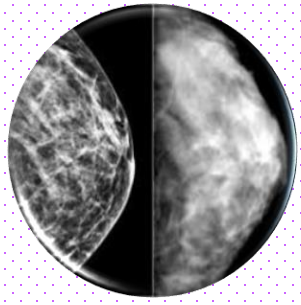



Data collection

Examination parameters

Patient parameters

- Patient type (inpatient, outpatient)
- Patient characteristics (age, compressed breast thickness, etc.)

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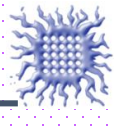
Data collection

Examination parameters

Patient parameters

Acquisition parameters

- Specific imaging system used to acquire the images (manufacturer and model, software version)
- Room used to perform the mammography examination
- Time of the examination (e.g. shift, period of year, etc)
- Radiographer/ technologist who performed
- Specific imaging protocol applied in the data acquisition (different mammography technologies)



Mammography data set

- Minimum 50 patients
- Some standardization through restriction of the range of breast thicknesses may be appropriate
- The average compressed breast thickens is very close to the reference value of 50 mm
- The MGD values determined from patient data corresponding to the range of thickness **40 to 60 mm** representative for entire breast thickness range

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Example: DRL values in mammography should be specific to breast thickness and image detector technology

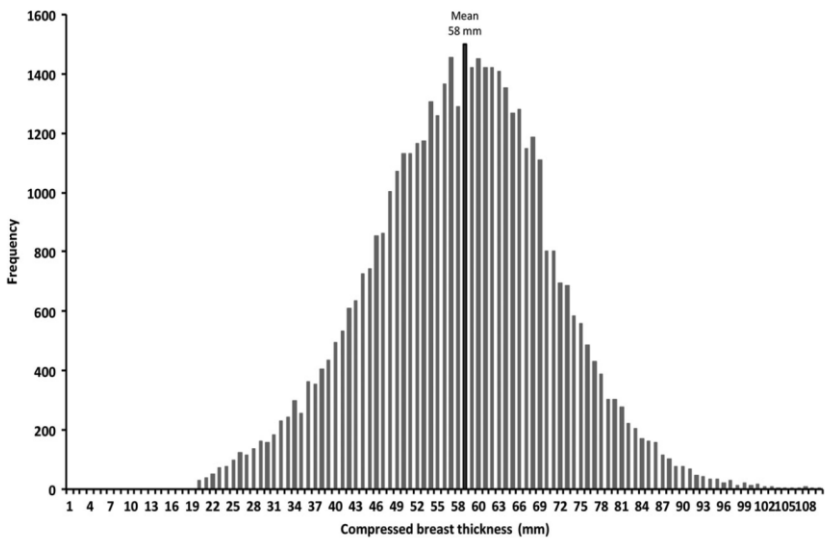


Fig. 1. Distribution of compressed breast thickness for 45,054 mammography images.

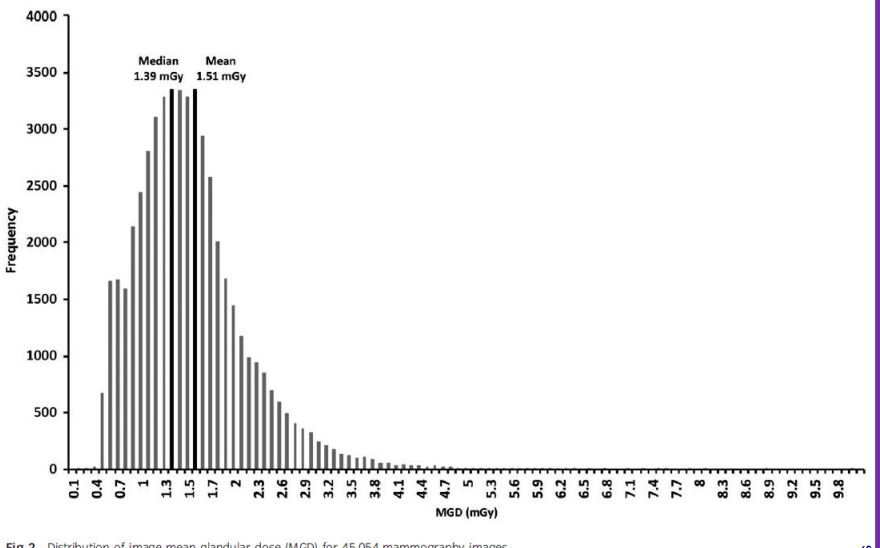


Fig 2. Distribution of image mean glandular dose (MGD) for 45,054 mammography images.

Suleiman M, et al. Diagnostic reference levels for digital mammography in New South Wales, J Med Imaging Radiat Oncol. 2017 Feb;61(1):48-57

Example: DRL values in mammography should be specific to breast thickness and image detector technology

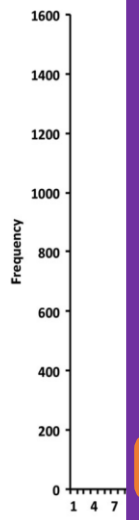


Table 4. 75th and 95th percentiles for different compressed breast thickness ranges and three different detector technologies, representing 45,054 mammograms from 61 BreastScreen units (Proposed DRLs for 60 ± 5 mm breast thickness are in **bold**).

Breast thickness range	All Units		CR		DR		Photon counting	
	75th % (mGy)	95th % (mGy)	75th % (mGy)	95th % (mGy)	75th % (mGy)	95th % (mGy)	75th % (mGy)	95th % (mGy)
20–29	0.97	1.19	1.17	1.26	0.97	1.11	0.58	0.63
30–39	1.13	1.50	1.50	1.52	1.12	1.22	0.60	0.65
40–49	1.31	1.86	1.92	2.08	1.30	1.41	0.58	0.65
50–59	1.67	2.38	2.48	2.58	1.65	1.80	0.65	0.69
60–69	2.37	3.00	3.08	3.21	2.35	2.57	0.88	0.99
70–79	2.23	4.38	4.41	4.46	2.08	2.67	1.08	1.56
80–89	2.48	6.24	6.39	6.74	2.34	3.07	1.12	1.52
90–99	2.89	7.75	7.84	7.85	2.63	3.48	0.99	1.39
DRLs 60 ± 5	**2.06**		**2.22**		**2.04**		**0.79**	

CR, computed radiography; DR, digital radiography.

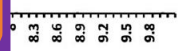
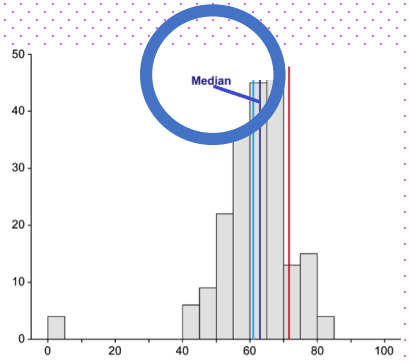


Fig. 1. Distribution of compressed breast thickness for 45,054 mammography images.

Suleiman M, et al. Diagnostic reference levels for digital mammography in New South Wales, J Med Imaging Radiat Oncol. 2017 Feb;61(1):48-57

Data analysis for a given mammography room or facility

- Statistical description: Minimum, Maximum, Average, Standard deviation, Median of patient sample
- Typical dose: Median



MEDIAN VALUE → TYPICAL DOSE

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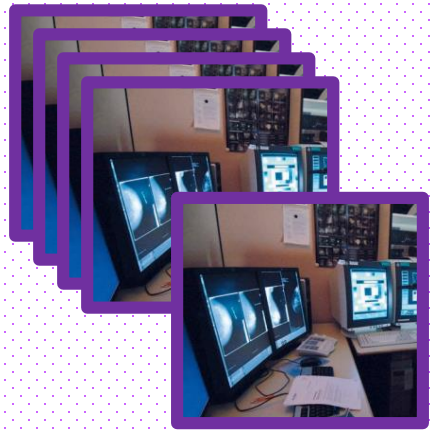
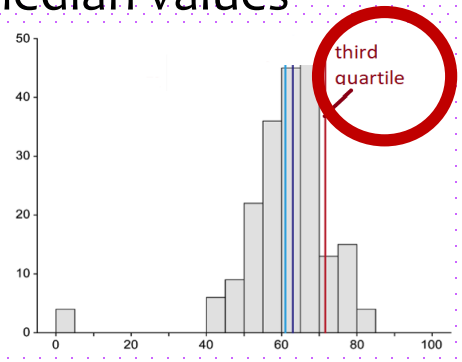
Local DRLs

- Collection of data from different mammography rooms (10-20 rooms), performing the same procedure or X ray rooms from a few facilities in local area
- Statistical description: Minimum, Maximum, Average, Standard deviation, Median
  of typical doses from different rooms
- Local DRL: Third quartile of median values





THIRD QUARTILE OF MEDIAN VALUES

LOCAL DRL

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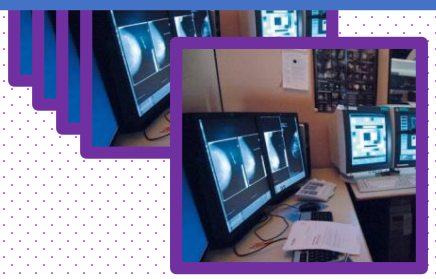
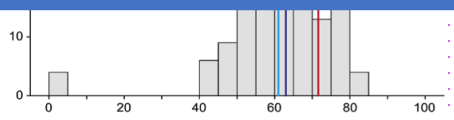
Local DRLs

- Collection of data from different mammography rooms (10-20 rooms), performing the same procedure or X ray rooms from a few facilities in local area
- Statistical description: Minimum, Maximum, Average, Standard deviation, Median
  of typical doses from different rooms

Local DRL values or typical DRLs can be established for newer technologies that enable lower dose levels to be used in achieving a similar level of image quality or diagnostic information.



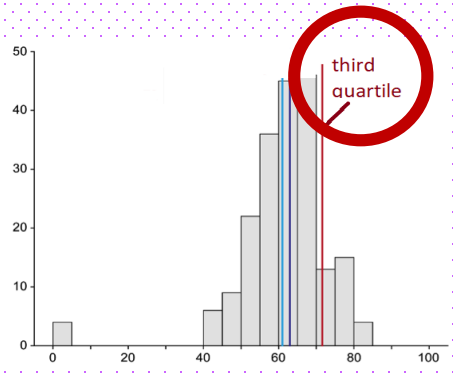


THIRD QUARTILE OF MEDIAN VALUES

LOCAL DRL

National DRLs

- Collection of data from representative sample of facilities covering an entire country
- Statistical description: Minimum, Maximum, Average, Standard deviation, Median
  of typical doses from different hospital
- National DRL: Third quartile of median values



THIRD QUARTILE OF MEDIAN VALUES

NATIONAL DRL

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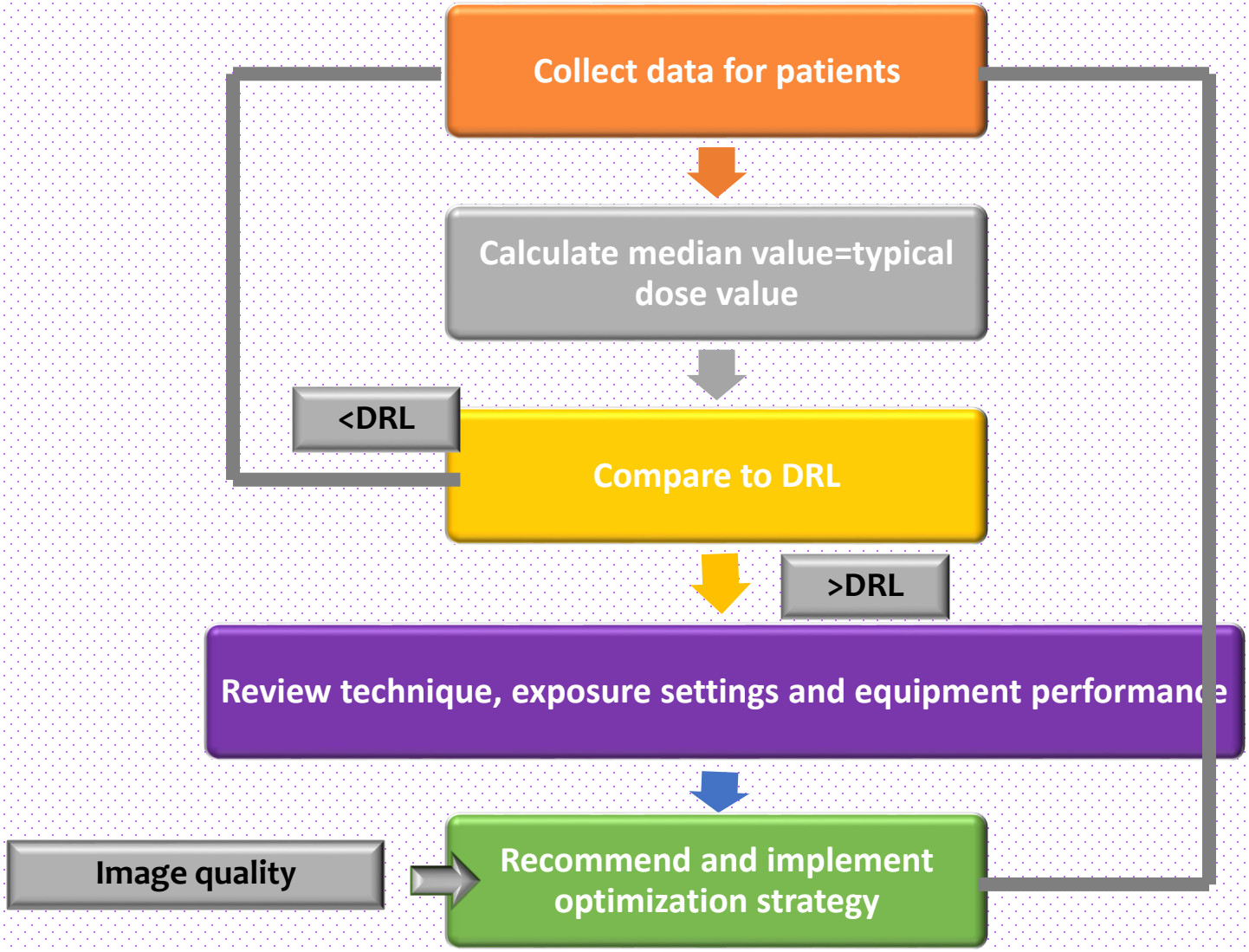
Application of DRLs in mammography



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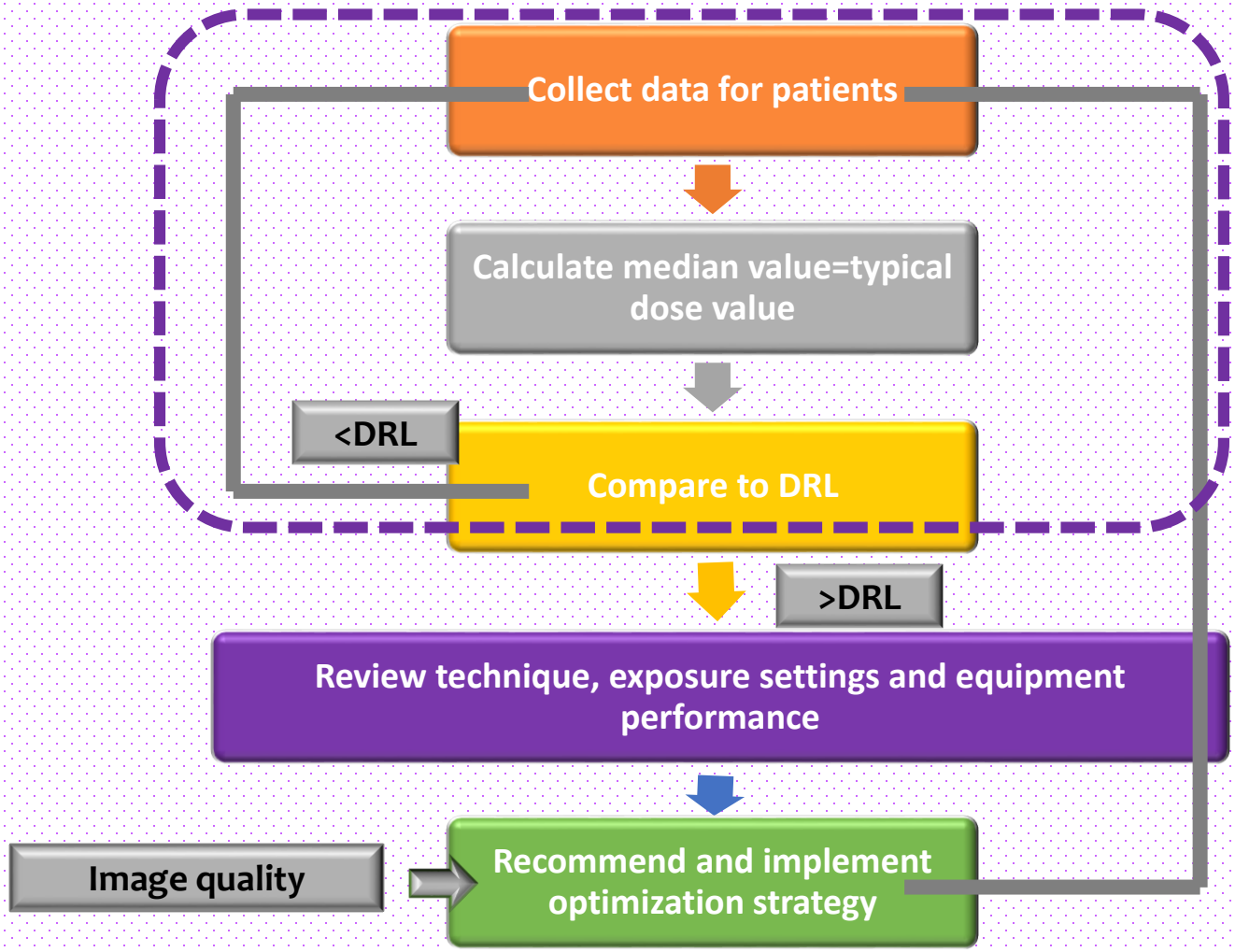
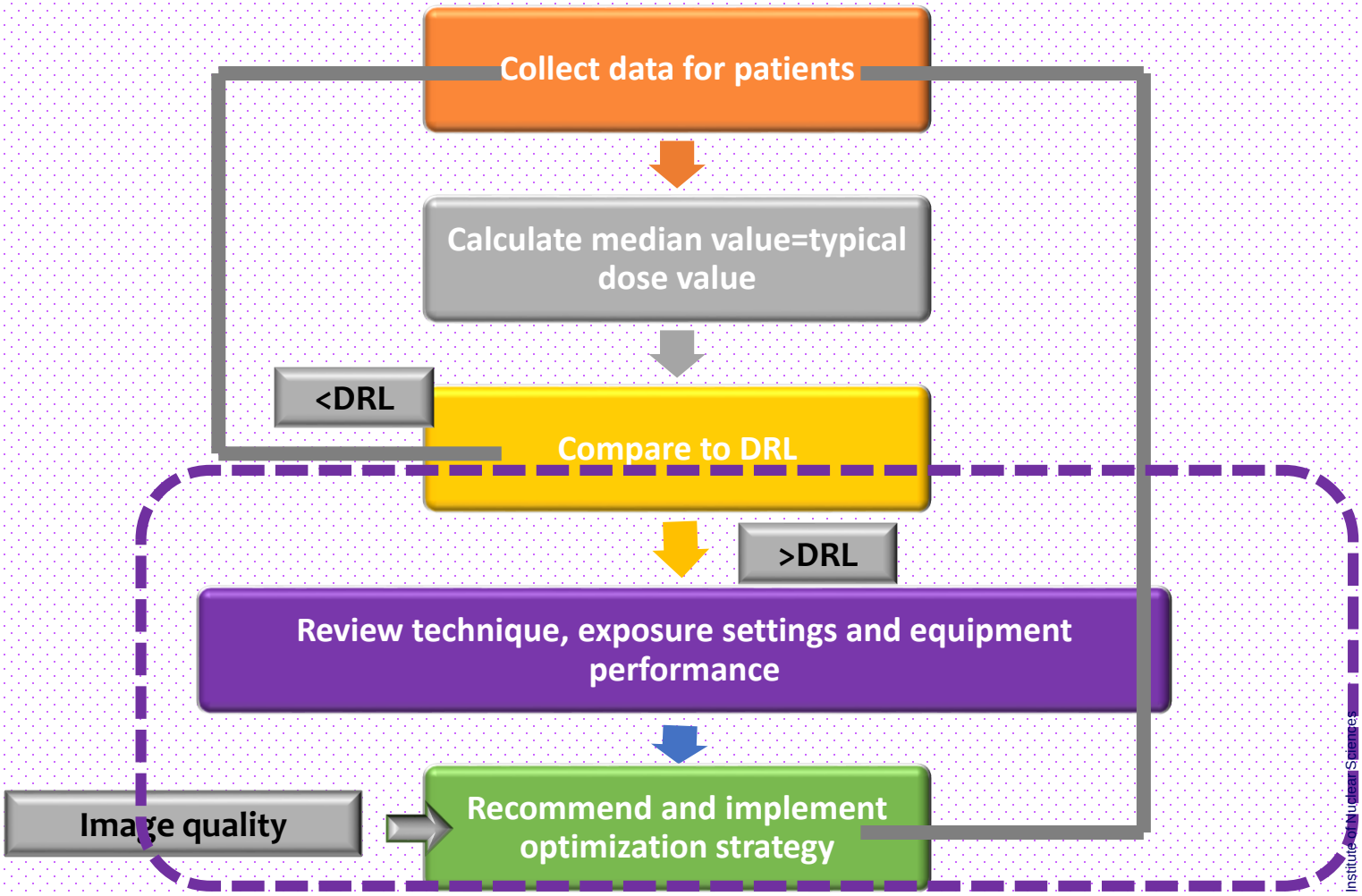
Application of DRLs in mammography



Application of DRLs in mammography



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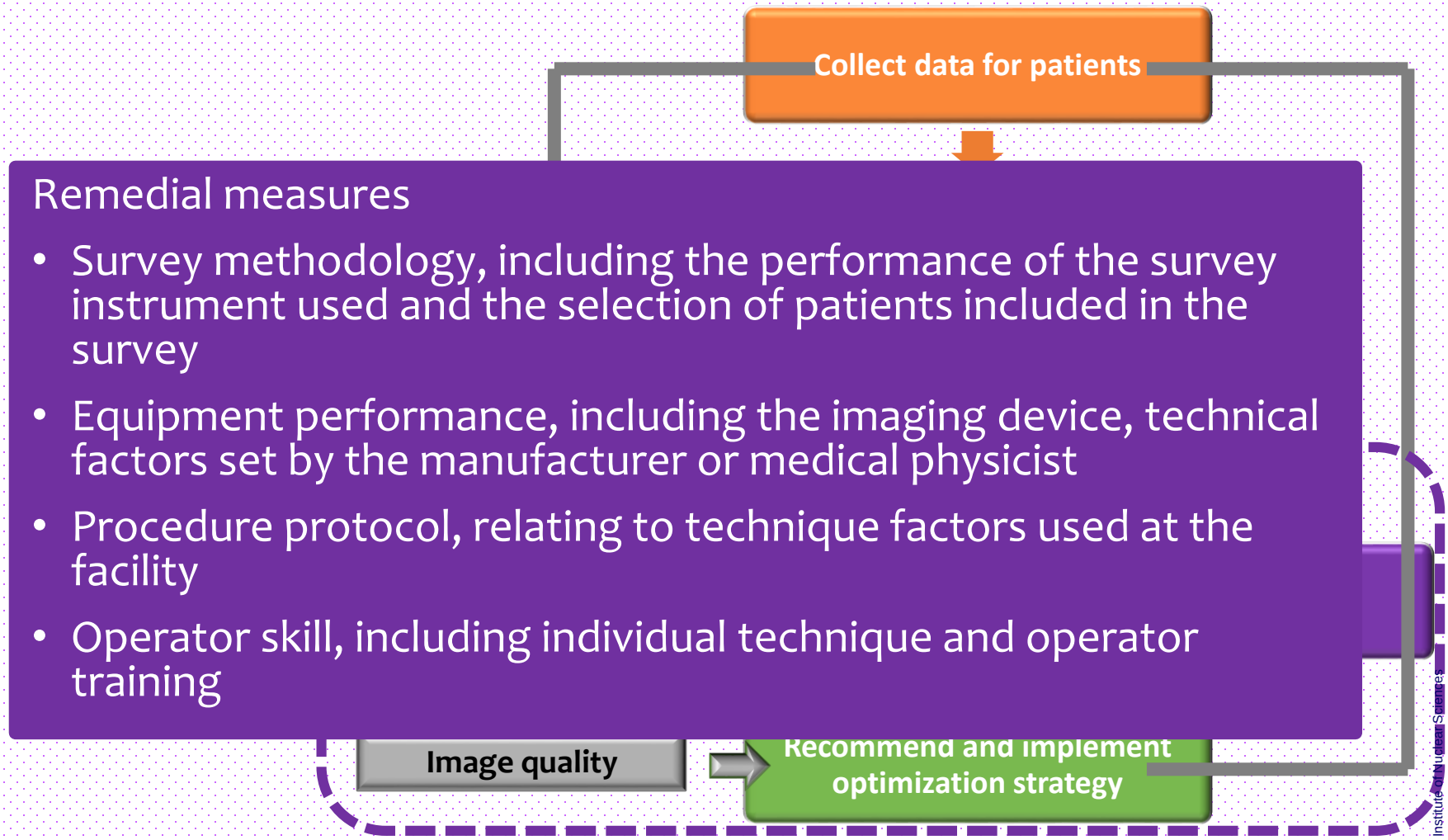
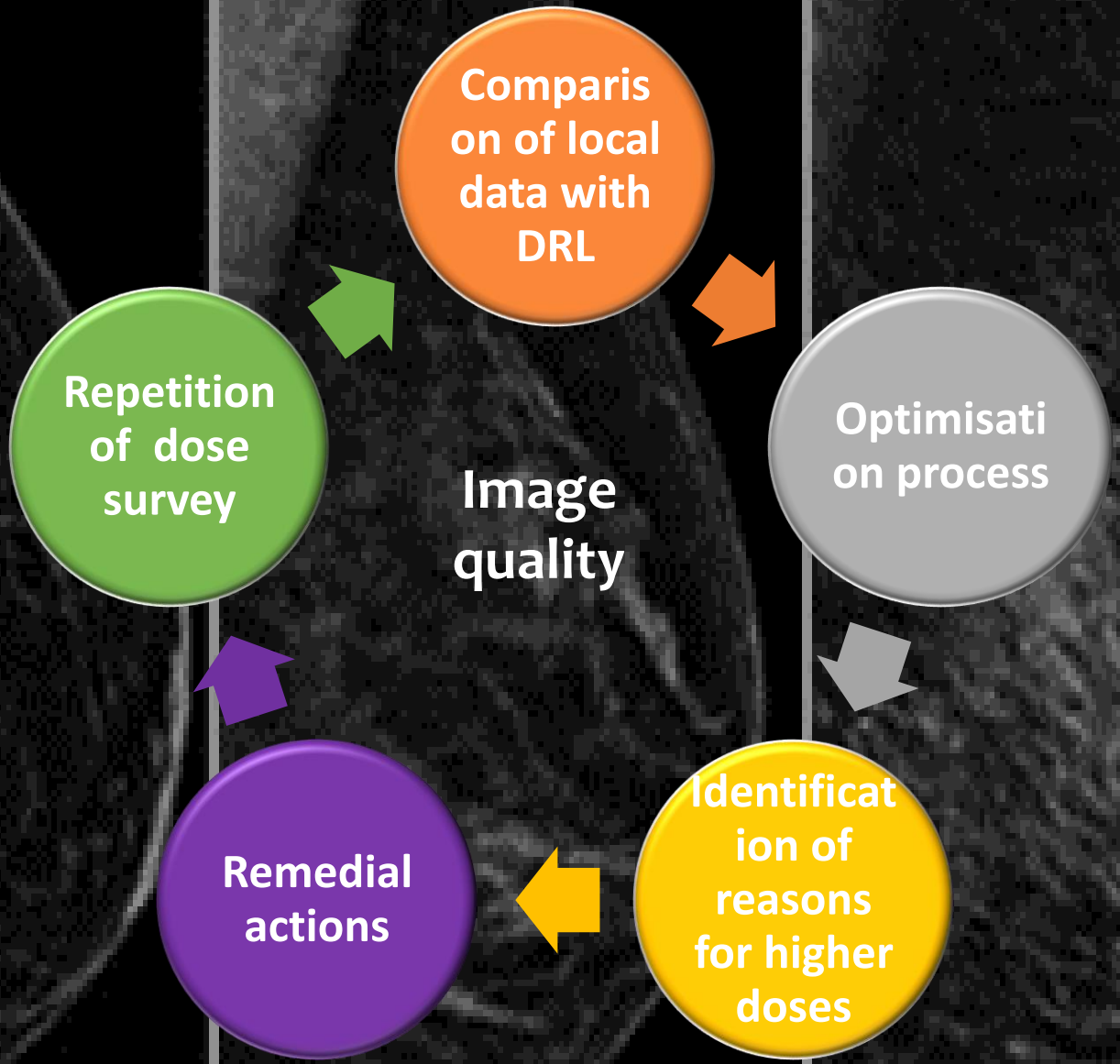
Application of DRLs in mammography



Outcome of the investigation

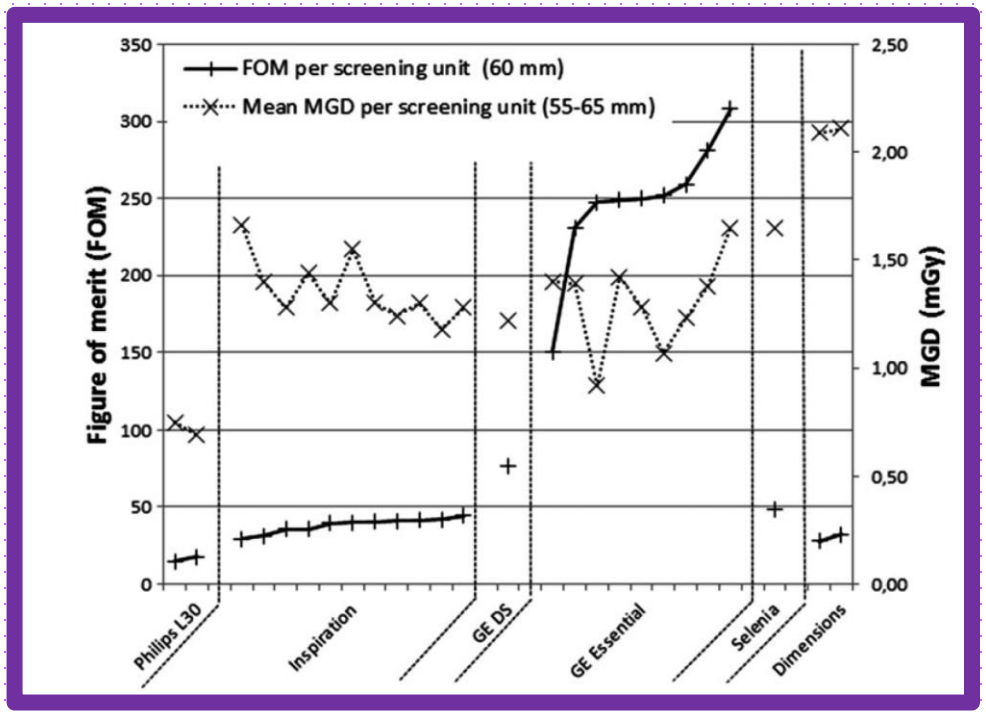


Application od DRLs in mammography

- Local surveys of DRL quantities in mammography:
  - in the 3 year intervals
  - whenever substantial changes in technology or software have been introduces
- If continuous collection of data is possible, the dose management process may take the form of a regular review

Example: DRLs vs Figure of Merit (FOM)

$$FOM = \frac{SDNR^2_{measured}}{MGD}$$



Hauge IH, et al. New diagnostic reference level for full-field digital mammography units. Radiat Prot Dosimetry. 2013 Dec;157(2):181-92.

Example: Different mammography technologies

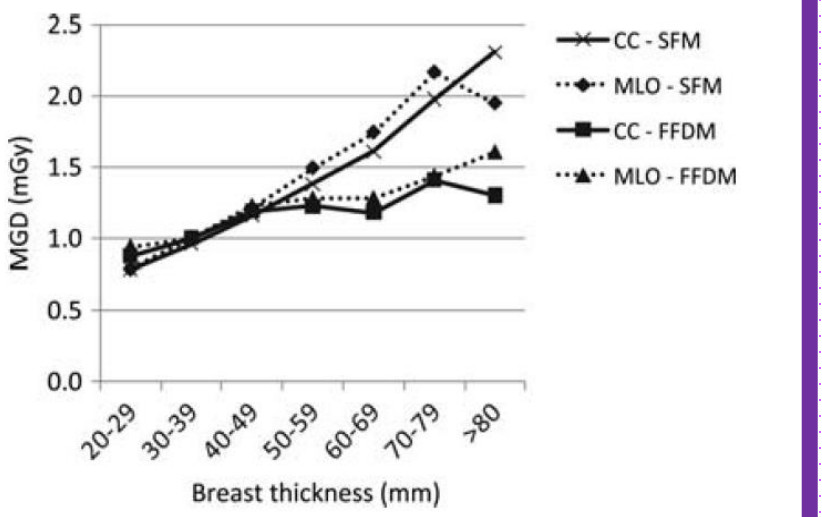


Figure 8. The average MGD (mGy) for SFM and FFDM systems versus compressed breast thickness (mm) for CC and MLO projection.

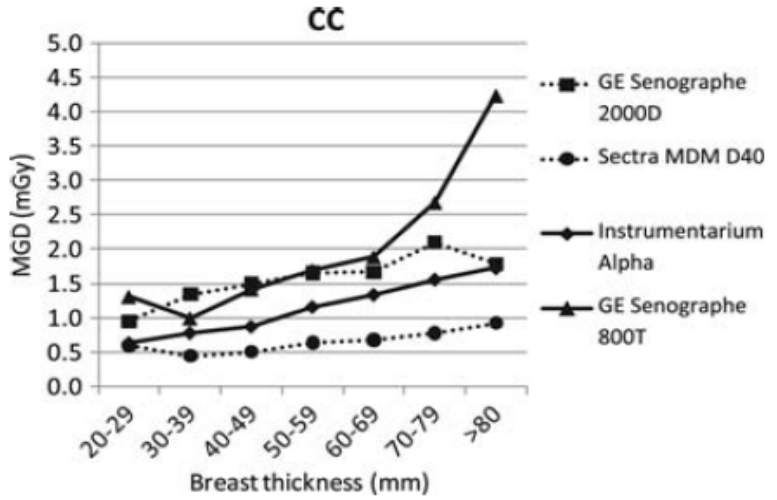
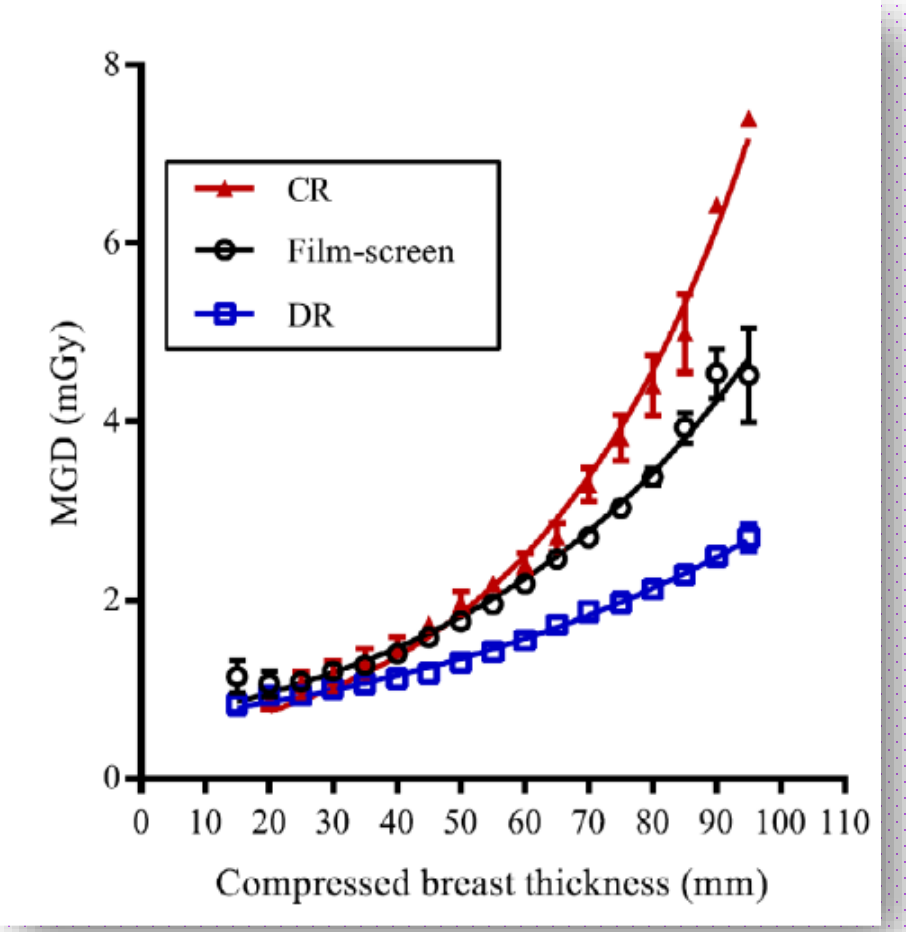
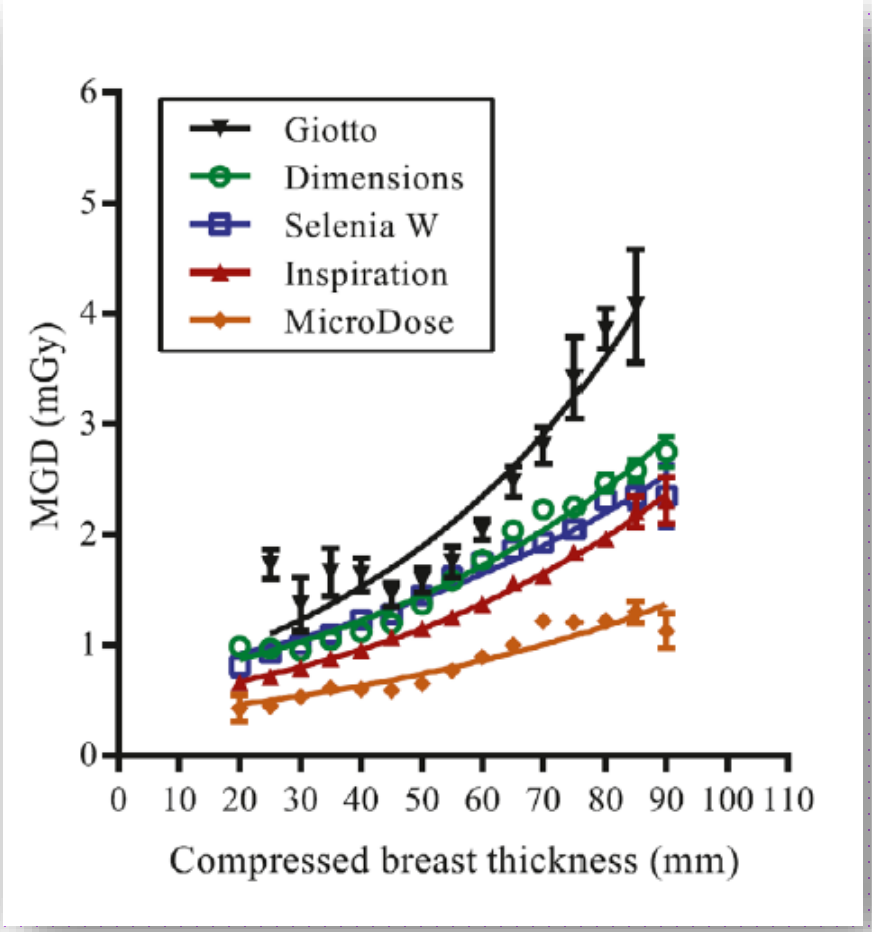


Figure 7. The distribution of MGD per exposure for one SFM and one FFDM system that provided the smallest MGD and one SFM and FFDM that provided the largest MGD.

Hauge IH, et al. Patient doses from screen-film and full-field digital mammography in a population-based screening programme. Radiat Prot Dosimetry. 2012 Jan;148(1):65-73.

Dose vs image detector technology





Young and Oduko (2016).

five different DR systems.

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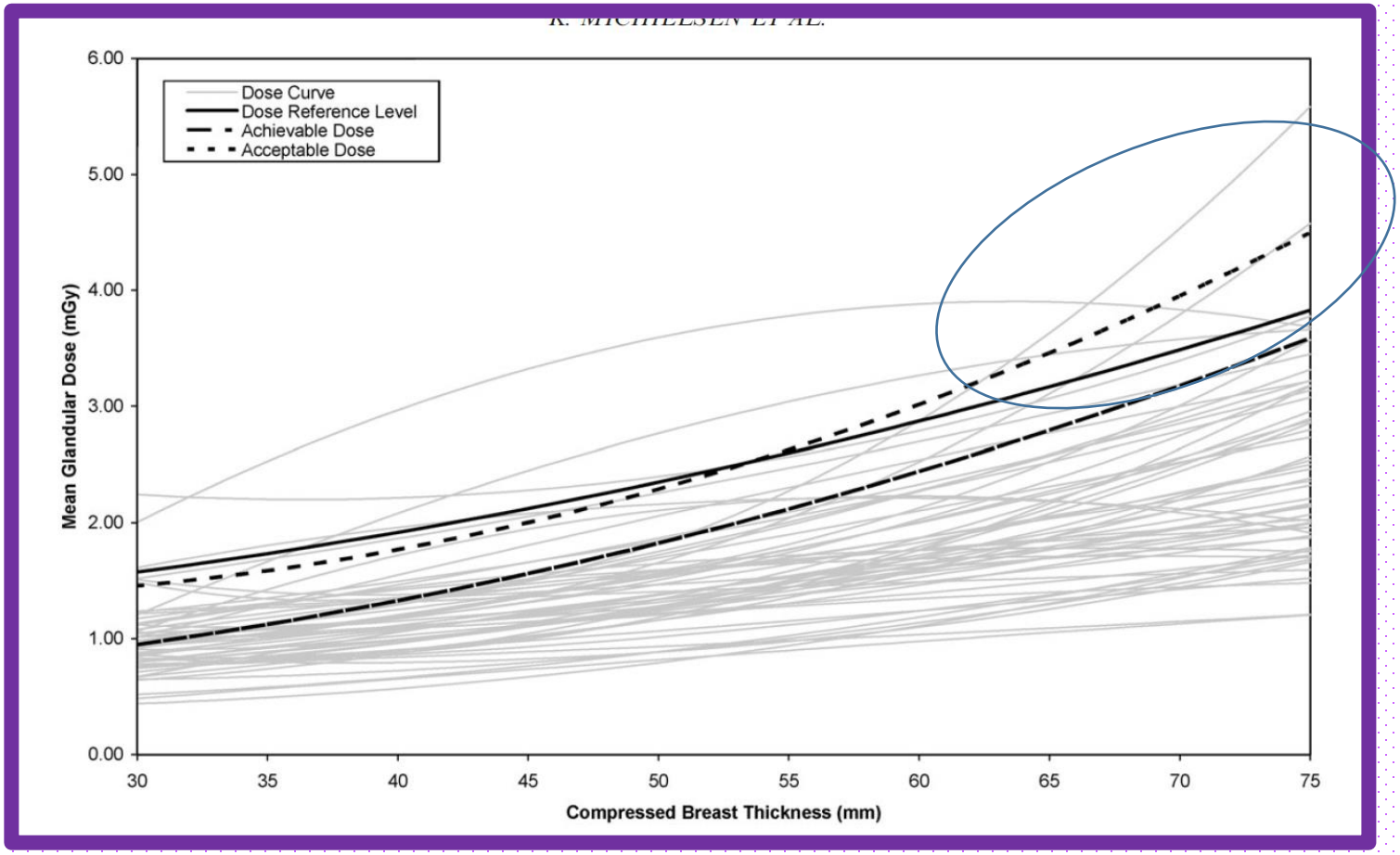
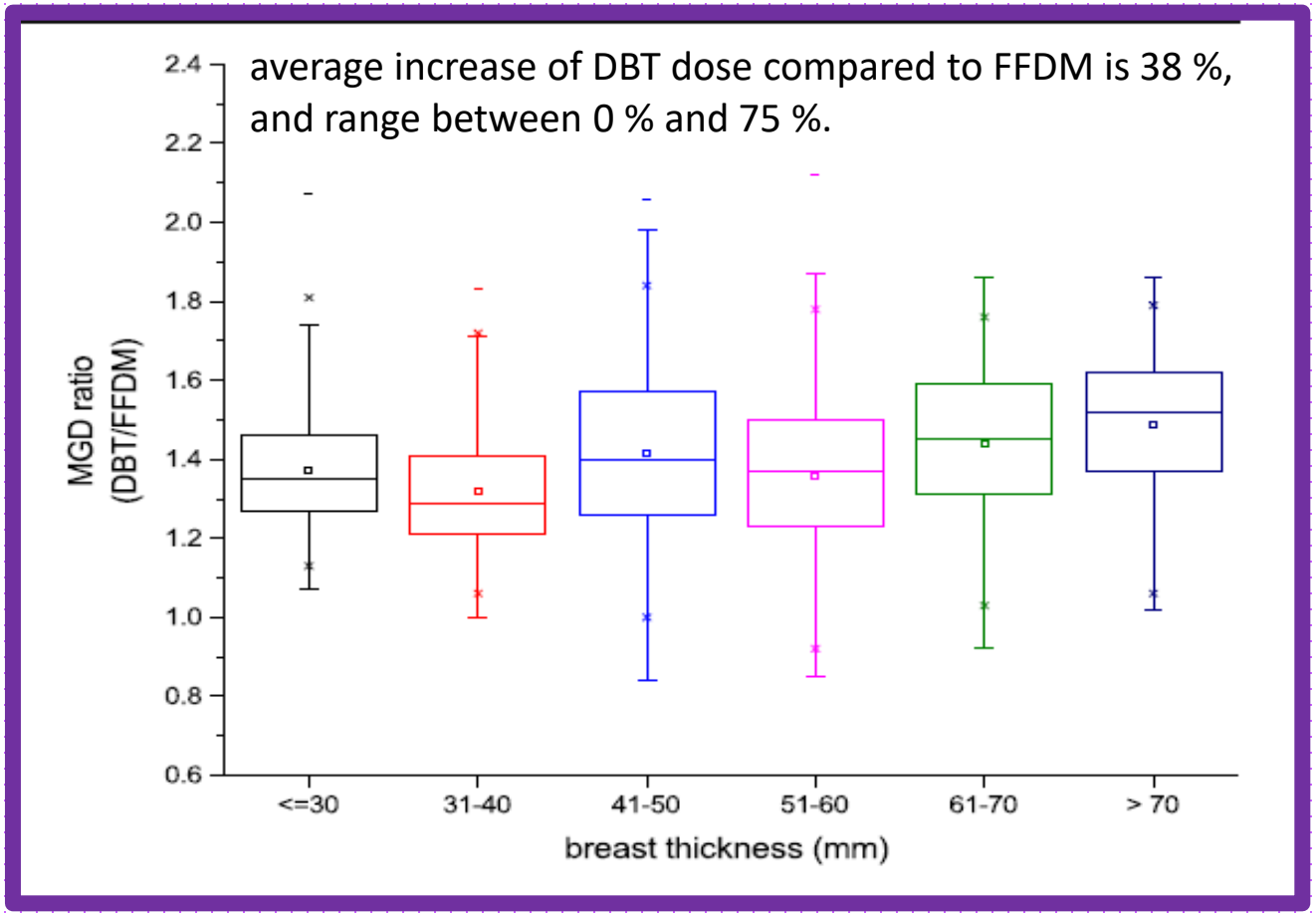
Example: Dose reference curve



Michielsen K, et al. ,. Results of a European dose survey for mammography. Radiat Prot Dosimetry. 2008;129(1-3):199-203.

Mean glandular dose: DBT vs FFDS



Gennaro G, et al. Radiation dose with digital breast tomosynthesis compared to digital mammography: per-view analysis. Eur Radiol. 2018 Feb;28(2):573-581

Example: DRL for digital mammography

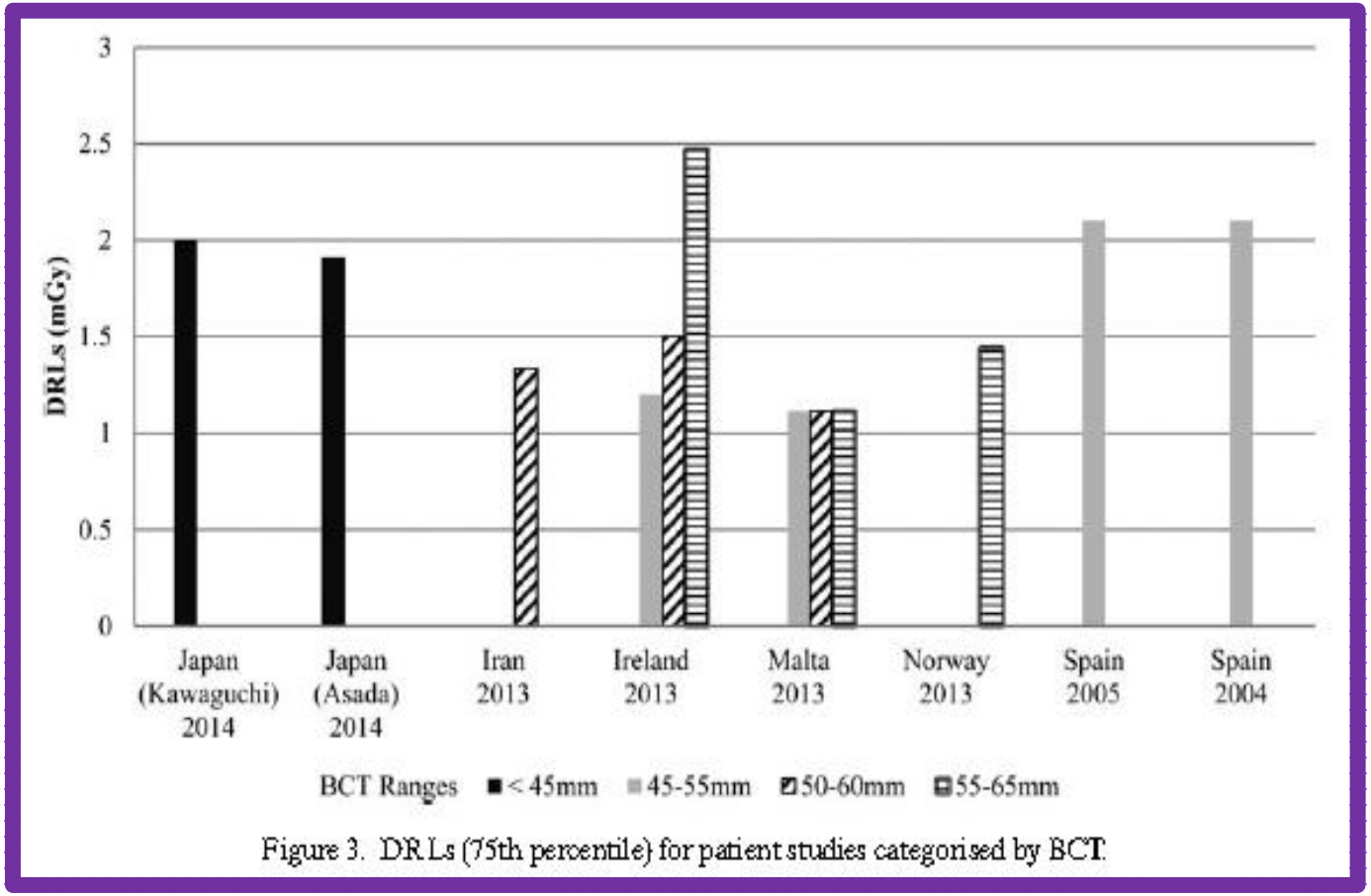


Figure 3. DRLs (75th percentile) for patient studies categorised by BCT.

Suleiman ME, Diagnostic reference levels in digital mammography: a systematic review. Radiat Prot Dosimetry. 2015,167(4):608-19

Example: Automatic dose registry

Table 4. Summary of MGDs found in this study.

	Mean MGD, mGy	75th percentile, mGy	95th percentile, mGy
Digital units			
All projections	1.33	1.5	2.26
CC projection	1.28	1.45	2.17
Mediolateral projection	1.37	1.56	2.4
Analogue units			
All projections	2.64	3.17	5.59
CC projection	2.49	2.99	5.13
Mediolateral projection	2.78	3.38	6.16

Irish National Breast Screening Programme

O'Leary D, et al. A comparison of mean glandular dose diagnostic reference levels within the all-digital Irish National Breast Screening Programme and the Irish Symptomatic Breast Services. Radiat Prot Dosimetry. 2013, 153(3):300-8

What was not covered?

- DBCT
- Photon counting
- Alternatives for dose assessment (MOSFET, TLD, OSL, RPL..)
- Dosimetry within a breast phantom

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Summary

- Mammography use low energy X ray and requires specific dosimetry procedures
- Three DRL quantities have been used for surveys of mammography and breast tomosynthesis: entrance surface air kerma, incident air kerma and mean glandular dose
- Phantoms can be useful for checking the performance of mammography units, however, patient survey should be used to set DRL
- Data set should contain at least 50 patients
- The dose surveys should be repeated periodically.

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