Universitätsspital Basel

Revised diagnostic reference levels in CT imaging: Progress in radiation protection?

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KSR Webinar

Radiation Protection in Medicine

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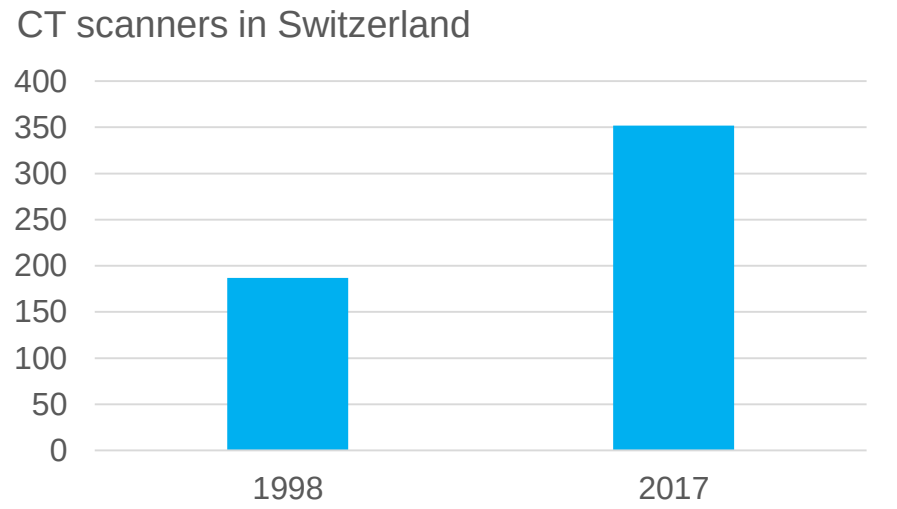
Outline

- Introduction
  - Radiation exposure due to CT
  - Diagnostic Reference Levels (DRLs)
- Current Swiss DRLs for CT
- Comparison to previous Swiss DRLs
- Dose and image quality
- Summary

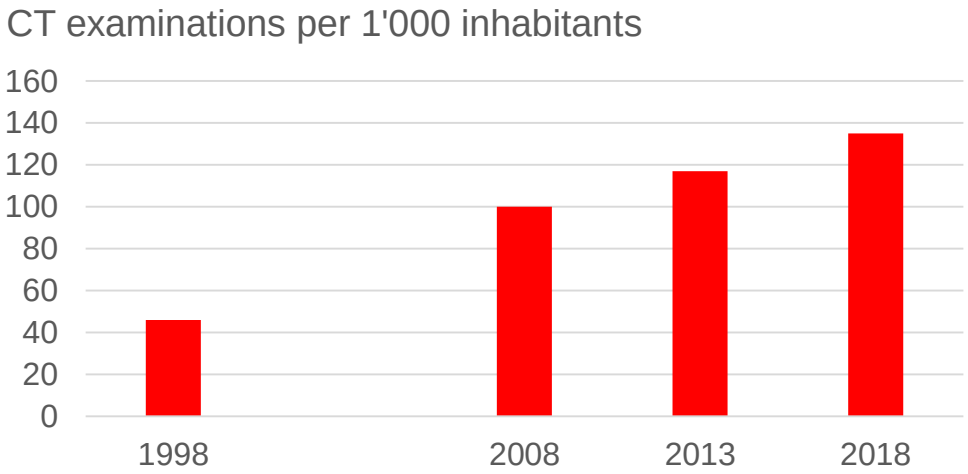
Introduction

- Sharp increase in the number of CT scanners from 1998 to 2017



numbers from [1]

- Corresponding increase in the number of CT examinations

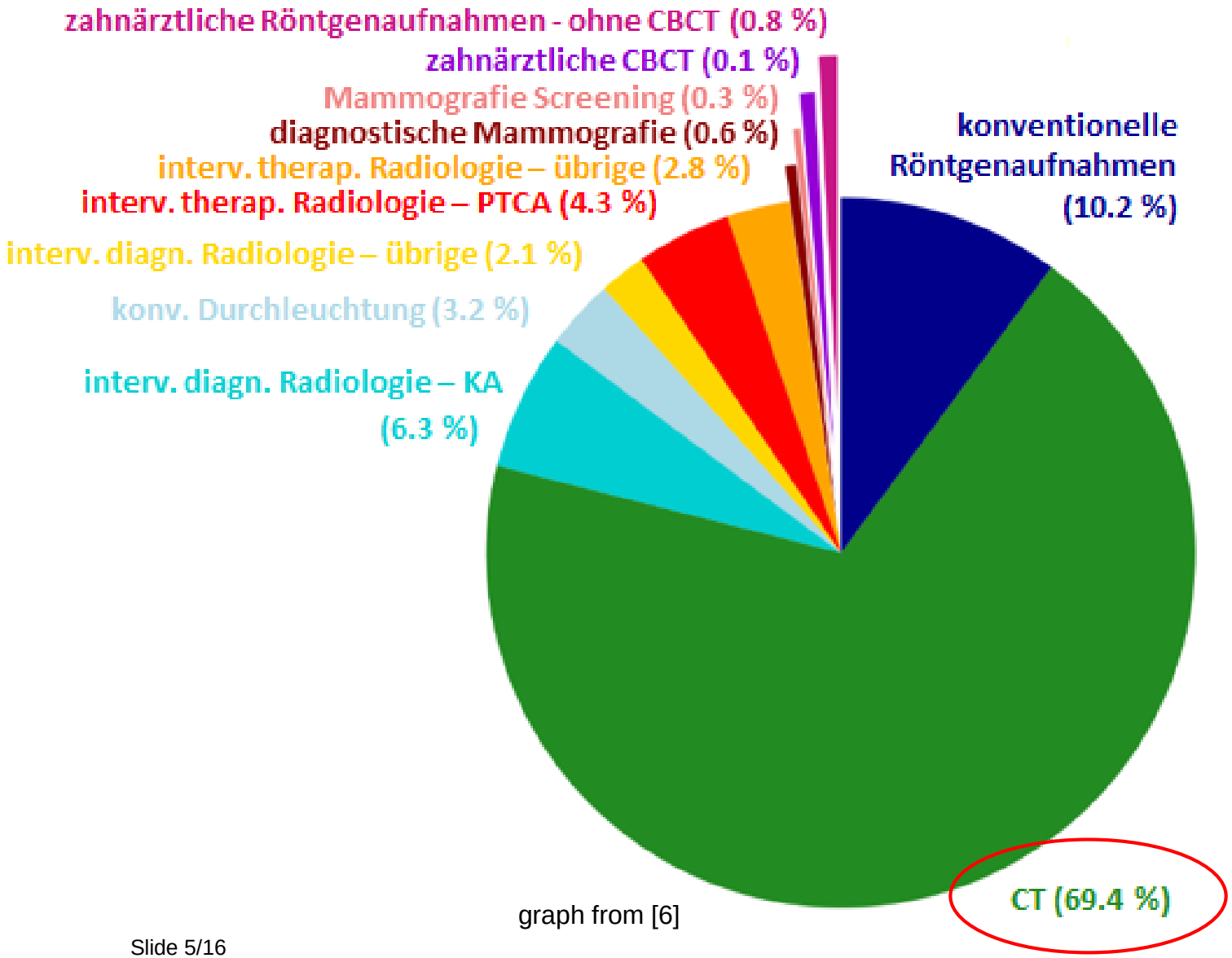


numbers from [2-6]

Introduction

- As of 2018, CT contributes **69.4%** to the radiation doses used in radiodiagnostic procedures.

- 0.96 mSv per inhabitant per year due to CT



graph from [6]

Introduction

- DRLs are a tool for dose optimization
- The DRL concept is implemented in the RPO

Art. 35 Diagnostic reference levels

[1] The FOPH shall publish recommendations on radiation doses for diagnostic, interventional or nuclear medicine examinations in the form of diagnostic reference levels.

[2] To this end, it shall conduct national surveys based on the data specified in Article 34 paragraph 2, take international recommendations into account and publish the results.

[3] Licence holders must regularly review their own practices and account for any deviations from diagnostic reference levels.

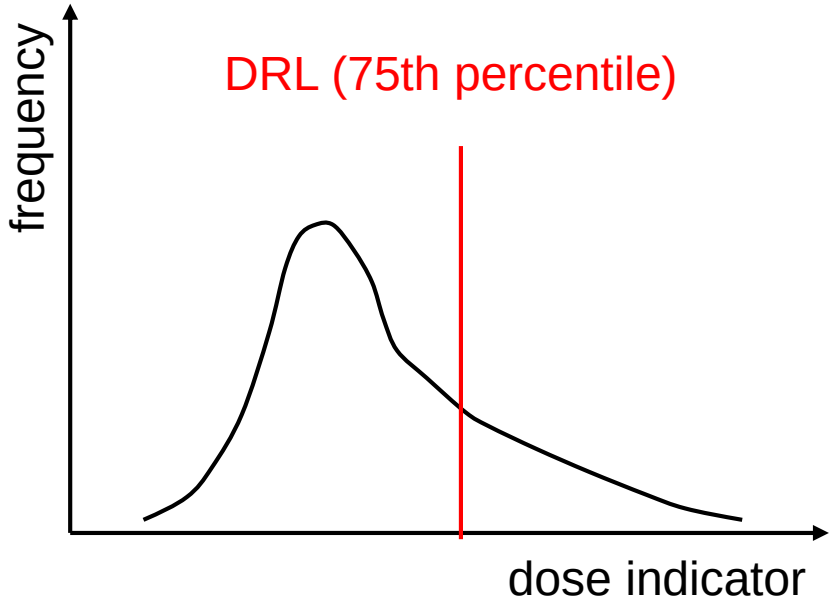
Introduction

Setting up DRLs:

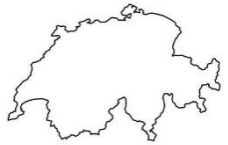
1. Dose distributions ($CTDI_{vol}$, DLP) for different examination types are obtained
2. DRLs are set at the 75th percentile

Application of DRLs:

1. If a DRL is consistently exceeded, investigations have to be performed
2. Dose levels have to be reduced if there is no good reason for elevated doses



Current Swiss DRLs for CT

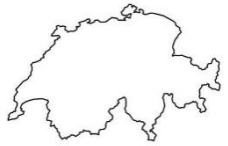


- published by the FOPH in 2018 [7,8]
- 14 participating institutes
- 50 CT scanners
- 5 dose management software tools
- Data from 2014-2017 included

Institute	Number of CTs	Dose Management Software
Centre Hospitalier Universitaire Vaudois (CHUV), Lausanne	5	DoseWatch (GE)
Kantonsspital Frauenfeld (KSF), Frauenfeld	2	Radimetrics (Bayer)
Kantonsspital Graubünden (KSGR), Chur	3	Radimetrics (Bayer)
Universitätsspital Zürich (USZ), Zürich	3	tqm|DOSE (Agfa)
Kantonsspital Münsterlingen (KSM), Münsterlingen	2	Radimetrics (Bayer)
Universitätsspital Basel (USB), Basel	3	Radimetrics (Bayer)
Hôpitaux Universitaires de Genève (HUG), Genève	7	Radimetrics (Bayer)
Affidea Schweiz, 5 sites	5	DoseWatch (GE)
Privatklinikgruppe Hirslanden, 9 sites	10	DoseM (INFINITT)
Stadtspital Triemli, Zürich	2	DoseWatch (GE)
Kantonsspital Aarau (KSA), Aarau	3	in-house solution
Merian Iselin Klinik, Basel	1	Radimetrics (Bayer)
Kantonsspital Baselland (KSBL), 3 sites	3	Radimetrics (Bayer)
Felix-Platter-Spital (FPS), Basel	1	Radimetrics (Bayer)

data from [8]

Current Swiss DRLs for CT



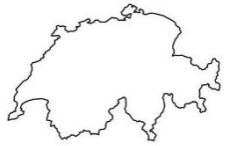
Anatomical region	Master protocol (depending on clinical indication)
Head	Head
	Facial Bones / Sinuses
	Low Dose Sinuses (Sinusitis)
Neck	Neck
	CT Angiography (Carotid Angio)
Chest	Chest
	CT Angiography (Exclusion Pulmonary Embolus -PE)
Abdomen-Pelvis	Abdomen-Pelvis
	Exclusion Kidney Stones
	Liver Multiphase (e.g. HCC)
	CT Angiography (Abdomen-Pelvis)
Chest-Abdomen-Pelvis	Chest-Abdomen-Pelvis
	CT Angiography (Chest-Abdomen-Pelvis)
Musculoskeletal	Cervical Spine
	Thoracic Spine / Lumbar Spine

Head phantom
(16 cm diameter)

Body phantom
(32 cm diameter)

data from [8]

Current Swiss DRLs for CT



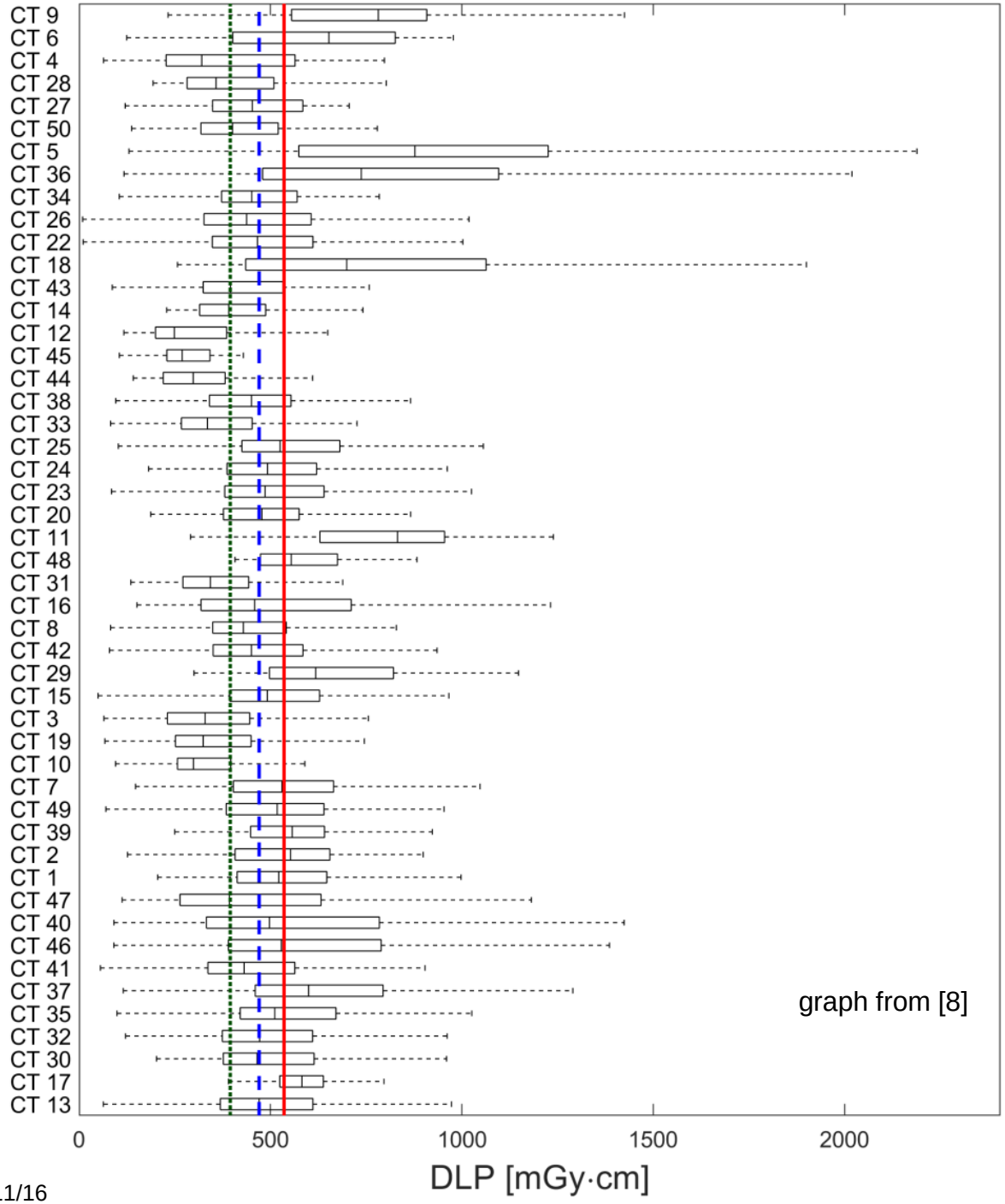
Master protocol	Number of exams	Number of CTs with at least 20 exams
Head	58,323	45
Facial Bones / Sinuses	6,322	31
Low Dose Sinuses (Sinusitis)	2,328	15
Neck	3,079	30
CT Angiography (Carotid Angio)	4,528	19
Chest	32,437	49
CT Angiography (Exclusion PE)	16,998	41
Abdomen-Pelvis	33,895	49
Exclusion Kidney Stones	12,625	35
Liver Multiphase (e.g. HCC)	3,621	26
CT Angiography (Abdomen-Pelvis)	1,102	18
Chest-Abdomen-Pelvis	25,613	35
CT Angiography (Chest-Abdomen-Pelvis)	2,480	22
Cervical Spine	8,710	36
Thoracic Spine / Lumbar Spine	8,208	35
Total	**220,269**	

data from [8]

Current Swiss DRLs for CT

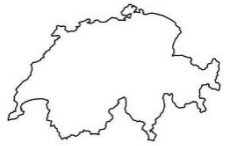
- Example: abdomen-pelvis master protocol
- DRL calculated according to ICRP publication 135 [9]: 75th percentile of the distribution of the CT scanner medians

DRL: 75th percentile
50th percentile
25th percentile



graph from [8]

Current Swiss DRLs for CT



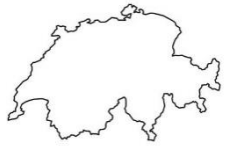
Master protocol	25th Percentile		50th Percentile		75th Percentile (DRL)	
	$CTDI_{vol}$ [mGy]	DLP [mGy cm]	$CTDI_{vol}$ [mGy]	DLP [mGy cm]	$CTDI_{vol}$ [mGy]	DLP [mGy cm]
Head	35	650	42	750	51	890
Facial Bones / Sinuses	9	150	15	240	25	420
Low Dose Sinuses (Sinusitis)	3	40	5	70	6	90
Neck	9	240	12	290	16	410
CT Angiography (Carotid Angio)	5	190	8	260	11	360
Chest	5	170	6	210	7	250
CT Angiography (Exclusion PE)	4	150	6	200	8	300
Abdomen-Pelvis	8	390	10	470	11	540
Exclusion Kidney Stones	4	150	4	180	6	280
Liver Multiphase (e.g. HCC)	7	220 [830]	9	300 [960]	11	350 [1170]
CT Angiography (Abdomen-Pelvis)	7	340	9	450	11	530
Chest-Abdomen-Pelvis	7	500	9	610	11	740
CT Angiography (Chest-Abdomen-Pelvis)	5	340	6	450	10	730
Cervical Spine	12	260	14	300	17	360
Thoracic Spine / Lumbar Spine	13	–	18	–	25	–

data from [8]

Values are per acquisition, only for liver multiphase a value for total examination DLP is quoted in addition [in square brackets]

DRLs

Comparison to previous Swiss DRLs



The average DRL reduction is -30% for $CTDI_{vol}$ (0% to -47%) and -22% for DLP (+20% to -40%).

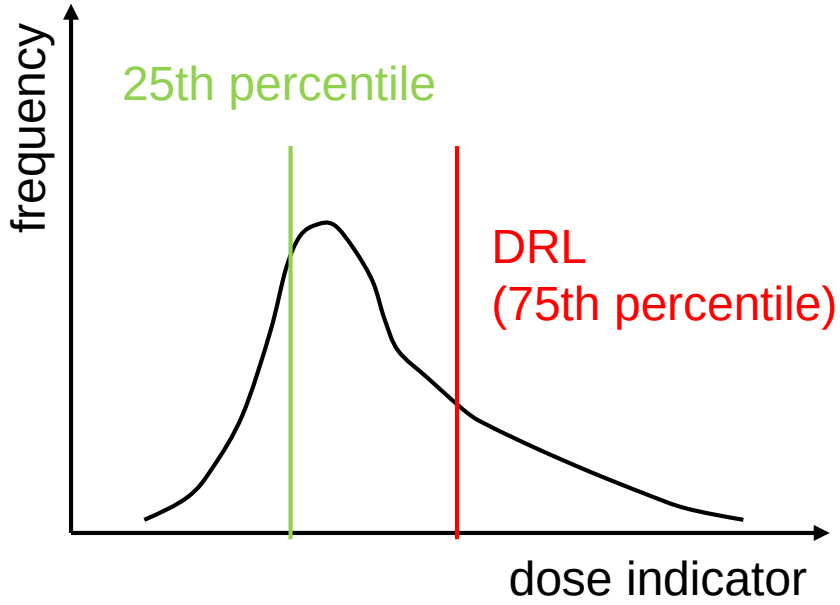
Master protocol	current Swiss DRLs [8]		previous Swiss DRLs (2010) [10]	
	$CTDI_{vol}$ [mGy]	DLP [mGy cm]	$CTDI_{vol}$ [mGy]	DLP [mGy cm]
Head	51 (78%)	890 (89%)	65	1000
Facial Bones / Sinuses	25 (100%)	420 (120%)	25	350
Low Dose Sinuses (Sinusitis)	6	90	–	–
Neck	16 (53%)	410 (68%)	30	600
CT Angiography (Carotid Angio)	11 (55%)	360 (72%)	20	500
Chest	7 (70%)	250 (63%)	10	400
CT Angiography (Exclusion PE)	8 (53%)	300 (67%)	15	450
Abdomen-Pelvis	11 (73%)	540 (83%)	15	650
Exclusion Kidney Stones	6	280	–	–
Liver Multiphase (e.g. HCC)	11	350 [1170]	–	–
CT Angiography (Abdomen-Pelvis)	11 (73%)	530 (82%)	15	650
Chest-Abdomen-Pelvis	11 (73%)	740 (74%)	15	1000
CT Angiography (Chest-Abdomen-Pelvis)	10	730	–	–
Cervical Spine	17 (57%)	360 (60%)	30	600
Thoracic Spine / Lumbar Spine	25 (83%)	-	30	–

Round brackets: values relative to the previous DRLs

data from [8,10]

Dose and image quality

- DRLs don’t measure image quality
- There is the possibility of excessive dose reduction
- If local dose values are below the 25th percentile, image quality should be considered the first priority for further optimization
- Optimization might also mean increasing the dose in some cases
- The goal is standardization of image quality



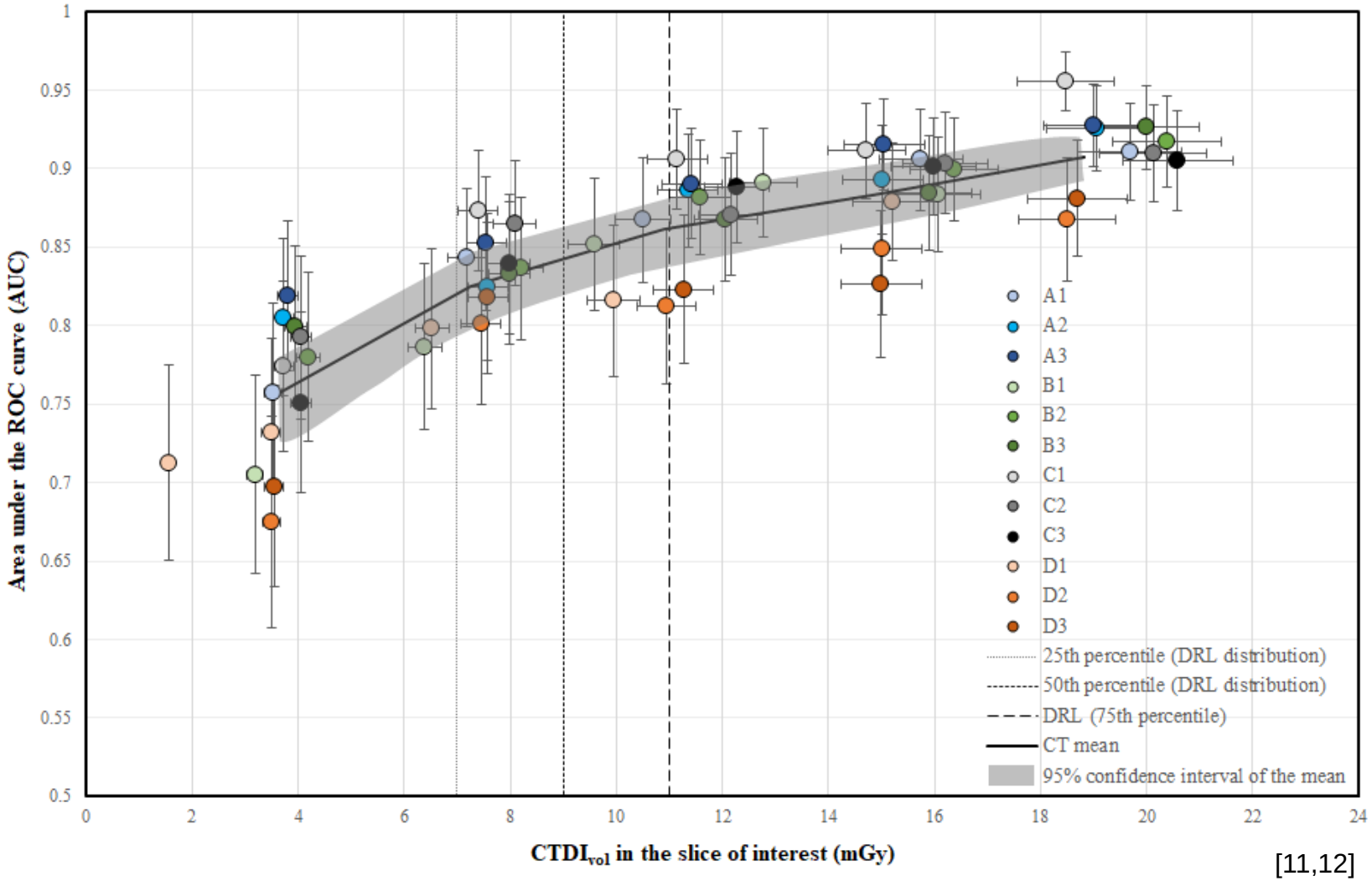
Dose and image quality

Follow-up project to study the link of DRLs to image quality:

- mathematical model observer phantom study
- The graph shows an example for low contrast lesion detection (5 mm diameter spheres with 20 HU contrast in a phantom)

→ Image quality is not very high around the DRL and it does not reach a plateau in the clinically relevant dose range

→ There is a need for specific dose optimization for each CT scanner



[11,12]

Summary

- Swiss DRLs for adult CT were updated in 2018
- There was a substantial average reduction of DRLs compared to 2010 due to new CT technology and optimization efforts.
- Average DRL reduction compared to 2010 by 30% for CTDIvol and 22% for DLP
- Dose optimization is not always dose reduction, image quality has to be standardized

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