PATIËNTEN DOSIMETRIE VOOR DETECTIE EN FOLLOW-UP VAN SUBOPTIMALE PROCEDURES

VBS-GBS Radioprotectie, Brussel
September 21, 2019

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Radiologie

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FOCUS

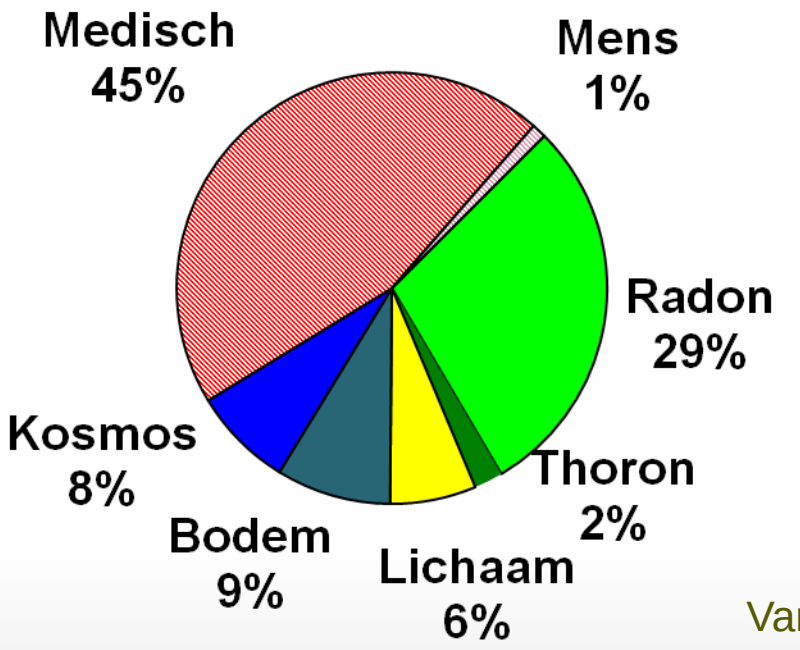
1. Level of **patient exposure during medical procedures** with x-ray imaging. Are dose values in your practice “acceptable” or are they “too high”.

2. Specific **dosimetric quantities** for medical exposure. Which quantities should I consider? Which are available?

3. How can I **improve quality** by dose assessment?

RADIATION DOSE FROM MEDICAL IMAGING

~ 2,5 mSv/y natural sources
~ 2,0 mSv/y medical imaging of which ~50% from CT



Vanmarcke et al, 2010

RADIATION DOSE FROM MEDICAL IMAGING

EUROPEAN COMMISSION

RADIATION PROTECTION N° 180

Medical Radiation Exposure of the European Population

Part 1/2

Directorate-General for Energy
Directorate D — Nuclear Safety & Fuel Cycle
Unit D3 — Radiation Protection
2014

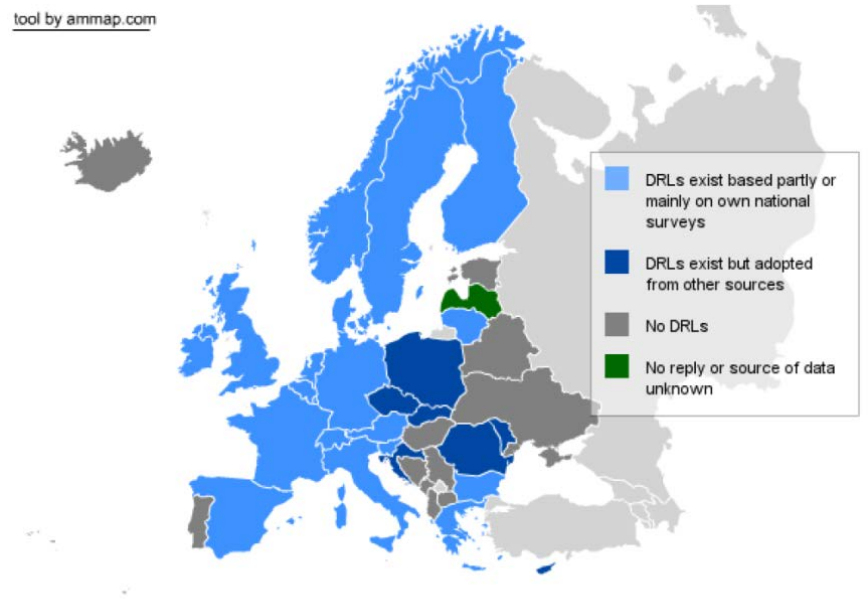


Figure 2.1. Diagnostic reference levels for adult x-ray examinations.

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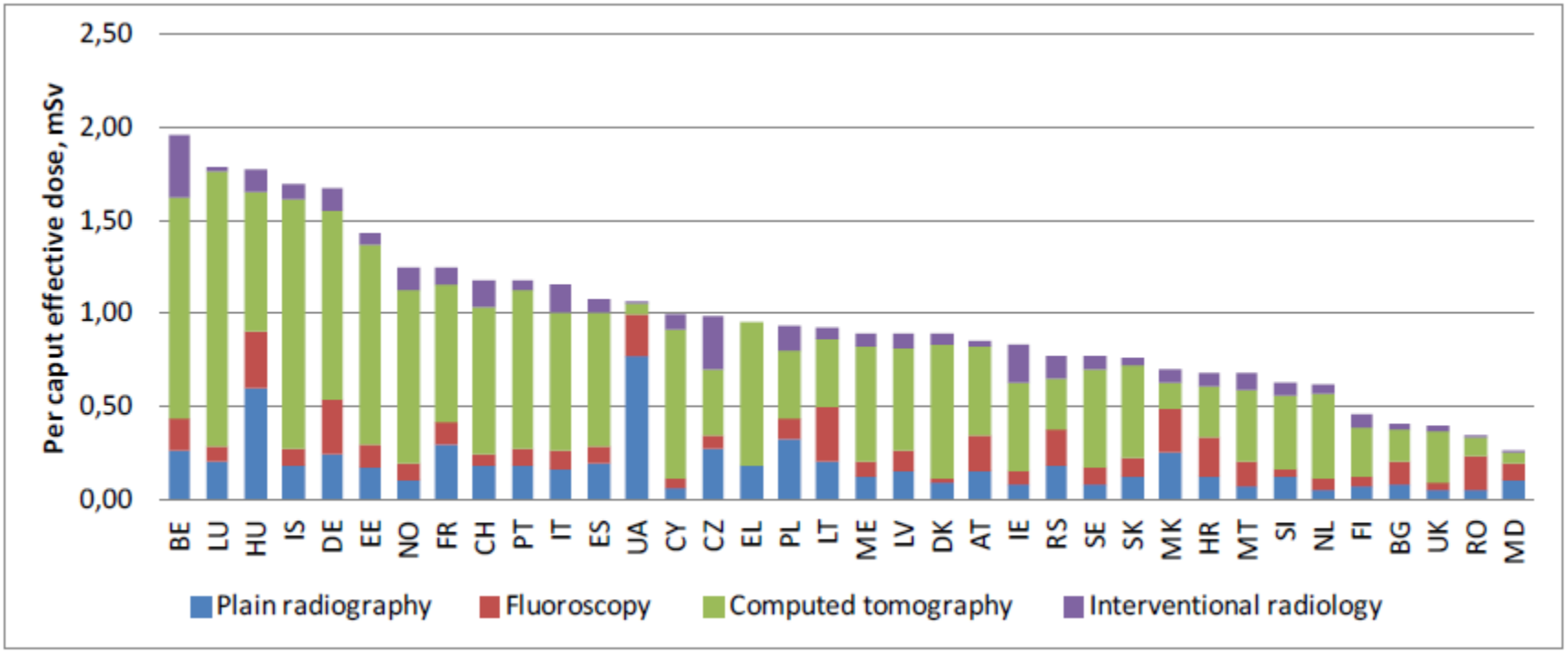
RADIATION DOSE FROM MEDICAL IMAGING



Source
Study on European Population Doses from Medical Exposure (Dose Datamed 2, DDM2), 2014

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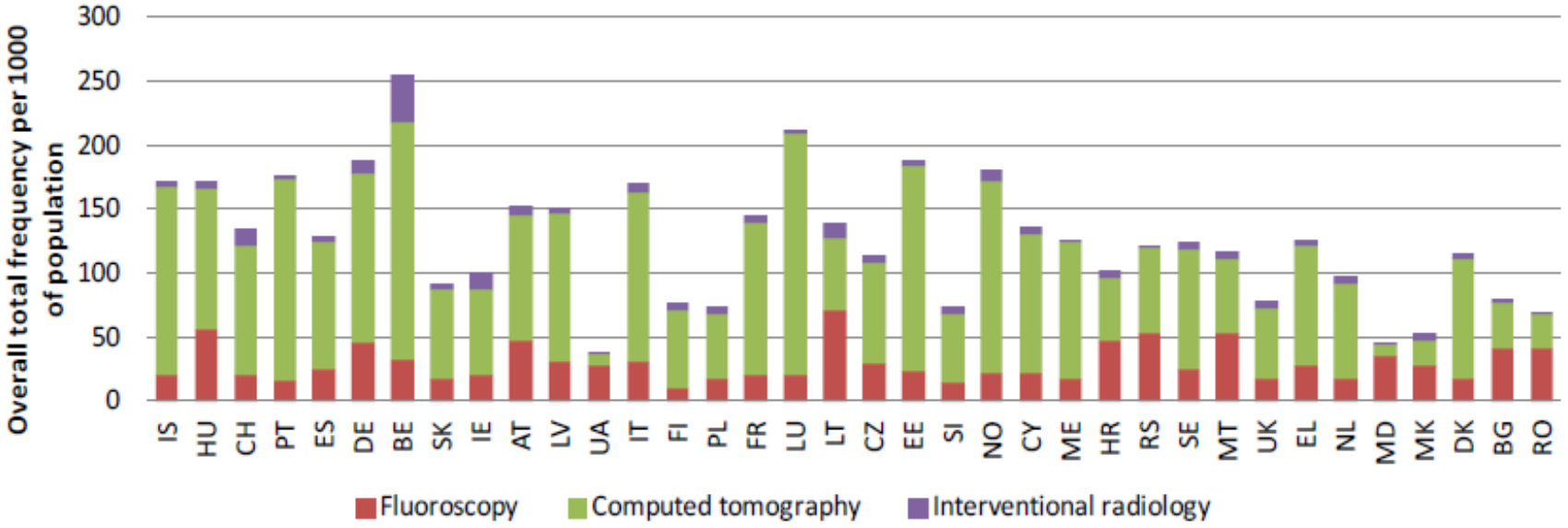
Largest fraction from CT

RADIATION DOSE FROM MEDICAL IMAGING



Source
Study on European Population Doses from Medical Exposure (Dose Datamed 2, DDM2), 2014

ORIGINAL RESEARCH ■ SPECIAL REPORT

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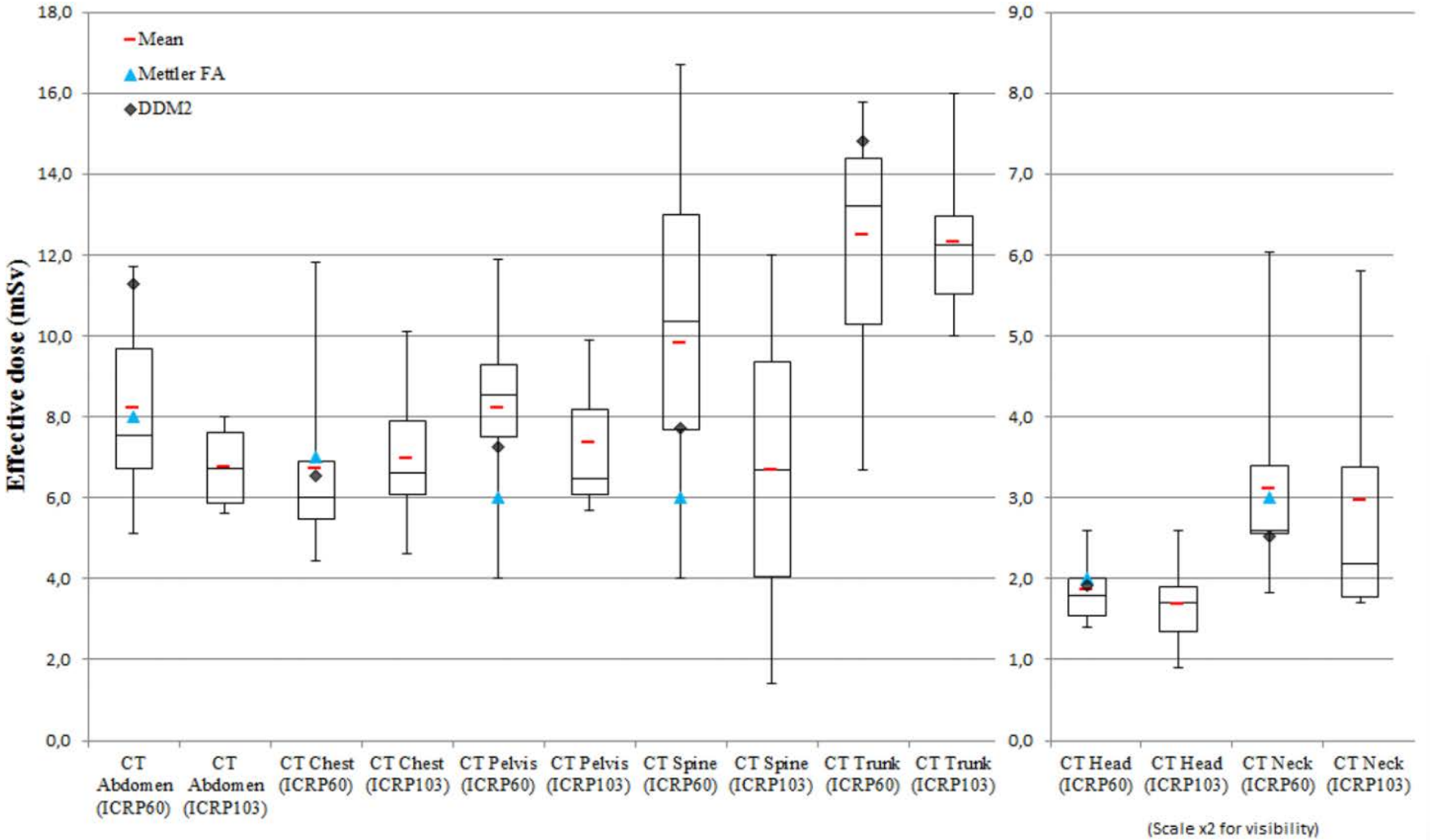
Effective Doses in Radiology and Diagnostic Nuclear Medicine: A Catalog[1]

Fred A. Mettler, Jr, MD, MPH
Walter Huda, PhD
Terry T. Yoshizumi, PhD
Mahadevappa Mahesh, MS, PhD

Medical uses of radiation have grown very rapidly over the past decade, and, as of 2007, medical uses represent the largest source of exposure to the U.S. population. Most physicians have difficulty assessing the magnitude of exposure or potential risk. Effective dose provides an approximate indicator of potential detriment from ionizing radiation and should be used as one parameter in evaluating the appropriateness of examinations involving ionizing radiation. The purpose of this review is to provide a compilation

Radiology

Mettler, Radiology, 2008



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J Villar-Palop, J Radiol Prot 2016

THE USE OF EFFECTIVE DOSE FOR MEDICAL EXPOSURE

The estimation of effective dose can be problematic in medical exposure.

(341) The assessment and interpretation of effective dose from medical exposure of patients is problematic when organs and tissues receive only partial exposure or a very heterogeneous exposure, which is the case especially with diagnostic and interventional procedures.

The inherent uncertainty for organ dose estimation in a **reference patient** is around ± 40%

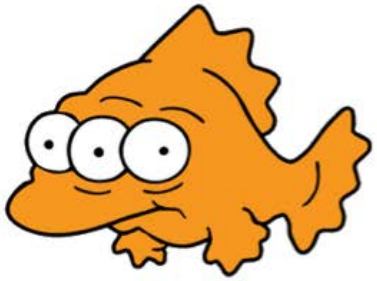
C. Martin, Br J Radiol (2007)

RADIATION DOSE FROM MEDICAL IMAGING

SIMPSONS GUIDE TO RADIATION DOSIMETRY

Bequerel [Bq]
How brightly your Cesium glows

Gray [Gy]
How brightly Cesium will make you glow



Sieverts [Sv]
How many extra eyes will you have after glowing?

RADIATION DOSE QUANTITIES AND UNITS

Physical quantities

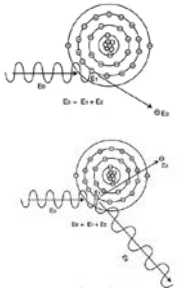
Describe physical effect
Can be measured directly
Fluence, Kerma (gray), Absorbed dose, *D* (gray)

Radiation Protection quantities

To consider health effects, to set legal dose limits
Can not be measured
Organ equivalent dose, H_T (sievert), Effective dose, *E* (sievert)

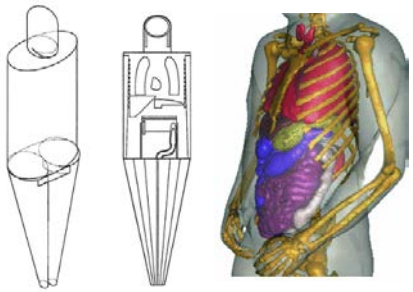
Operational quantities

Measurable for compliance with dose limits
Area monitoring and individual monitoring $H_p(d)$, d = 10 mm



Primary physical quantities

Kerma (gray)
Absorbed dose, *D* (gray)



Calculated using simple phantoms (sphere or slab) validated by measurements

by conversion factors

By Simulation

- Human model
- Radiation w_r and tissue w_t weighting factors

Operational quantities

Ambient dose equivalent (Sv)
Personal dose equivalent, $H_p(10)$ (Sv)

Protection quantities

Organ dose, (Sv)
Effective dose, (Sv)

Related by calibration and calculation

Relate to

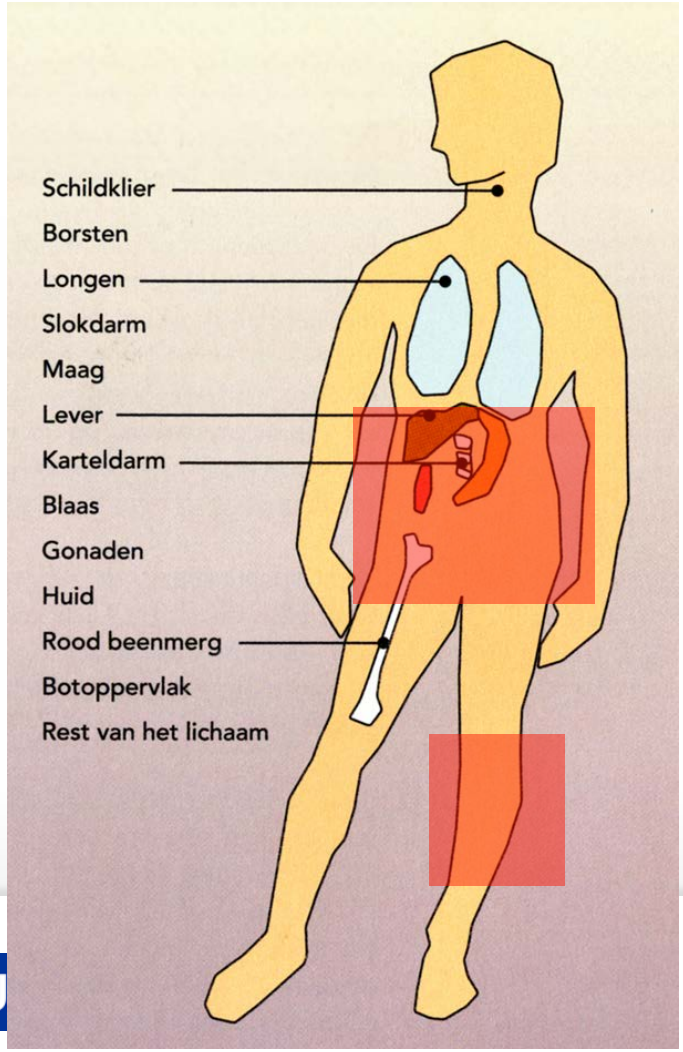
Monitored quantities

Instrument responses

Radiation health risk

Cancer risk, tissue effects, etc

EFFECTIVE DOSE (SIEVERT)



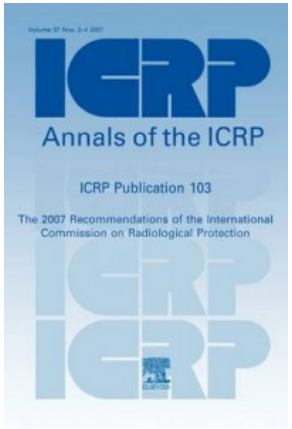
Effective dose is the sum of all organ doses corrected for differences in organ sensitivity (tissue weight factors).

$$E = \sum w_T \times H_{T,R} \quad [Sv]$$

Related to the biological effect

Depends on exposed region

TISSUE WEIGHTING FACTORS



ICRP report 103 recommendations (2007)

Table 3. Recommended tissue weighting factors.

Tissue	w_T	$\sum w_T$
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04
	Total	1.00

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (♂), Small intestine, Spleen, Thymus, Uterus/cervix (♀).

TISSUE WEIGHTING FACTORS

The knowledge of radiation effects is constantly evolving

epidemiological evidence, exposed populations

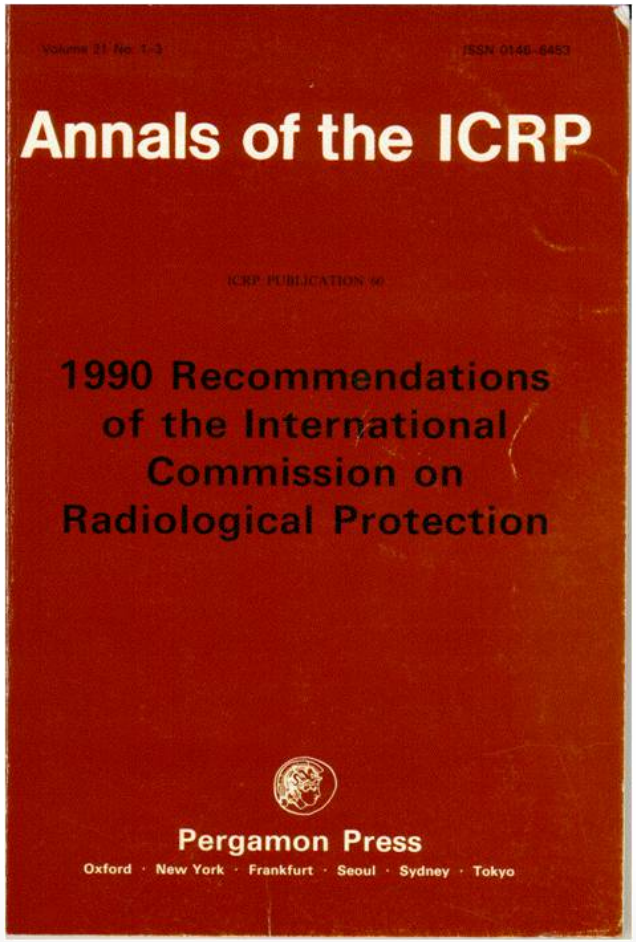
radiobiological evidence

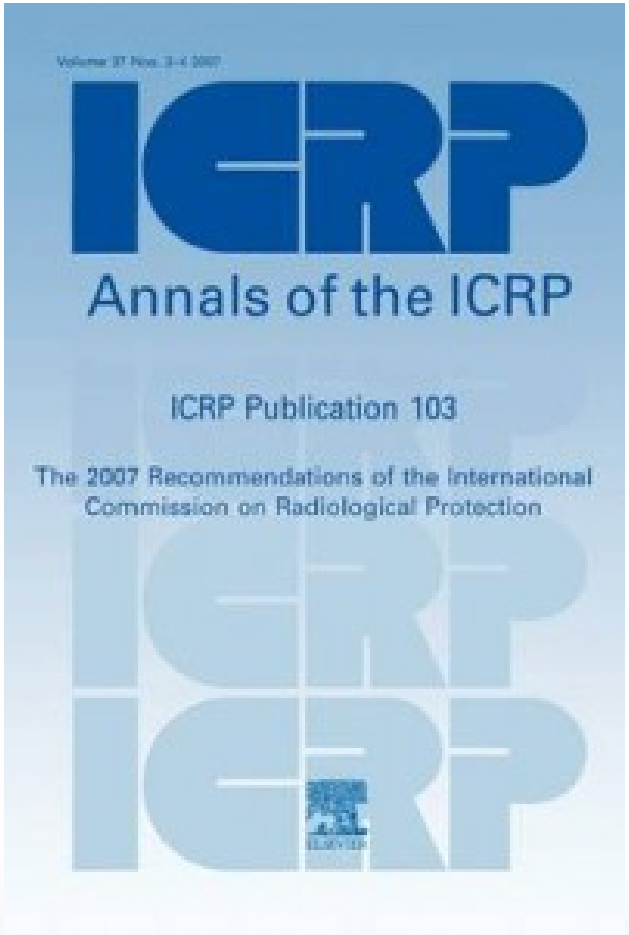
Scientific progress is not fully reflected in present legislation and recommendations

Tissue weighting coefficients depend on our current knowledge of radiobiology

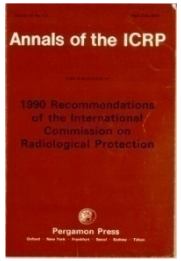
REGULATORY FRAMEWORK

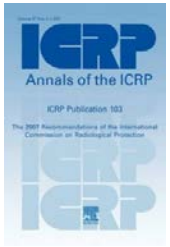
REGULATORY FRAMEWORK





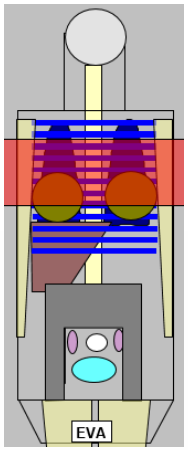
EVOLUTION TISSUE FACTORS

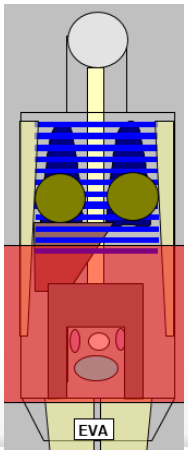




	ICRP 60, 1990	ICRP 103, 2007
Breast	0.05	0.12
Gonads	0.20	0.08
RBM, lung, colon, stomach	0.12	0.12

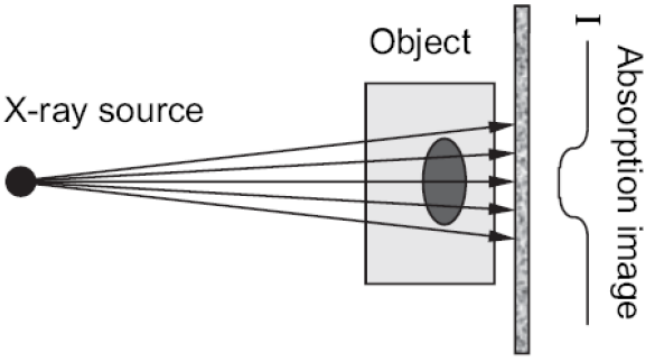
CONSEQUENCE...





Examples	ICRP 60, 1990	ICRP 103, 2007
Cardiac CT 120 kVp, 16cm, DLP = 200 Gycm	4.1 mSV	5.4 mSv
Abdomen CT, 1 sequence 120 kVp, 50cm, DLP = 800 Gycm	15 mSv	12 mSv

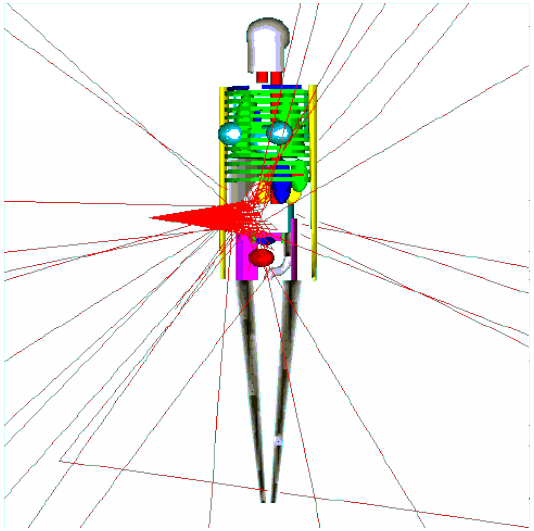
EFFECTIVE DOSE FROM X-RAY'S?



$$I = \int_{0}^{E\max} I_0(E) \cdot e^{-\int_0^d \mu(E)\cdot ds} \, dE$$

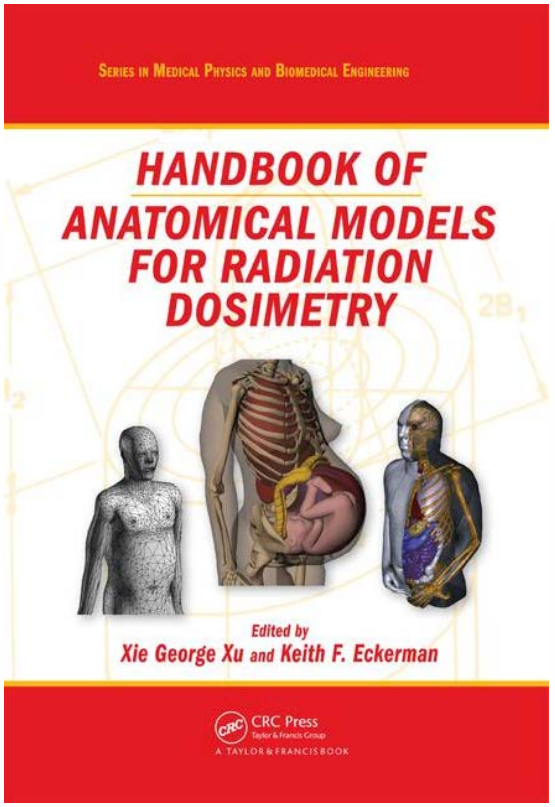
FROM GRAY TO SIEVERT IN MEDICAL IMAGING

exposure model



tracing photons

patient model



COMPUTATIONAL PHYSICS: TRACING PHOTONS BY SIMULATION

New Mexico, USA

Los Alamos
NATIONAL LABORATORY
EST. 1943

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COMPUTATIONAL PHYSICS: TRACING PHOTONS BY SIMULATION

Los Alamos NATIONAL LABORATORY EST. 1943

Founded during World War II as a secret, centralized facility to coordinate the scientific research of the Manhattan Project

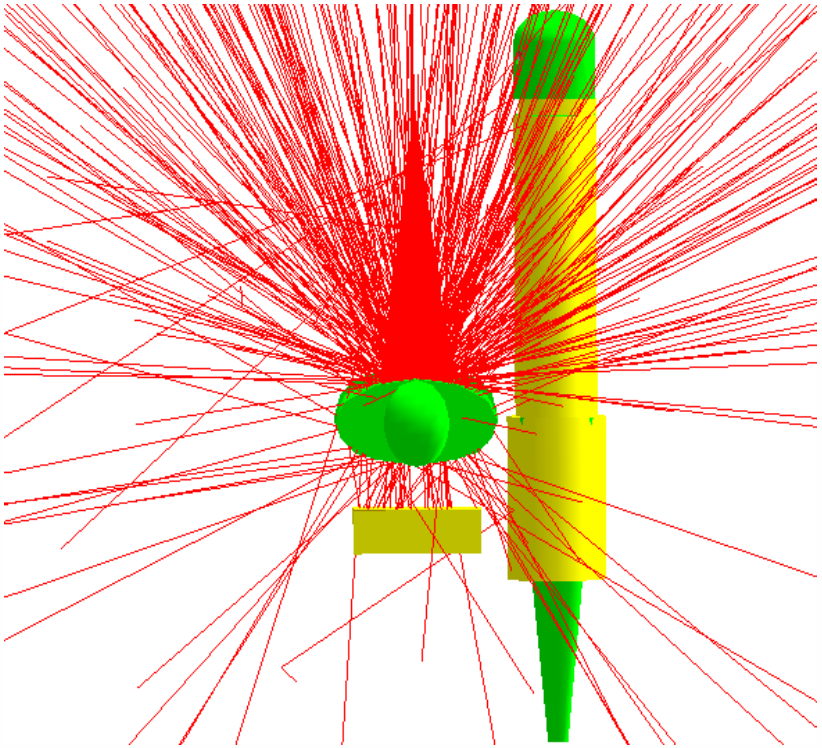
J. Robert Oppenheimer

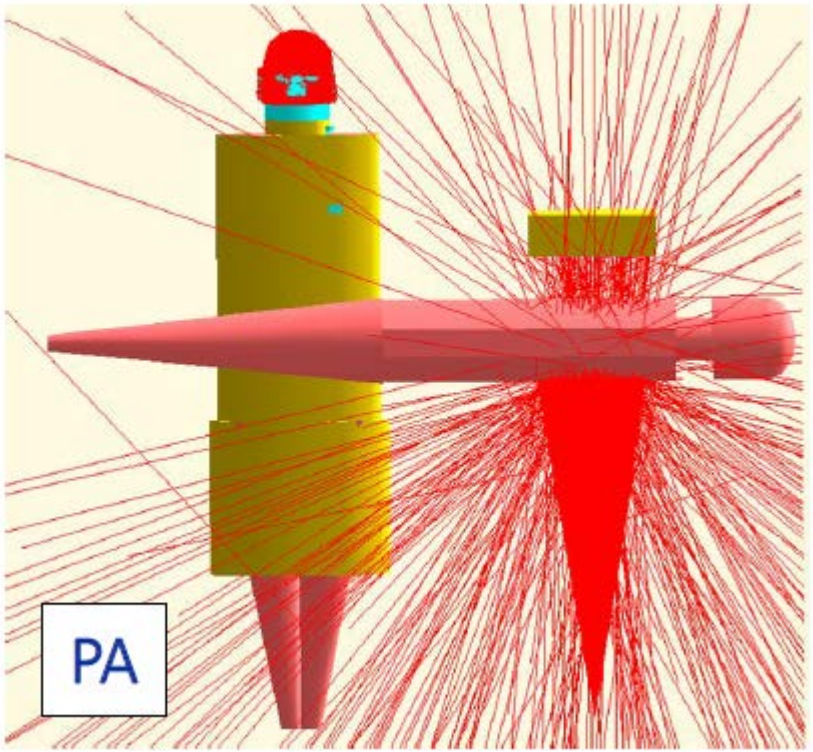
First director (1943-1945)

Today one of the largest science and technology institutions in the world. Multidisciplinary research in fields such as

- national security
- space exploration
- nuclear fusion
- renewable energy
- **medicine**
- nanotechnology
- supercomputing

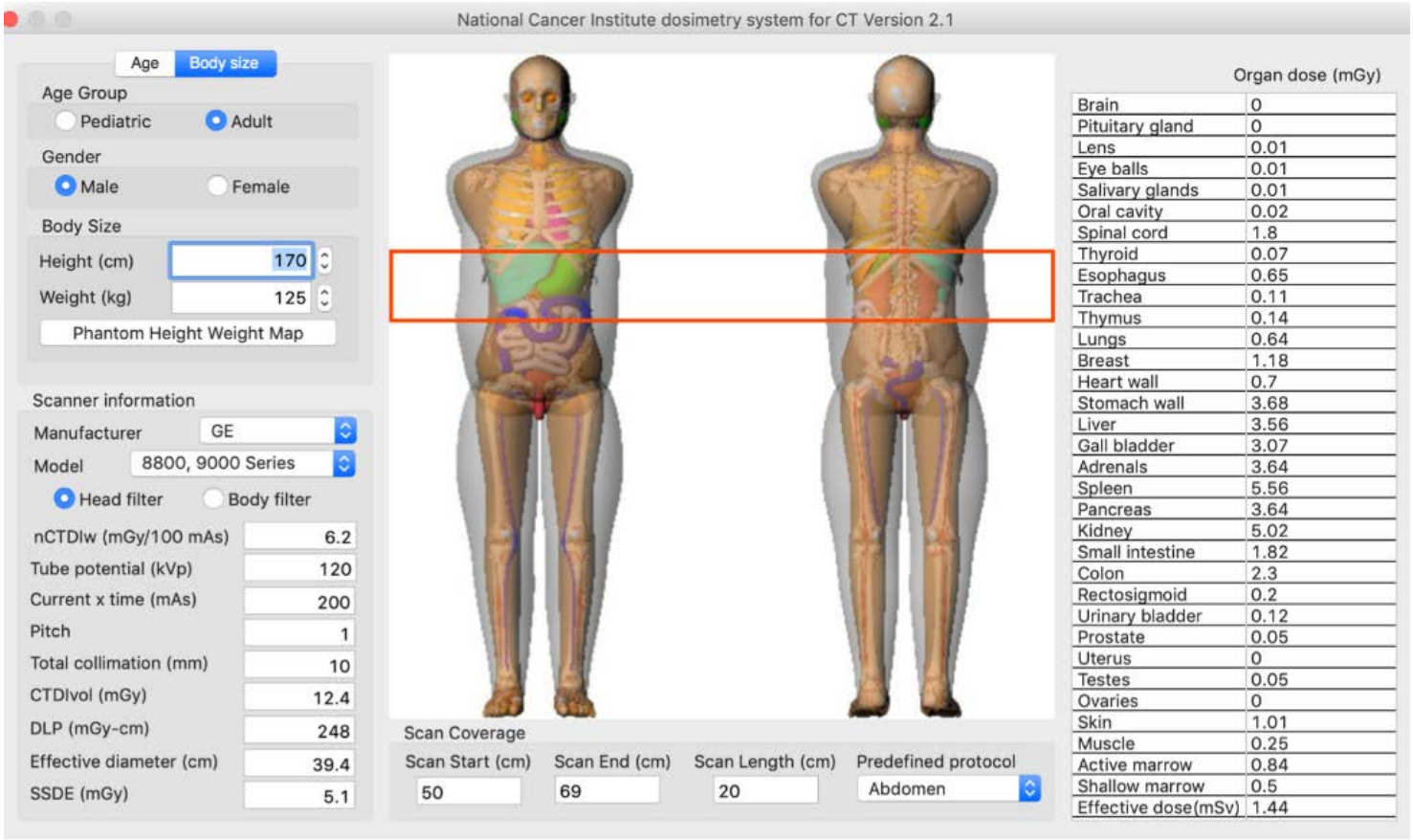
TRACING PHOTONS BY MONTE CARLO SIMULATION MODELS





Photon transport simulations with Monte Carlo N-Particle Transport Code

FROM GRAY TO SIEVERT IN MEDICAL IMAGING – EXAMPLE CT



https://ncidose.cancer.gov/#ncict

GENERIC CONVERSION FATORS – EXAMPLE CT

DLP to E conversion coefficients

TABLE 3 Normalised values of effective dose per dose-length product (DLP) over various body regions and (standard) patient ages (Shrimpton, 2004)

Region of body	Effective dose per DLP (mSv (mGy cm)$^{-1}$) by age				
	0 y old[a]	1 y old[a]	5 y old[a]	10 y old[a]	Adult[b]
Head & neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen & pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

Notes:

[a]All data normalised to $CTDI_w$ measured in the 16 cm diameter CT dosimetry phantom.

[b]Data for the head & neck regions normalised to $CTDI_w$ in the 16 cm diameter CT dosimetry phantom; data for other regions normalised to $CTDI_w$ in the 32 cm diameter CT dosimetry phantom.

EFFECTIVE DOSE – EXAMPLE CT

AJ Einstein et al, Radiology 2010

Method Used	Effective Dose Derived from	Helical	Helical ESTCM	Prospective Helical	Volume with Standard Exposure Time	Volume with Optimized Exposure Time	Volume 100 kVp: Optimized Exposure Time
ICRP publication 103†	Organ doses	35.4	22.3	9.3	8.2	5.8	4.4
ICRP publication 60	Organ doses	26.5	16.6	7.0	5.9	4.1	3.1
2000 European guidelines	DLP × *k* factor	20.4	14.0	5.9	4.8	3.2	2.2
2004 European guidelines	DLP × *k* factor	16.8	11.6	4.9	4.0	2.7	1.8
DLP (mGy·cm)		1201.3	826.2	348.9	284.7	189.8	128.6
Dose reduction from helical (ICRP publication 103) (%)			37.0	73.7	76.8	83.6	91.2

Same scan, difference in effective dose x 2

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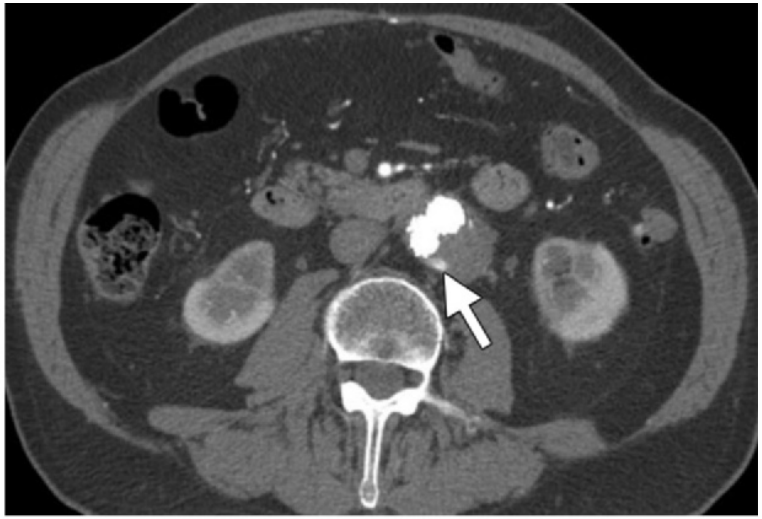
PATIENT DOSE REGISTRATION

Okay, we have to be careful when we use **effective dose** in medical exposure

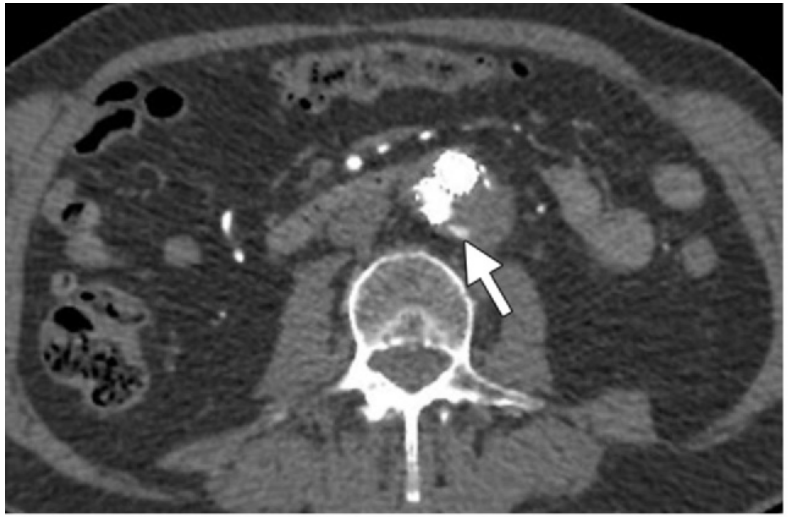
Yes, we have to consider other, practical metrics that can be easily **measured**

Optimisation and good practice (ALARA)

“Standard” dose



“Low” dose ~ ÷ 5



Effect of technical parameters (kVp, mA, s, pulse time, pitch, collimation, etc) on dose?

PRACTICAL QUANTITIES FOR MEDICAL EXPOSURE

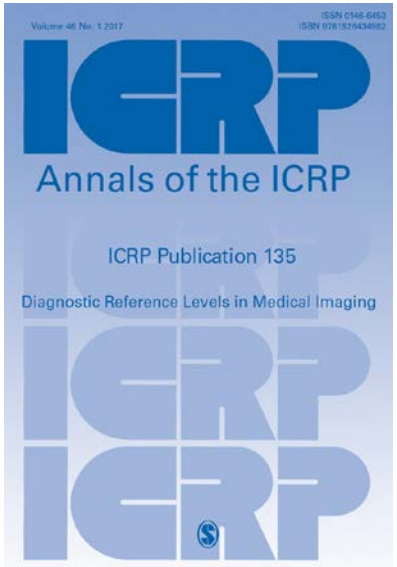
We require PRACTICAL radiation dose quantities for patient dosimetry from medical exposures

Immediate feedback : indicated before (estimation), during and immediately after the examination.

dose indicators characterizing radiation exposure in imaging for the purposes of **comparison of practice**.

these quantities are **not patient doses** (directly reflecting **risk to individuals**)

DIAGNOSTIC REFERENCE LEVELS (DRL)



Diagnostic reference level (DRL)

A diagnostic reference level is a form of investigation level used as a tool to aid in optimisation of protection in the medical exposure of patients for diagnostic and interventional procedures. It is used in medical imaging with ionising radiation to indicate whether, in routine conditions, the amount of radiation used for a specified procedure is unusually high or low for that procedure. For

DRL quantity

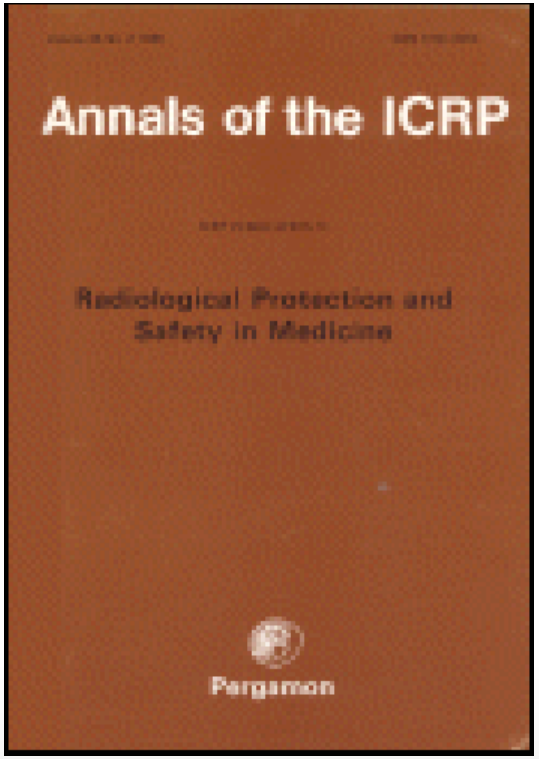
A commonly and easily measured or determined radiation metric (e.g. $K_{a,e}$, $K_{a,i}$, $CTDI_{vol}$, DLP, P_{KA}, $K_{a,r}$, D_G, administered activity) that assesses the amount of ionising radiation used to perform a medical imaging task. The quantity or quantities selected are those that are readily available for each type of medical imaging modality and medical imaging task. Suitable quantities

Dose archiving, reporting and benchmaring

Diagnostic Reference Levels (DRL)

PRACTICAL DOSIMETRY FOR

Dose archiving, reporting and benchmaring



ICRP report 73 (1996)

Council directive 97/43/Euratom of 30 juin 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure and repealing directive 94/466/Euratom.

Art 4 : Member States promote the establishment and the use of diagnostic reference levels for radiodiagnostic examinations

LEGAL BASIS

FANC decree : 28.09.2011 (BS 11.10.2011)

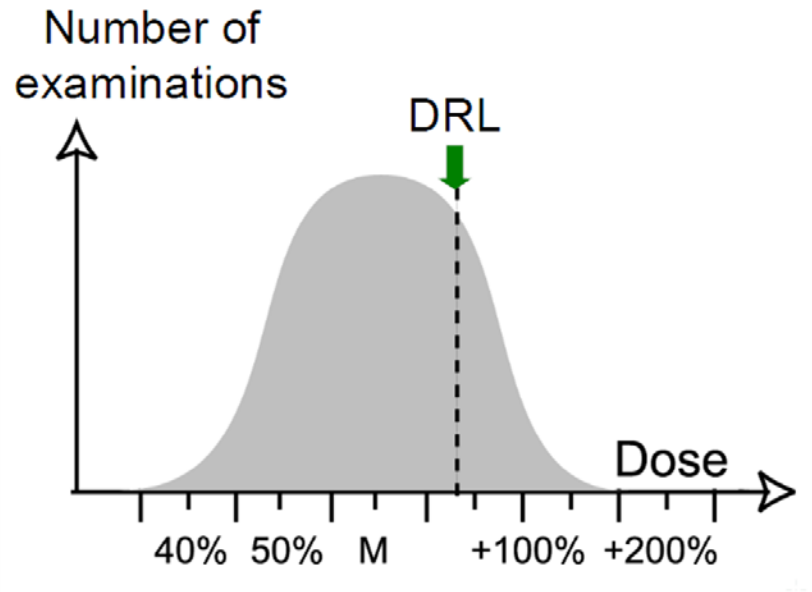
Conduct periodical studies to determine Diagnostic Reference Levels (DRL) for standard examinations

CT: yearly

RX en IR: 3-yearly

In each center, the average dose should be compared to the latest DRL for optimization purposes

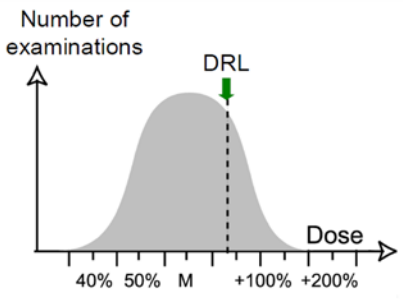
OPTIMISING CLINICAL PRACTICE BY DRL



75 percentile of dose distribution

Iterative process

OPTIMISING CLINICAL PRACTICE BY DRL



- **DRN's bij volwassenen**

VOLWASSENEN	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)			
	Enkelvoudig onderzoek		Enkelvoudig onderzoek		Volledig onderzoek	
Onderzoek	P25	DRN (P75)	P25	DRN (P75)	P25	DRN (P75)
Abdomen	7	10	320	490	350	570
Angio CT van de thorax	5	11	165	300	180	330
Hart (CCTA)	10	25	140	290	190	480
Colon	3*	4*	150*	200*	230	460
Cervicale wervelzuil	14	25	230	450	-	-
Lumbale wervelzuil	18	26	380	600	-	-
Schedel (hersenen)	35	50	640	900	-	-
Sinussen	2,5	6	35	80	-	-
Thorax	5	8	170	260	-	-
Thorax - abdomen	5	8,5	320	550	480	800

RADIATION DOSE QUANTITIES MEDICAL EXPOSURE

Depends on modality

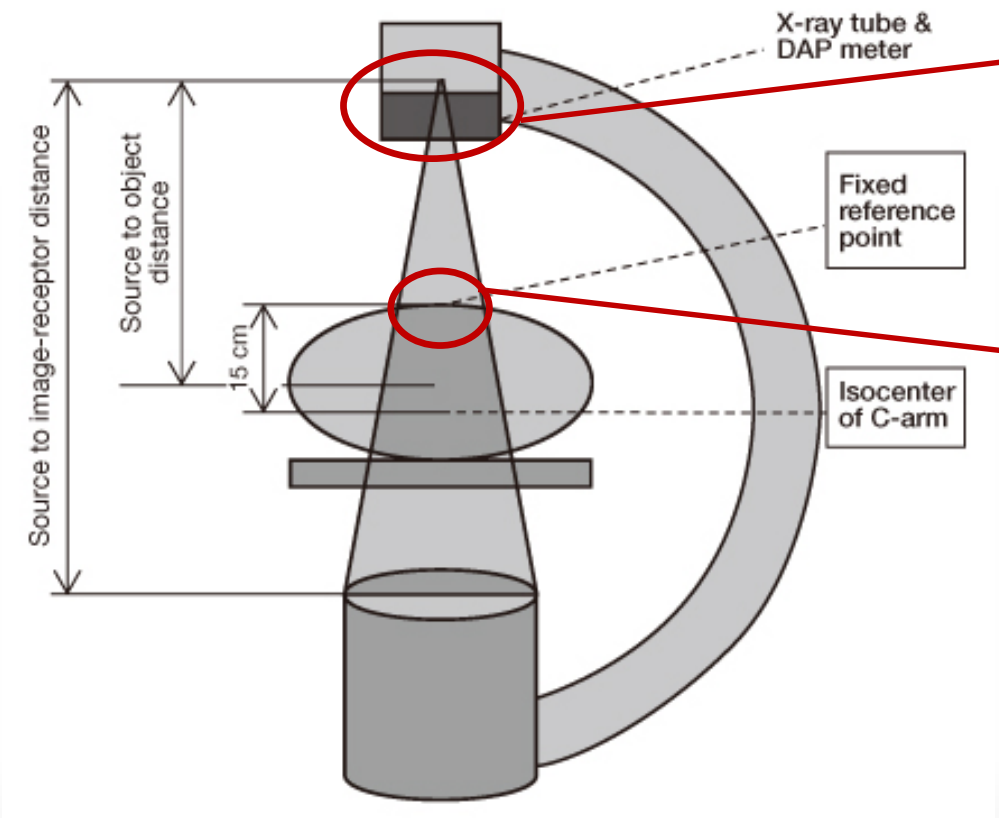
air kerma at reference point ***(mGy)***
dose-area product ***DAP (mGy.cm²)***

the CT dose index ***CTDIvol (mGy)***
dose length product ***DLP (mGy.cm)***

entrance skin dose ***ESD (mGy)***
Average Glandular Dose ***AGD (mGy)***

RADIOGRAPHY AND FLUOROSCOPY

Two operational units



Dose Area Product (DAP)
Gy.cm²

Cumulative dose (CD) in **patient entrance reference point** in mGy

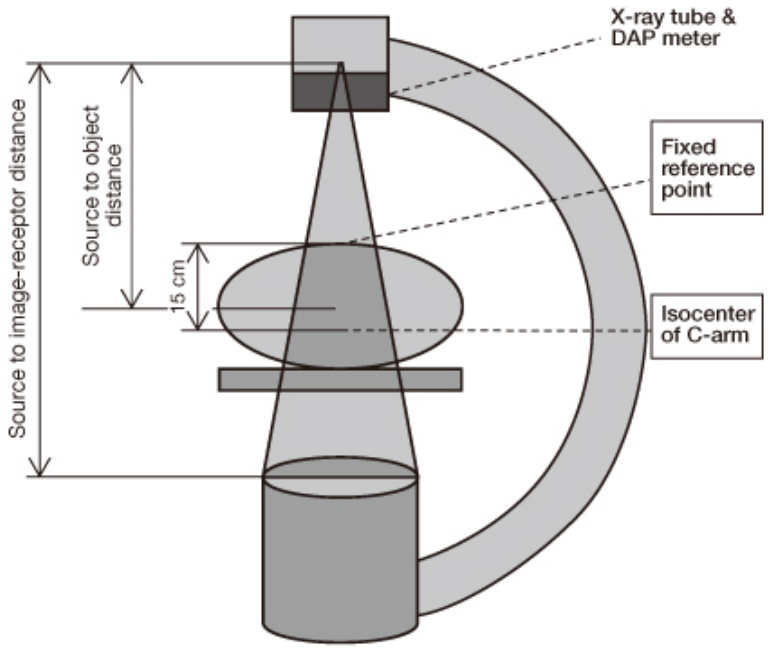
represent the air kerma
incident on the patient's skin surface

IEC 60601-2-43:2010/AMD1:2017

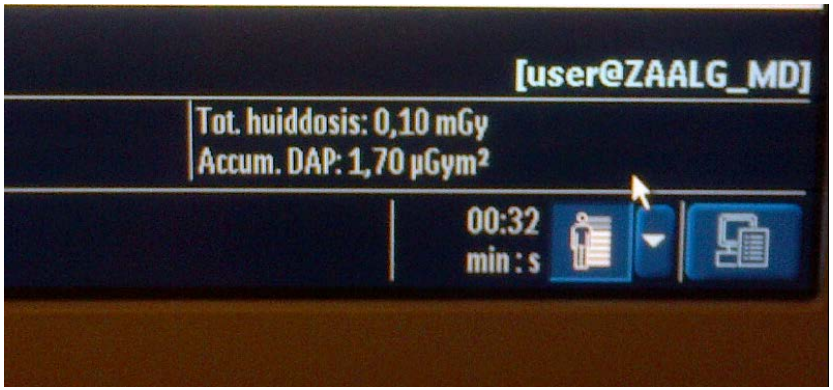
Amendment 1 - Medical electrical equipment - Part 2-43: Particular requirements for the basic safety and essential performance of X-ray equipment for interventional procedures

RADIOGRAPHY AND FLUOROSCOPY

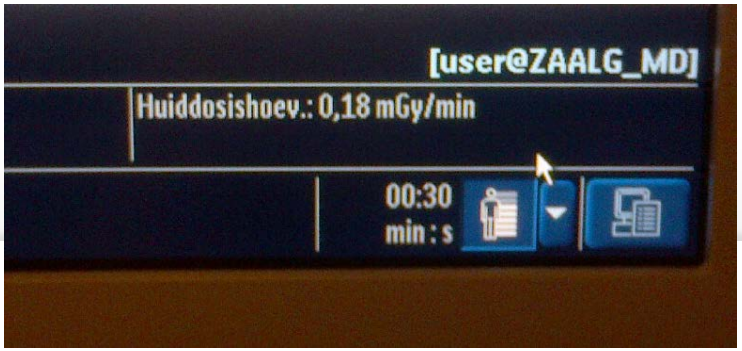
Two operational units



During examination

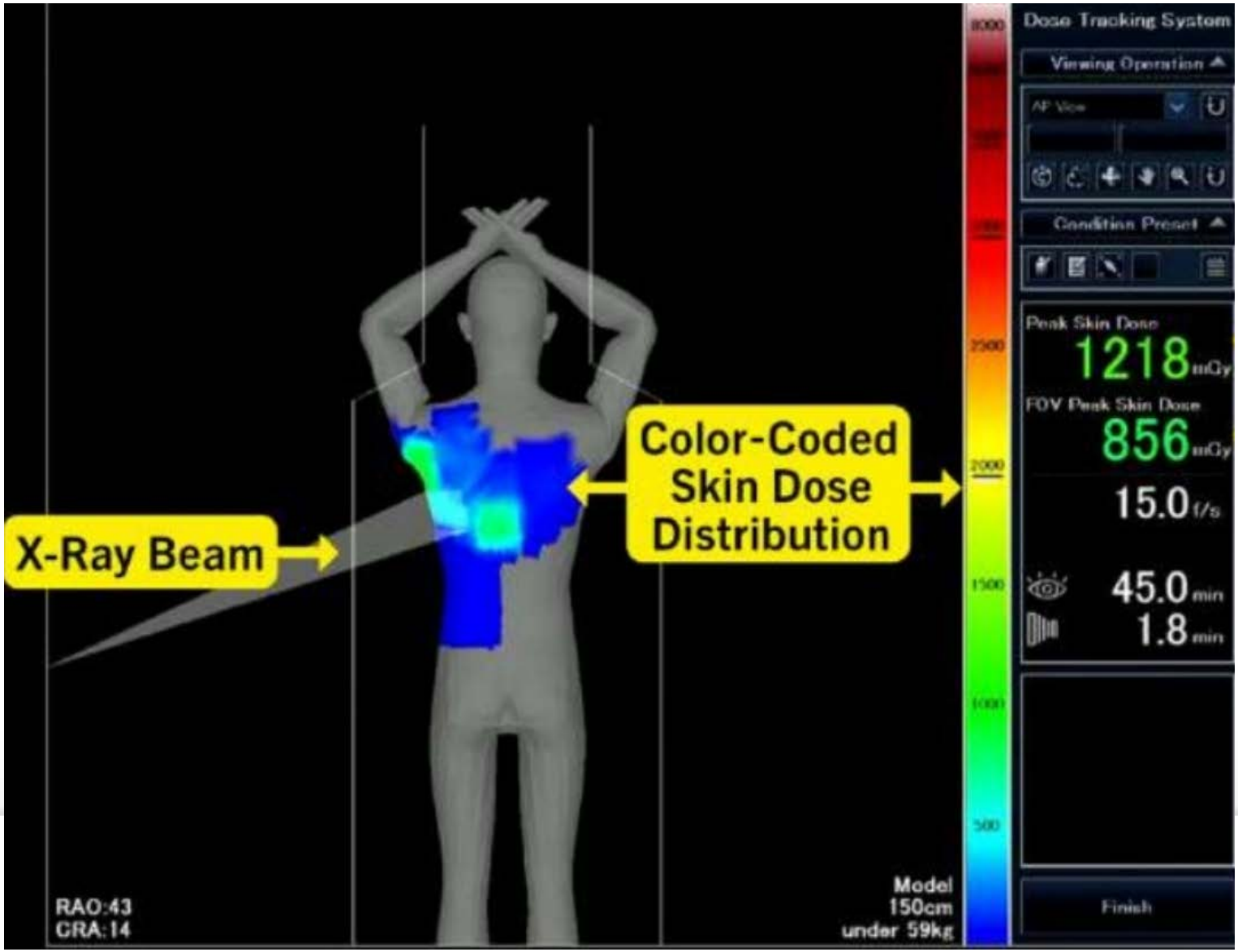


During fluoroscopy



RADIOGRAPHY AND FLUOROSCOPY

Real time skin dose mapping



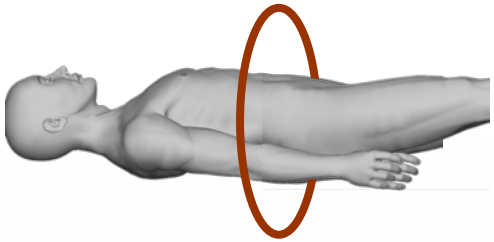
Example from medical canon

COMPUTED TOMOGRAPHY

Two operational units

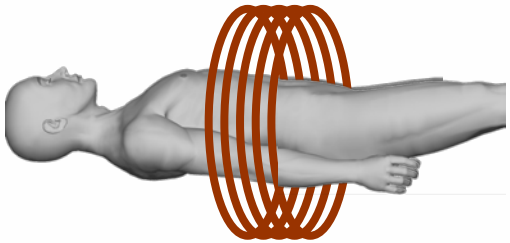
Dose from one tube rotation

- weighted CT dose index (**$CTDI_w$**)
- volume weighted CT dose index (**$CTDI_{vol}$**)



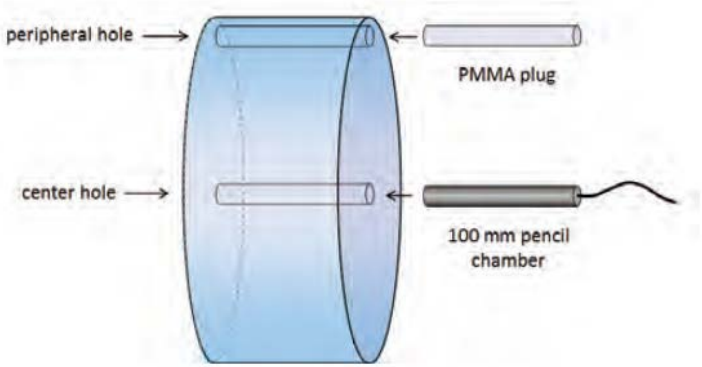
Dose from one sequence

- dose-length product (**DLP**)



COMPUTED TOMOGRAPHY

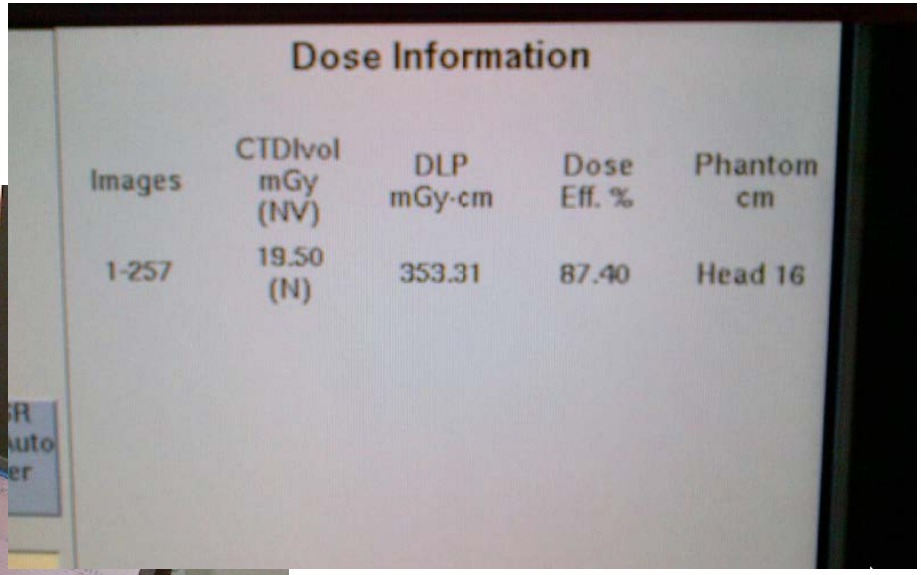
CT systems indicate CTDI and DLP doses based on measurements in **standardized** PMMA phantoms

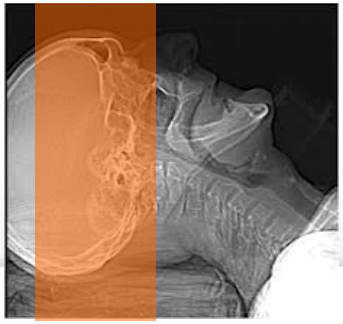


Does not directly reflect dose in patient (patient size, ...)

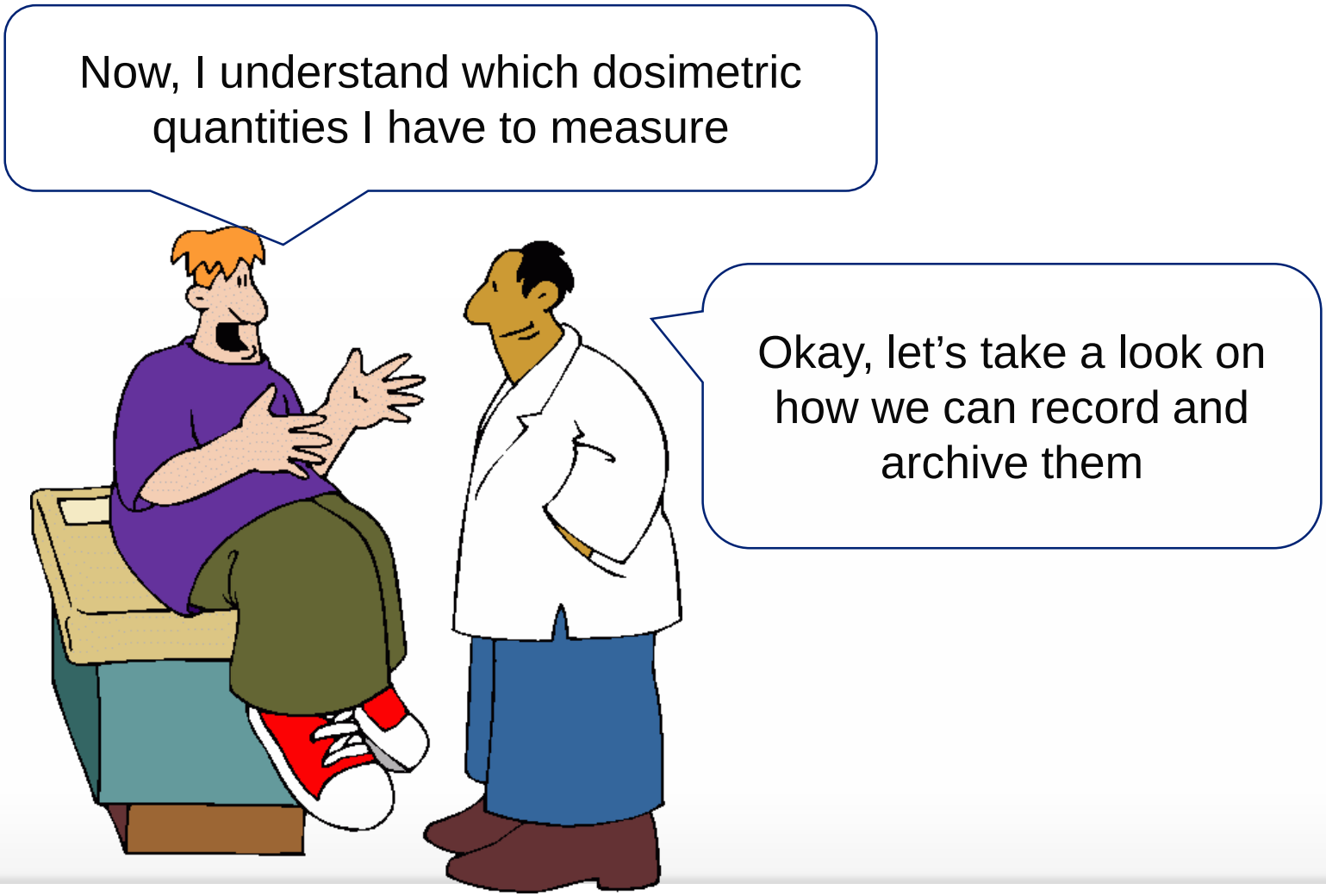
COMPUTED TOMOGRAPHY

Projected CTDIvol and DLP during planning of scan





PATIENT DOSE REGISTRATION



REGISTRATION OF PATIENT DOSES

BIJLAGE 3. Registratieformulier voor patiëntendosisgegevens - eenvoudige x-stralen onderzoeken (inclusief fluoroscopie voor positionering) bij minimum 50 patiënten per procedure of gedurende 3 maanden (driejaarlijkse dosisstudies)

Identificatie zaal: RX Toestel: Prestilix 160a Opera G50 * enkel indien DAP niet gebruikt wordt

Detector: Film-scherm CR (fosfor) DR Geneeten ** facultatief

Datum laatste DAP verificatie : *** duid de eenheid aan

Onderzoek: RX Bekken **** gecorrigeerde dosis (geef eenheid op)

Gevalideerd door: SSD (Skin Source Distance - focus-huid afstand)

Contactpersoon: Stralings/ysicus :

Periode: RESET DAP meter na elk onderzoek !

Nr.	Datum dd/mm/jj	Patient m/v	Patient leeft.	kV*	mAs*	Scopie (tijd)	SSD** (cm)	ED mGy	Veld-grootte**	Aantal opnamen	DAP *** mGy/cm²	Dosis corr.****	Init.	Opm.
1	zelfde	V	31	97	10,2	/				1	718			
2	zelfde	V	63	97	9,8	/				1	658			
3	"	M	72	97	15	/				1	1228			
4	zelfde	V	69	97	11	/				1	763			
5	"	V	68	97	16,6	/				1	1128			
6	zelfde	M	77	97	10,4	/				1	717			
7	zelfde	M	68	97	17	/				1	1169			
8	zelfde	V	38	97	8	/				1	563			
9	"	V	52	97	12,4	/				1	848			
10	"	M	63	97	14,8	/				1	728			

2014

MONITEUR BELGE — 11.10.2011 — BELGISCH STAATSBLAD

Gezien om gevoegd te worden bij het besluit van het Federaal Agentschap voor nucleaire controle van 28 september 2011 betreffende patiëntendosimetrie.

Brussel, 28 september 2011

De Directeur-generaal.

BIJLAGE 5. Registratieformulier voor patiëntendosisgegevens - CT-onderzoeken bij minimum 20 patiënten per procedure of gedurende 3 maanden (jaarlijkse dosisstudies)

Centrum:	UZ Brussel
Merk scanner:	GE Healthcare
Type scanner:	Revolution CT
Aantal slices:	256 slices - 16 cm
Iteratieve reconstructie software:	ASIR-V
Onderzoek:	**Hart (CCTA)**

Contactpersoon: Naam: Gert Van Gompel Voornaam: e-mail: gert.vangompel@uzbrussel.be

Periode: Van 1/02/2018 tot 19-10-2018

TCM = Tube Current Modulation * duid gebruikte CTDI aan

Nr	Datum dd/mm/jjjj	Patient Geslacht (M of V)	Patient Leeft. (j)	kVp (kV)	TCM (JA of NEE)	Iteratieve reconstructie (JA of NEE)	Low dose (JA of NEE)	Contrast-injectie (JA of NEE)	CTDI_vol CTDI_w* (mGy)	DLP (mGy.cm)	Aantal scans	initialen	Opmerking(en)
1	19-10-2018	M	43,06	100	JA	JA	JA	JA	16,97	364,82	1		
2	19-10-2018	M	64,1	100	JA	JA	JA	JA	7,34	172,48	1		
3	19-10-2018	M	51,94	100	JA	JA	JA	JA	14,09	366,38	1		
4	10/10/2018	V	69,05	100	JA	JA	JA	JA	5,05	100,92	1		
5	9/11/2018	M	52,55	100	JA	JA	JA	JA	6,83	160,44	1		
6	9/07/2018	V	74,4	120	JA	JA	JA	JA	24,96	411,80	1		
7	9/07/2018	V	77,82	120	JA	JA	JA	JA	2,37	37,94	1		
8	9/05/2018	M	76,48	120	JA	JA	JA	JA	4,32	60,45	1		
9	9/05/2018	M	71,4	120	JA	JA	JA	JA	7,14	149,96	1		
10	9/04/2018	M	78,47	100	JA	JA	JA	JA	10,31	242,28	1		
11	30-08-2018	M	44,41	120	JA	JA	JA	JA	11,01	242,20	1		
12	29-08-2018	M	57,55	120	JA	JA	JA	JA	21,79	414,08	1		
13	28-08-2018	V	80,98	100	JA	JA	JA	JA	7,46	149,26	1		
14	28-08-2018	V	74,46	120	JA	JA	JA	JA	10,49	167,88	1		
15	27-08-2018	M	71,6	120	JA	JA	JA	JA	29,43	474,49	1		
16	24-08-2018	M	62	120	JA	JA	JA	JA	4,5	71,28	1		
17	23-08-2018	M	56,86	100	JA	JA	JA	JA	14,1	225,85	2		
18	23-08-2018	M	56,86	100	JA	JA	JA	JA	10,6	381,64			
19	20-08-2018	V	83,39	100	JA	JA	JA	JA	8,67	173,41	1		
20	14-08-2018	M	38,88	100	JA	JA	JA	JA	5,96	128,13	1		
21	13-08-2018	V	63,98	120	JA	JA	JA	JA	2,10	33,62	1		
22	13-08-2018	M	72,41	100	JA	JA	JA	JA	15,93	374,38	1		
23	8/08/2018	V	62,1	120	JA	JA	JA	JA	3,13	43,79	2		
24	8/08/2018	V	62,1	100	JA	JA	JA	JA	17,21	404,54			
25	8/06/2018	M	63,76	100	JA	JA	JA	JA	13,32	306,25	1		
26	8/03/2018	M	18,06	100	JA	JA	JA	JA	5,15	121,08	1		
27	8/03/2018	V	64,92	100	JA	JA	JA	JA	7,59	163,14	1		
28	8/02/2018	V	80,27	100	JA	JA	JA	JA	12,86	257,11	1		
29	8/02/2018	V	40,2	120	JA	JA	JA	JA	3,71	51,97	1		
30	8/02/2018	M	72,15	100	JA	JA	JA	JA	9,87	222,09	1		
31	7/09/2018	M	59,38	120	JA	JA	JA	JA	11,70	275,03	1		
32	28-06-2018	M	57,98	100	JA	JA	JA	JA	12,37	290,61	1		
33	26-06-2018	M	67,83	100	JA	JA	JA	JA	10,42	244,85	1		
34	13-06-2018	M	80,18	100	JA	JA	JA		9,70	213,30	1		
35	6/12/2018	V	50,33	120	JA	JA	JA		22,95	539,40	1		
36	6/06/2018	M	62,07	100	JA	JA	JA		9,57	224,98	1		
37	6/05/2018	V	69,95	100	JA	JA	JA		4,73	101,78	1		
38	6/04/2018	V	74,21	120	JA	JA	JA		12,92	297,18	1		
39	31-05-2018	V	62,94	100	JA	JA	JA	JA	10,51	168,14	1		
40	31-05-2018	V	75,99	100	JA	JA	JA	JA	3,69	68,29	1		
41	31-05-2018	M	55,65	100	JA	JA	JA		10,84	232,98	1		
42	31-05-2018	V	73,91	100	JA	JA	JA	JA	5,78	92,54	1		

2018

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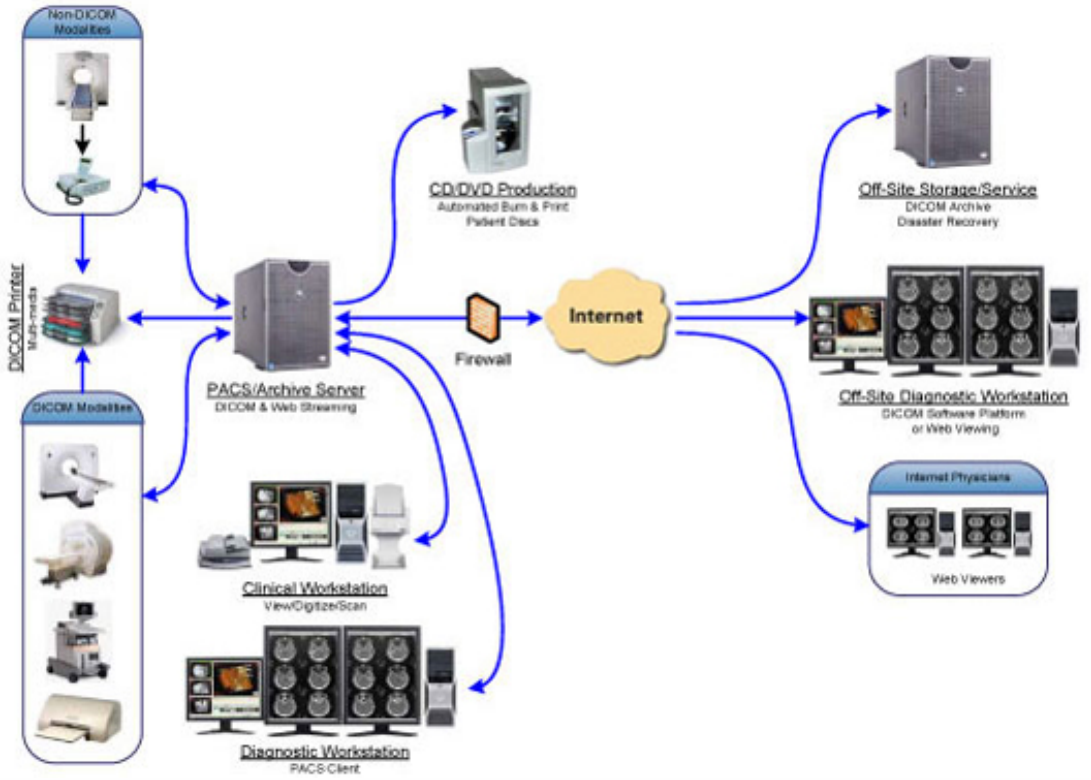
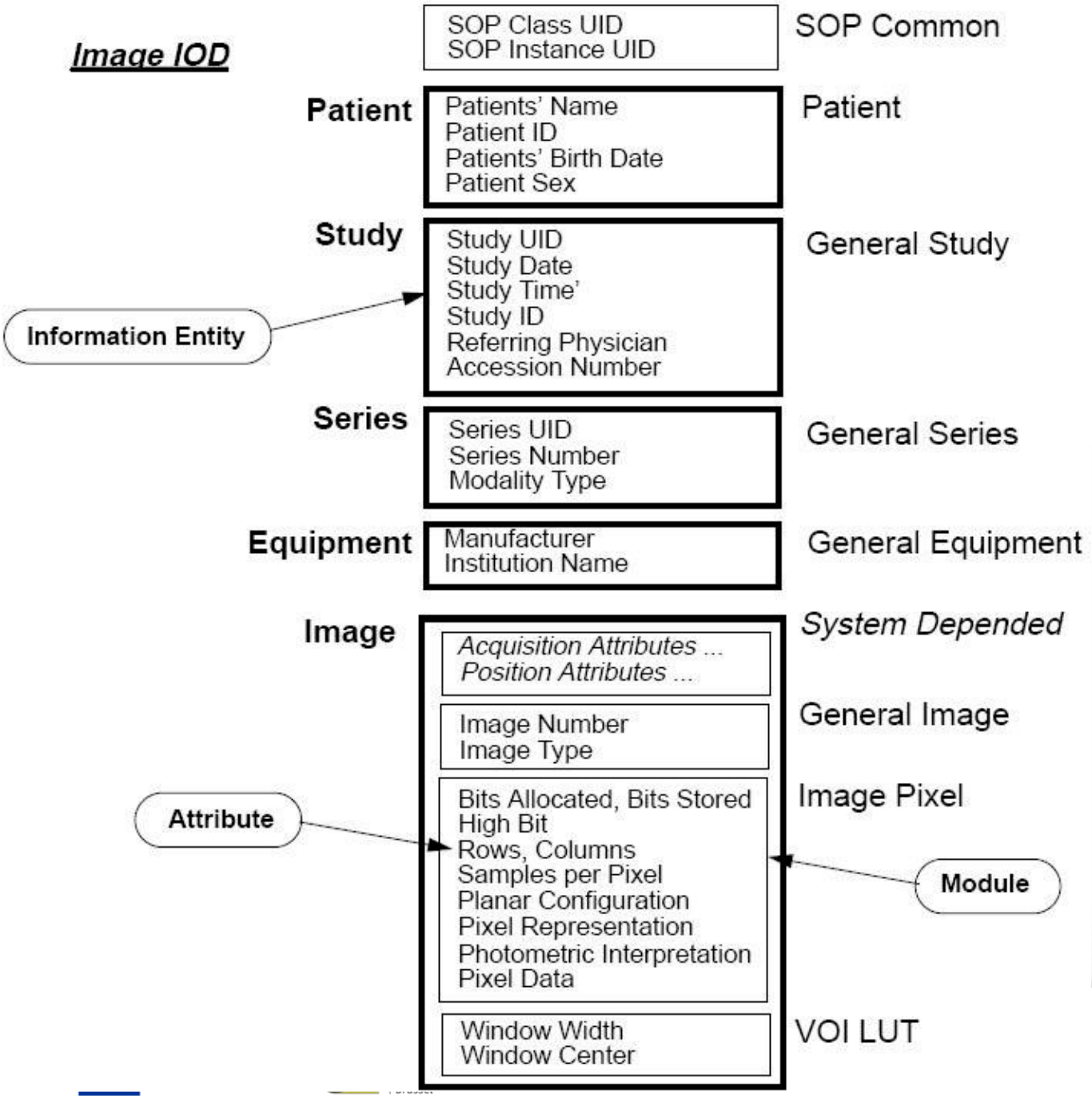
Universitair Ziekenhuis Brussel

REGISTRATION OF DOSES IN PATIENT IMAGES

Individual dose data are indicated on the console and archived in images (DICOM headers).





metadata provides information about the procedure, including dose

DICOM HEADER

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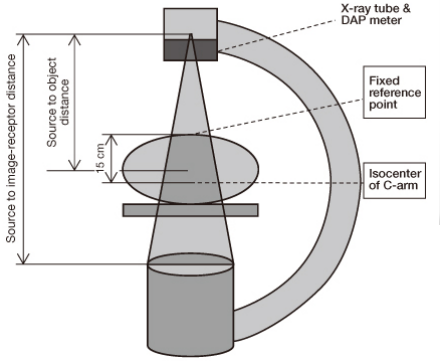
0018 0060	6	kvp	DS	1	"125.0"
0018 1000	12	device_serial_number	LO	1	"966169249110"
0018 1020	32	software_versions	LO	1-n	"3.1.2\PMS81.101.1.1 GXR GXRIM9.1"
0018 1030	6	protocol_name	LO	1	"Thorax"
0018 1050	6	spatial_resolution	DS	1	"0.143"
0018 1110	6	distance_source_to_detector	DS	1	"1800.0"
0018 1111	6	distance_source_to_patient	DS	1	"1746.0"
0018 1150	2	exposure_time	IS	1	"3"
0018 1152	2	exposure	IS	1	"1"
0018 1153	4	exposure_in_uas	IS	1	"700"
0018 115e	4	image_area_dose_product	DS	1	"0.23"
0018 1164	12	imager_pixel_spacing	DS	2	"0.143\0.143"
0018 1166	2	grid	CS	1-n	"IN"
0018 1400	64	acquisition_device_processing_description	LO	1	"UNIQUE: S:200 L:4.0 FC d:1,8
0018 1405	4	relative_x_ray_exposure	IS	1	"270"
0018 5101	2	view_position	CS	1	"PA"
0018 7050	16	filter_material	CS	1-n	"COPPER\ALUMINIUM"



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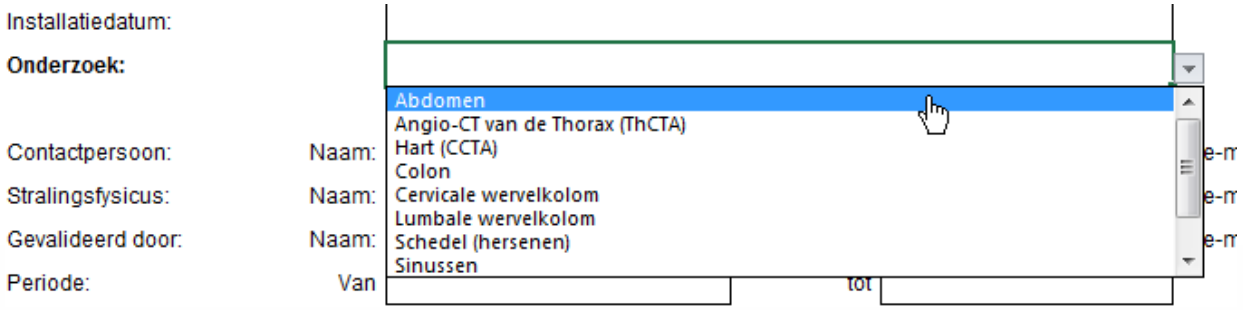
COMPARE LOCAL DOSE TO DRL



VOLWASSENEN	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)			
	Enkelvoudig onderzoek		Enkelvoudig onderzoek		Volledig onderzoek	
Onderzoek	P25	DRN (P75)	P25	DRN (P75)	P25	DRN (P75)
Abdomen	7	10	320	490	350	570
Angio CT van de thorax	5	11	165	300	180	330
Hart (CCTA)	10	25	140	290	190	480
Colon	3*	4*	150*	200*	230	460

CAVEAT: DATA CLEANUP

Example: CT abdomen

34 different protocols used for 1 study description

- Wrong protocol selection
- Pediatric data
- Combined studies (thorax - abdomen)
- Ultra-low dose protocol for follow up included

→ IMPACT on statistics

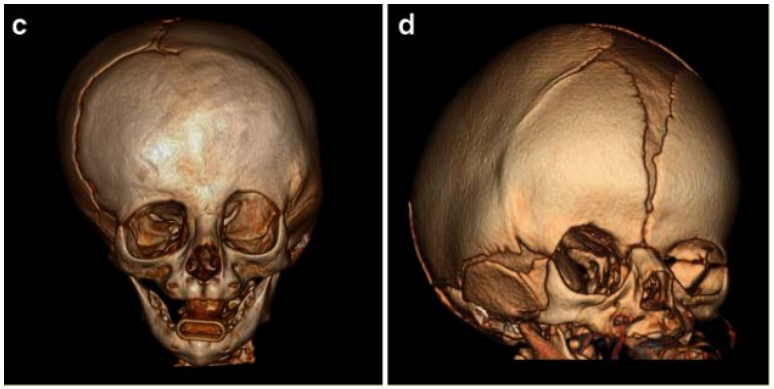
→ Data should be cleaned up before analysis

WHAT IS THE INDICATION?

Today, technical exposure parameters (including dose) are selected based on indication

Example CT head

Diagnosis of craniosynostosis in children with cranial deformities



C. Ernst, Eur Radiol (2016)

Soft tissue information is not required

80 kVp; 8 mAs; CTDIvol = 0,9 mGy

Belgian DRL CT Head: CTDIvol = 45 mGy

WHAT IS THE INDICATION?

Today, technical exposure parameters (including dose) are selected based on indication

Example CT chest

Assessment of structural lung abnormalities in patients with cystic fibrosis (CF)

C. Ernst, Radiology (2014)

80 kVp; 4 mAs; CTDIvol = 0,09 mGy

Belgian DRL CT chest: CTDIvol = 3,5 mGy

STANDARD RADIOLOGY CODES

A standard system for naming radiology procedures, based on the elements which define an imaging exam such as modality and body part.

RPID code

RSNA Informatics
RadLex® Playbook

Search Core Playbook Orderables

MODALITY	---Select---	ANATOMIC_FOCUS	---Select---
POPULATION	---Select---	LATERALITY	---Select---
BODY_REGION	---Select---	REASON_FOR_EXAM	---Select---
MODALITY_MODIFIER	---Select---	TECHNIQUE	---Select---
PROCEDURE_MODIFIER	---Select---	PHARMACEUTICAL	---Select---
		VIEW	---Select---

Search

RPID	Letter Code	Short Description	Long Description
RPID2	CTABCA	CT Abd Angio w/wo	CT Abdomen Angio w and wo IV Contrast
RPID3	CTABU	CT Abd wo	CT Abdomen wo IV Contrast
RPID4	CTABC	CT Abd w/wo	CT Abdomen w and wo IV Contrast
RPID5	CTABE	CT Abd w	CT Abdomen w IV Contrast
RPID6	CTCHCA	CT Chest Angio w/wo	CT Chest Angio w and wo IV Contrast
RPID7	CTHDCA	CT Head Angio w/wo	CT Head Angio w and wo IV Contrast
RPID10	CTCLECAR	CT Leg Angio w/wo	CT Lower Extremity Angio w and wo IV Contrast
RPID11	CTNKCA	CT Neck Angio w/wo	CT Neck Angio w and wo IV Contrast
RPID12	CTPLCA	CT Pelv Angio w/wo	CT Pelvis Angio w and wo IV Contrast

CAVEAT: DATA CLEANUP

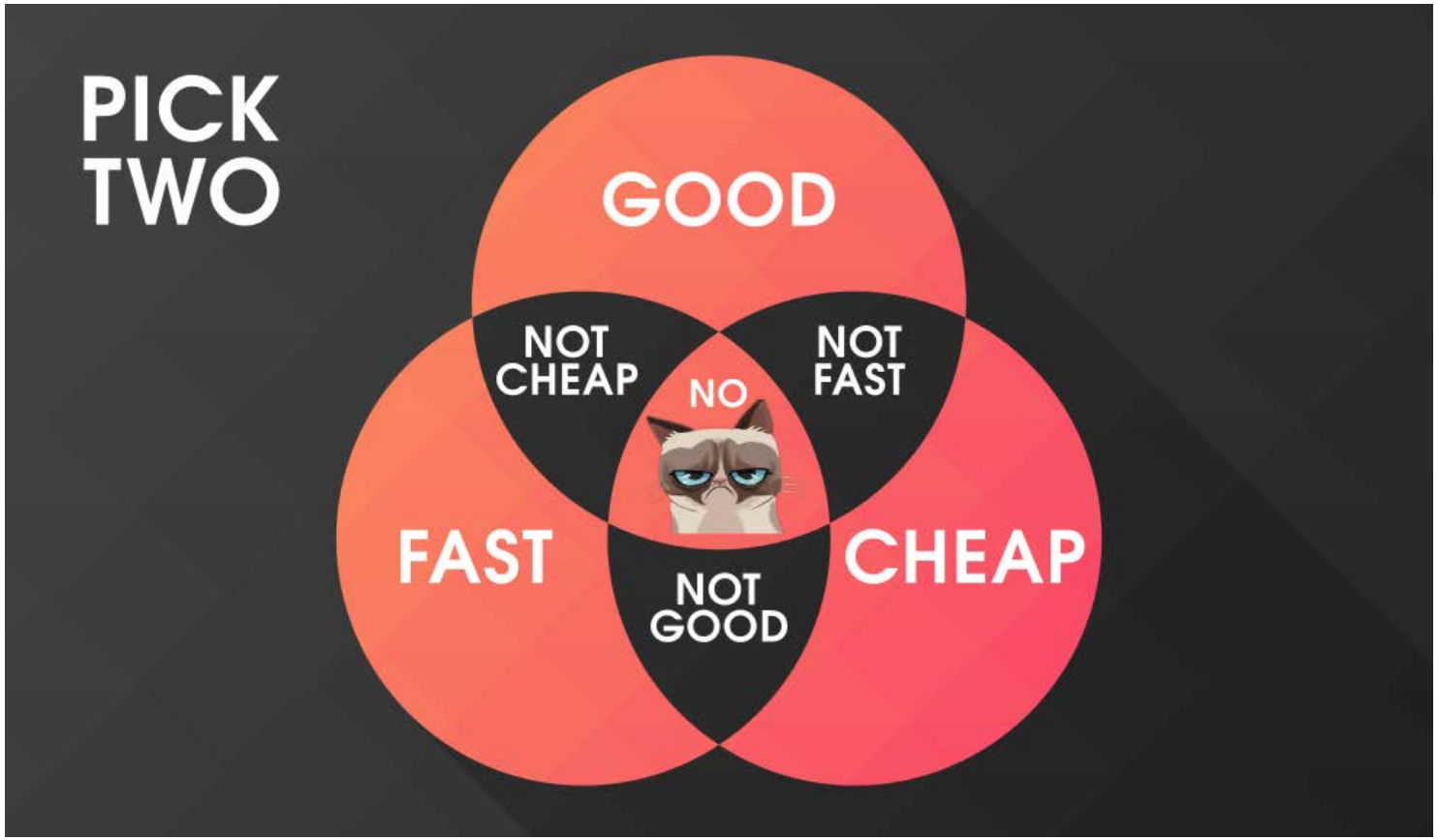
Example: CT head

	RadLex code	# patients	CTDIvol (mGy)
CT Hersenen (ALL)		**1153**	**34,0**
Hersenen axiaal	22	612	40,4
CT stroke (hersenen+perfusie+halsvaten)	96	458	25,1
Hersenen axiaal -/+ contrast	23	34	34,7
Flebo hersenen (sinus trombose)	7	49	21,1

RSNA Informatics
RadLex® Playbook

Belgian DRL CT Head
$CTDI_{vol}$ = 50 mGy

PROJECT MANAGEMENT TRIANGLE



DOSE MANAGEMENT

- Protocols with high dose compared to national and international reference values
  - Optimisation of higher-dose protocols
  - Uniformisation between systems

- New systems
- New techniques / changed protocols
- Check correct practices

  CT positioning

  Retakes

  ...

COMPARISON WITH NATIONAL AND INTERNATIONAL REFERENCE VALUES

ICRP 117 report, 2010

Table 4.6. Typical patient dose levels (rounded) from gastroenterology and hepatobiliary procedures.

Procedure	Relative mean effective dose to patient (0 mSv 35)	Relative mean radiation dose to patient*	Reported values: Fluoroscopy time (min)	Entrance skin dose (mGy)	Dose-area product (Gycm^2)	Effective dose (mSv)	Reference†
ERCP (diagnostic)		C,D	2–3	55–85	15	3–6	a,b
ERCP (therapeutic)		E,F	5–10	179–347	66	20	a,b
Biopsy		C	n.a.	n.a.	6	1.6	a,c
Bile duct stenting		E	n.a.	499	43–54	11–14	a,c,d
Percutaneous transhepatic cholangiography		D	6–14	210–257	31	8.1	a
Bile duct drainage		F,G	12–26	660	38–150	10–38	a,d,e
Transjugular intrahepatic portosystemic shunt creation		F,G	15–93	104–7160	14–1364	19–87	a,e,f
Transjugular hepatic biopsy		D	6.8	n.a.	34	5.5	f

ERCP, endoscopic retrograde cholangio-pancreatography; n.n., not available.
† (a) UNSCEAR, 2010; (b) Olgar et al., 2009; (c) Hart et al., 2002; (d) Dauer et al., 2009; (e) Miller et al., 2003a; (f) McParland, 1998.
* A, <1 mSv; B, 1–<2 mSv; C, 2–<5 mSv; D, 5–<10 mSv; E, 10–<20; F, 20–35 mSv; G, >35 mSv, based on effective dose.

ICRP

TABLE 14 : Summary of data on other examinations and interventional procedures (adults)

Examination/procedure	Number Hospitals	Rooms	Patients	Mean of room mean DAP (Gy cm^2)	Mean of room mean fluoro. time (seconds)	Mean tube voltage (kV)
AICD	6	9	222	7	235	
Angiography (Cerebral)	5	8	913	69	772	85
Angiography (Mesenteric)	8	11	118	151	1009	74
Angiography (Renal)	6	7	64	48	361	71
Angioplasty (Femoral)	6	7	149	49	588	
Angioplasty (Iliac)	8	9	225	52	401	
Aortography (Arch)	9	13	179	21	249	70
Arthrography (Hip)	8	10	82	1.4	55	
Dacryocystogram	6	12	180	2.4	63	
Electrophysiology	6	11	399	11	1019	72
Embolisation (Uterine fibroid)	10	11	273	120	1715	
Embolisation (Varicocele)	8	8	71	20	625	70
ERCP (Diagnostic)	9	14	362	4	154	73
ERCP (Interventional)	7	16	820	10	263	70
Filter (Inferior Vena Cava)	10	18	198	21	214	71
Hip	6	14	1713	4	46	71
Naso-gastric feeding tube	11	19	198	7	270	71
Oesophageal dilation	6	10	55	7	233	71
Pacemaker (Biventricular)	8	14	332	30	1472	
Pacemaker (Temporary)	8	16	234	4.5	191	70
Patent Foramen Ovale closure	5	5	90	15	664	
Pelvis	9	27	1761	3	32	70
Percutaneous Endoscopic Gastrostomy	8	13	69	4	138	71
Percutaneous Transhepatic Cholangiography	12	19	246	45	891	69
PTCA 2 stents*	9	19	815	52	653	
Radio Frequency cardiac catheter ablation*	9	21	2510	23	1348	70
Radiologically Inserted Gastrostomy	5	6	65	8	165	70
Retrograde pyelography	7	8	34	5	82	74
Right Heart Catheterisation*	6	7	99	27	270	81
Stent (Biliary)	8	11	97	37	671	70
Stent (Bowel)	5	10	51	36	691	75
Stent (Iliac artery)	5	5	77	52	722	70
Stent (Superior Vena Cava)	7	8	39	21	338	71
Stent (Ureteric)	12	19	206	14	525	75
Thoracic spine	7	22	1238	3		
Urodynamics	10	14	803	4	47	77

* Mean patient weight range 75–85 kg.

Internationale referenties (HPA 2010)

DRL

FANC
federaal agentschap voor nucleaire controle

• DRN's bij volwassenen

VOLWASSENEN	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)			
	Enkelvoudig onderzoek		Enkelvoudig onderzoek		Volledig onderzoek	
Onderzoek	P25	DRN (P75)	P25	DRN (P75)	P25	DRN (P75)
Abdomen	7	10	320	490	350	570
Angio CT van de thorax	5	11	165	300	180	330
Hart (CCTA)	10	25	140	290	190	480
Colon	3*	4*	150*	200*	230	460
Cervicale wervelzuil	14	25	230	450	-	-
Lumbale wervelzuil	18	26	380	600	-	-
Schedel (hersenen)	35	50	640	900	-	-
Sinussen	2,5	6	35	80	-	-
Thorax	5	8	170	260	-	-
Thorax - abdomen	5	8,5	320	550	480	800

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COMPARISON WITH NATIONAL AND INTERNATIONAL REFERENCE VALUES

	CT a			CT b			CT c			DRL CTDI enklel		DRL DLP enkel		DRL DLP totaal	
	CTDI	DLP enkel	DLP totaal	CTDI	DLP enkel	DLP totaal	CTDI	DLP enkel	DLP totaal	P25	P75	P25	P75	P25	P75
thorax	5.42	228.56	240.67	10.70	377.75	378.93	4.32	164.97		5.5	9	200	320		
abdomen	9.21977	519.78993	532.3206	11.88	614.40	634.45	7.31	395.77	425.65	7.5	12	350	600		
thorax-abdomen			753.34			750.35	5.05	278.77	420.23					550	960
CWZ	14.73939	397.18788	460.3429	28.37	569.09		10.61	231.63		16	30	280	490		
LWZ	26.96135	837.1366	838.3216	27.11	711.16		21.80	616.45		20	30	400	650		
schedel				23.32	439.22	529.29	41.58	854.78	873.69	39	55	660	950		
sinussen	6.37	108.67		1.76	25.02	87.38				3	7	40	90		
hart CTCA	13.95857	246.8	255.3566				6.76	100.44	110.92	14	35	200	490		
angio CT thorax	8.3	402.30	528.3				2.22	89.75	156.96	6	15	180	410		
colon			501.9											230	530

	dosis
	lager dan p25
	iets boven P25
	tussen p25-p75
	iets onder p75
	boven p75

Justification / optimization needed !

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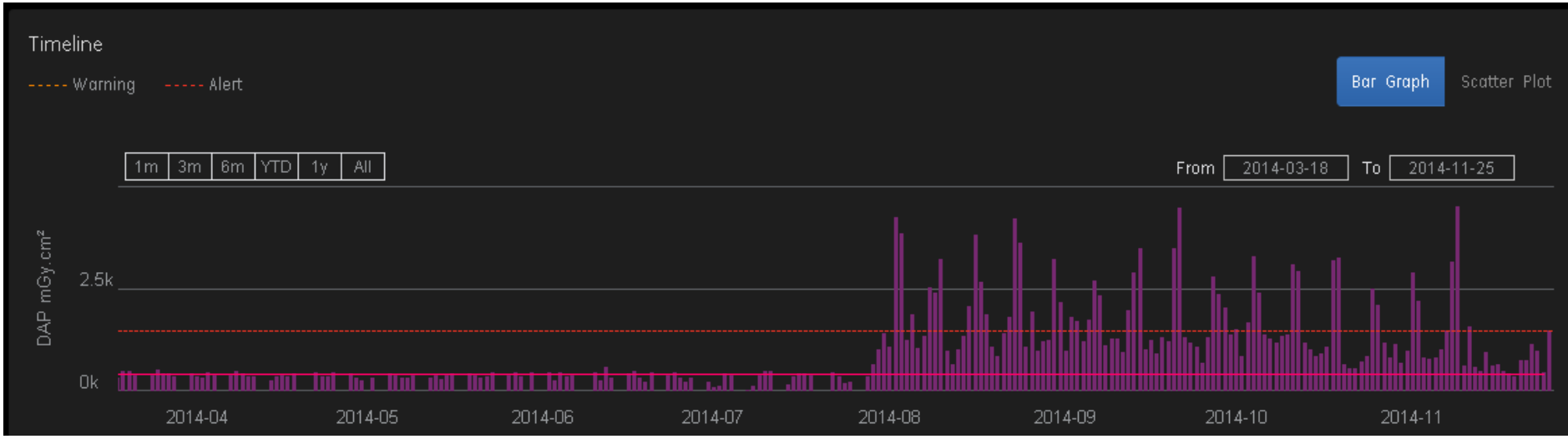
FOLLOW-UP ON NEW SYSTEMS

Daily dose UZ Brussel

Thorax PA+LAT

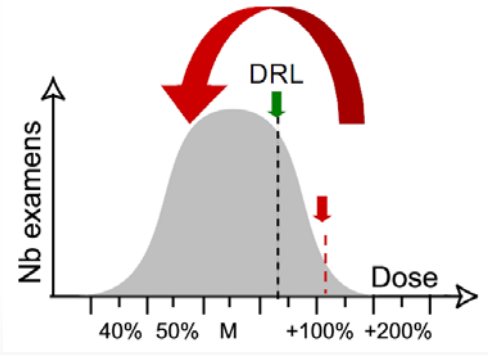


New RX system connected with dose registration

FOLLOW UP ON NEW SYSTEMS

	Room A	Room B	Room C	Room D	Room E	Room F	national P25	national P75 (DRL)
DAP (mGy.cm²)	506.37	352.16	468	297	58.05	2654	530	1450
aantal procedures	7580	484	265	10	1482	1728		

FANC
federaal agentschap voor nucleaire controle



Conventionele radiologie bij volwassenen

Onderzoek		DRN in DAP (cGy.cm²) 25e p	75e p
Abdomen		120	330
Bekken face (AP)		170	450
Thorax PA		13	35
Thorax lateraal		40	110
Thorax aan bed		12	25
Lumbale wervelzuil	volledig (*)	7,5 (*)	21 (*)
	face	95	280
	profiel	200	500
Schedel	volledig	60	150
	face	25	60
	profiel	20	60

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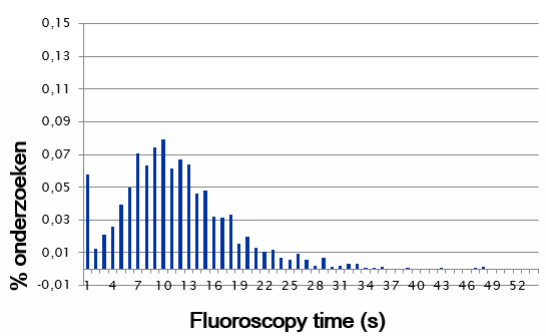
FOLLOW-UP ON NEW SYSTEMS

	Room A	Room B	Room C	Room D	Room E	Room F	national P25	national P75 (DRL)
DAP (mGy.cm²)	506.37	352.16	468	297	58.05	2654	530	1450
aantal procedures	7580	484	265	10	1482	1728		

Reason?

Human

Awareness

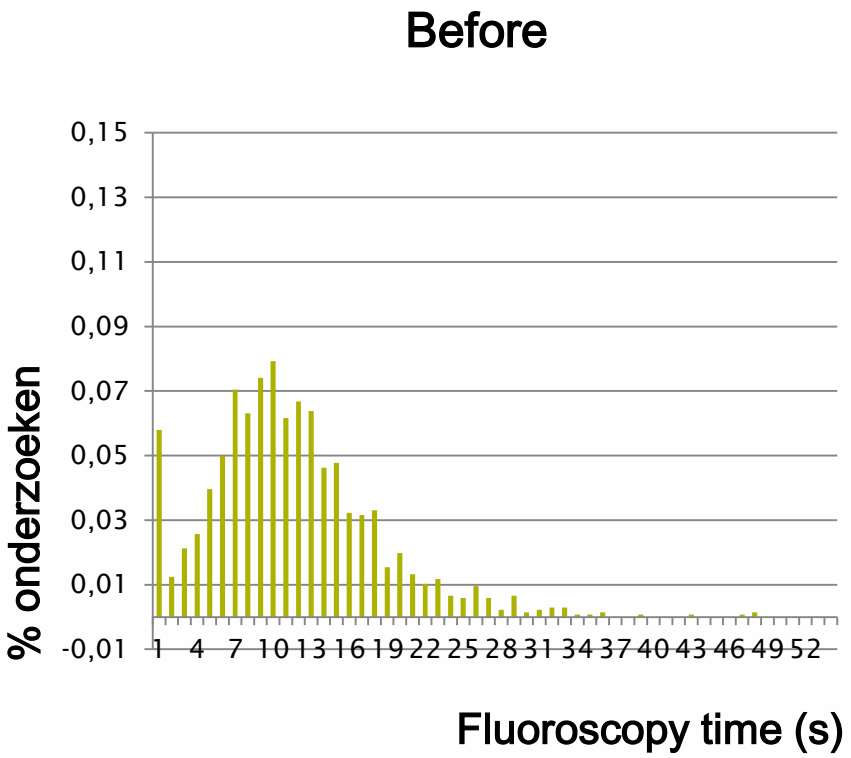


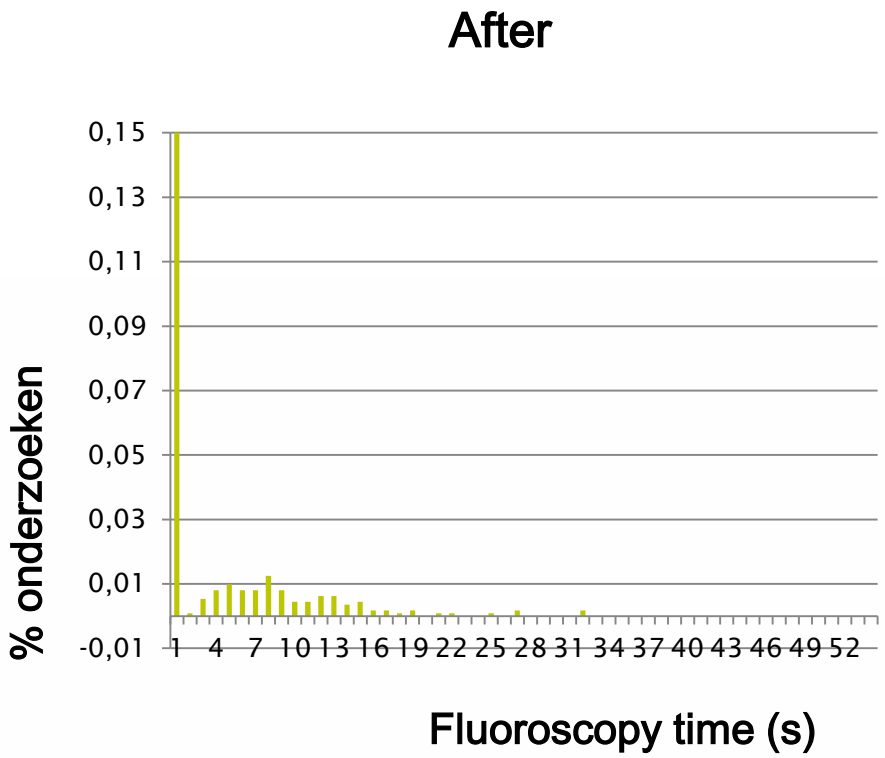
Equipment

Fluoroscopy dose rate very high
Dose of 1 sec fluoroscopy = PA+lat radiography

→ Technical intervention

USE OF FLUOROSCOPY FOR POSITIONING





Awareness + Training

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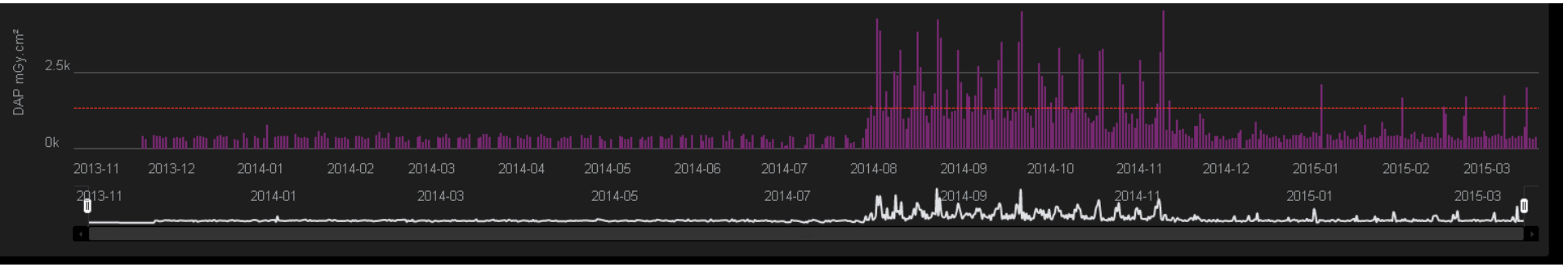
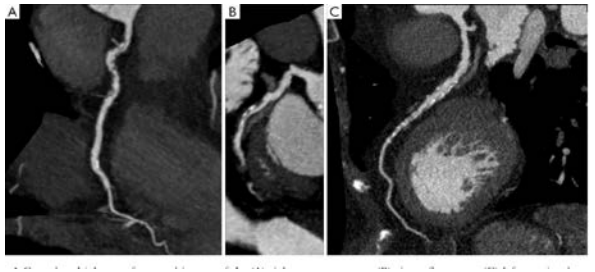
4 MONTHS LATER …

Mean dose over time in Radiology department for thorax PA + lateral



COMPARE CT SCANNERS



Impact new CT technology for CCTA:

Analysis

Local Study Description

Lexicon Element

Protocol

Date Range:

From YYYY-MM-DD To YYYY-MM-DD

Study 1

Site: Universitair Ziekenhuis Brussel

Device: PHILIPS ICT

Local Study Description: CT HART

Age Range: From To

Study 2

Site: Universitair Ziekenhuis Brussel

Device: GE Revo CT

Local Study Description: CT HART

Age Range: From To

Comparison Data

MEAN DLP

343.39 mGy.cm

Range: 1.00 - 2391.70 mGy.cm

Number of studies: 2019

Comparison Data

MEAN DLP

148.32 mGy.cm

Range: 9.66 - 486.09 mGy.cm

Number of studies: 73

Prospective scan

Prospective one heartbeat scan

Comparison chart

1m 3m 6m YTD 1y All

Study 1 Study 2

From 2013-10-01 To 2015-09-21

DLP (mGy.cm)

2k

1k

0k

Nov '13 Dec '13 Jan '14 Feb '14 Mar '14 Apr '14 May '14 Jun '14 Jul '14 Aug '14 Sep '14 Oct '14 Nov '14 Dec '14 Jan '15 Feb '15 Mar '15 Apr '15 May '15 Jun '15 Jul '15 Aug '15 Sep '15

2014-01 2014-04 2014-07 2014-10 2015-01 2015-04 2015-07

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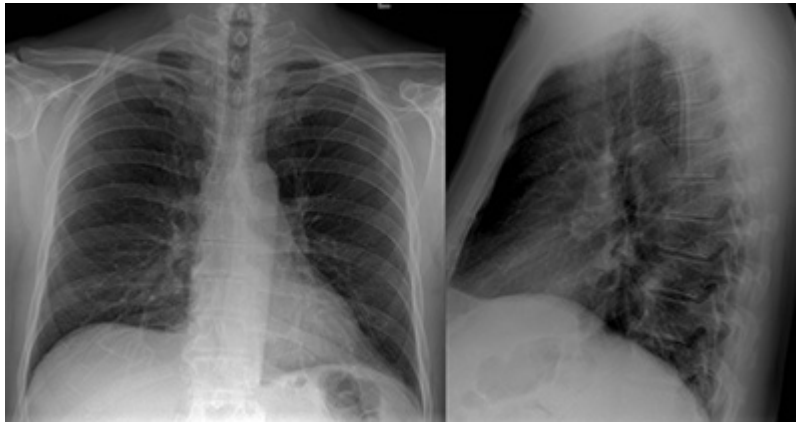
CASE STUDY RX THORAX : #RETAKES ?



2 Month follow up

1377 thorax examinations

Standard of care : 2 images (PA and lateral)

269 / 1377 (15%) examinations with 3 or more images → retakes ?

→ individual comparison with PACS

- 192 DE opnames (separate protocol needed ?)
- 26 insp/exp opnames (separate protocol needed ?)
- **56 retakes (4%)**

CONCLUSIONS

- Use the proper **dosimetric quantity** for your clinical practice
- Maintain dose values **as low as reasonably achievable** considering the clinical benefit of the procedure
- Work **under radiation dose limits** (for professionals) and use "**Diagnostic Reference Levels" (DRLs)** for patients. Avoid too high or too low doses.
- **Avoid radiation injuries** and establish a clinical follow-up for high dose procedures

TAKE HOME MESSAGE

A lot of technical tools are available to measure, record and evaluate patient doses from medical imaging