TG 108 Digital Workshop: Part 2

Optimisation of Radiological Protection in Digital Radiology Techniques for Medical Imaging

20 March 2023 | 12:00 - 15:00 (GMT) | Virtual Event

MDCT in clinical practice

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CT protocols

- **MDCT is the reference imaging modality for a wide variety of clinical indications**

- **Each clinical indication will have their own needs in terms of diagnostic image quality level, that also depend on the patient characteristics (morphometry, tissue composition distribution, disease stage…)**

- **CT protocols (acquisition and reconstruction parameters) are developed around the clinical indications and/or diagnostic needs and sometimes, adapted to sub-cohorts of patients**

Examples: In our CT system we may have…

Range of thorax CT protocols depending on clinical indication (ultra-low dose thorax CT, lesion follow-up, high resolution thorax CT, trauma-thorax…)

Family of paediatric head CT protocols depending on age (related to head size and attenuation)

CT protocols

- **Each CT protocol is based on a selection of values/options (among a wide range) for each acquisition/reconstruction parameter, many of them with intertwined effects on dose and image quality**

  - Acquisition parameters: mA, kV, collimation, slice thickness, rotation time…
  - Reconstruction parameters: rec. Method (FBP, IR, DLR), filter, reconstruction method level…
  - Differences exist among vendors and even between models of the same vendor

- **CT protocol optimization is challenging and requires dedicated time and a good knowledge about how your system operates**

Dose variability in CT

European Radiology (2022) 32:1971–1982
https://doi.org/10.1007/s00330-021-08266-1

COMPUTED TOMOGRAPHY

Check for updates

Diagnostic reference levels and median doses for common clinical indications of CT: findings from an international registry

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Abstract

Objectives The European Society of Radiology identified 10 common indications for computed tomography (CT) as part of the European Study on Clinical Diagnostic Reference Levels (DRLs, EUCLID), to help standardize radiation doses. The objective of this study is to generate DRLs and median doses for these indications using data from the UCSF CT International Dose Registry.

Methods Standardized data on 3.7 million CTs in adults were collected between 2016 and 2019 from 161 institutions across seven countries (United States of America (US), Switzerland, Netherlands, Germany, UK, Israel, Japan). DRLs (75th percentile) and median doses for volumetric CT-dose index ($CTDI_{vol}$) and dose-length product (DLP) were assessed for each EUCLID category (chronic sinusitis, stroke, cervical spine trauma, coronary calcium scoring, lung cancer, pulmonary embolism, coronary CT angiography, hepatocellular carcinoma (HCC), colic/abdominal pain, appendicitis), and US radiation doses were compared with European.

Results The number of CT scans within EUCLID categories ranged from 8,933 (HCC) to over 1.2 million (stroke). There was greater variation in dose between categories than within categories ($p < .001$), and doses were significantly different between categories within anatomic areas. DRLs and median doses were assessed for all categories. DRLs were higher in the US for 9 of the 10 indications (except chronic sinusitis) than in Europe but with a significantly higher sample size in the US.

Conclusions DRLs for $CTDI_{vol}$ and DLP for EUCLID clinical indications from diverse organizations were established and can contribute to dose optimization. These values were usually significantly higher in the US than in Europe.

Key Points

- *Registry data were used to create benchmarks for 10 common indications for CT identified by the European Society of Radiology.*
- *Observed US radiation doses were higher than European for 9 of 10 indications (except chronic sinusitis).*
- *The presented diagnostic reference levels and median doses highlight potentially unnecessary variation in radiation dose.*

- **There still exists a wide variability of CT doses among countries and continents for similar clinical indications due to:**
  - Availability of CT technology and how advanced the systems are in the area
  - Personnel training on dose optimization/patient workflow
  - Absence of an adequate dose management in the QA programme for CT

Table 3 Observed diagnostic reference levels (DRLs) and median doses for $CTDI_{vol}$ (in mGy) in the United States (US) and Europe (EU), and relative DRLs and median doses in the US compared with Europe (and 95% CI) for EUCLID indications. Doses were adjusted for patient size and age.

Body region	EUCLID category	US		EU		Relative median US/EU [95% CI]		Relative DRL US/EU [95% CI]	
		Median	DRL (75th)	Median	DRL (75th)				
Head	Chronic sinusitis	18.6	26.9	17.6	37.5	1.06	[1,05; 1.06]	0.72	[0.71; 0.72]
	Stroke	49.7	56.2	37.8	42.6	1.32	[1,32; 1.32]	1.32	[1.32; 1.32]
Neck	Cervical spine trauma	18.8	24.1	11.3	13.6	1.67	[1,66; 1.68]	1.77	[1.76; 1.79]
Chest	Coronary calcium scoring	6.1	8.0	1.6	1.9	3.92	[3,85; 4.00]	4.25	[4.15; 4.38]
	Lung cancer	8.8	11.9	3.5	5.3	2.51	[2,50; 2.52]	2.22	[2.20; 2.24]
	Pulmonary embolism	11.1	14.9	3.7	5.5	2.96	[2,92; 3.00]	2.73	[2.70; 2.76]
	Coronary CT angiography	13.7	26.5	5.5	9.6	2.49	[2,41; 2.62]	2.76	[2.66; 2.85]
Abdomen	Hepatocellular carcinoma	9.8	12.5	6.9	7.7	1.42	[1,40; 1.45]	1.62	[1.58; 1.66]
	Colic/abdominal pain	10.0	12.6	6.9	9.5	1.44	[1,43; 1.46]	1.32	[1.29; 1.35]
	Appendicitis	11.6	14.5	8.9	11.9	1.31	[1,30; 1.31]	1.22	[1.22; 1.23]

Dose variability in CT

- In surveys, even among facilities with similar CT scanner models, we can observe a large variation in doses for similar (or even the same) clinical indication…

→ It is not only the car…but also your knowldege about how it works and how you drive it!

- There exists an increased awareness about the need for optimisation → Dose levels continue to be reduced globally mainly due to:

  → Vendor and software improvements (such as iterative/AI based reconstruction inception)

  → Educational programs (both general and also local/regional)

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Dose variability in CT

- Protocol optimisation can result in significant dose reduction but depends on appropriate selection of:
  - ❑ scanning parameters
  - ❑ an understanding of the interdependence of the exposure parameters (and their link to reconstruction options, especially in combination with Automatic Tube Current Modulation and also Auto kV selection (if it exists in your device) .

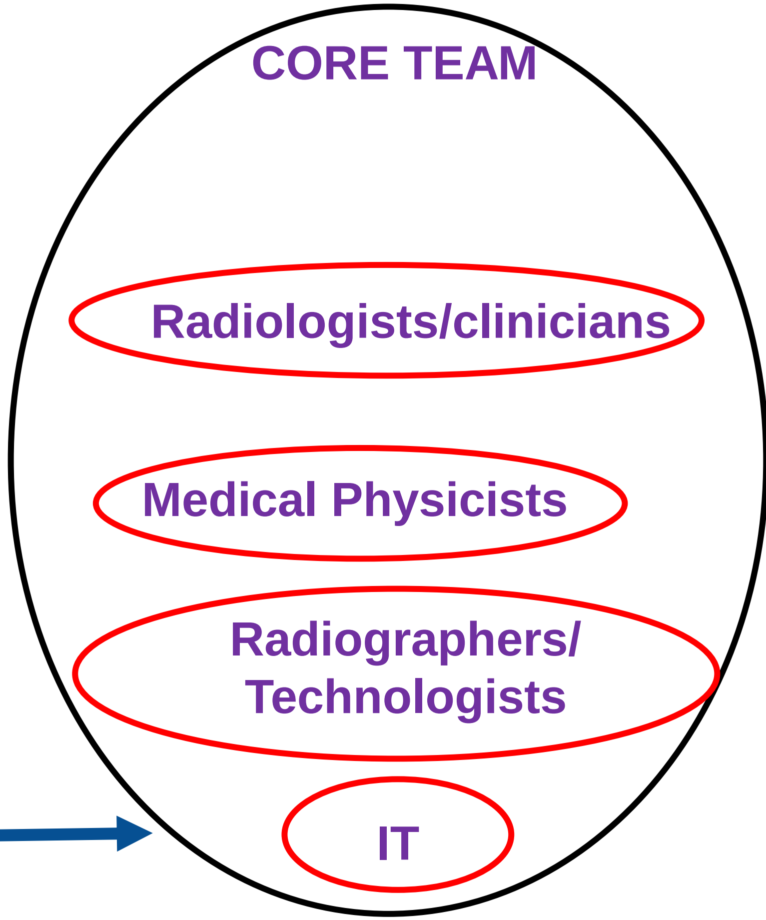
- ***We have homework to do in terms of optimisation of protection worldwide. The existing resources, characteristics and challenges in each center/country/region need to be taken into account.***

Where to start with optimisation?

- Always consider your particular circumstances in your service/region/country… (available CT systems, personeel and time resources)

- If **time/resources** are **limited,** set up first protocols for examinations that are performed **FREQUENTLY** and the ones that are for **URGENT** indications.
  - → Lean as much as you can on CT vendor initial support (especially at initial CT setup) for protocol implementation if this is the case.

- If **personnel** and **resources are available,** for the optimised use of MDCT in clinical practice (balancing dose and image quality) requires a close cooperation among a core team of (ideally)



+ vendor applications specialist (if needed)

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What can be found in the report..

Box 4.6. Optimisation arrangements at different levels of development.

In ICRP (2022) and in the introductory section of this document the range in resources and expertise that are available in different facilities is discussed. This presents significant challenges in setting out steps in optimisation that are appropriate for each facility. In order to provide assistance to users in the development of optimisation strategies for their department, the arrangements that should be in place for facilities at different stages of development are listed below for C: Basic; B: Intermediate; and A: Advanced levels. Facility staff and managers should use these lists as a guide to reflect on the arrangements that are already in place and identify those that it would be appropriate to focus on for their next stage of development. Facilities in Level D, still in the very early stages of developing optimisation should consider arrangements within level C: Basic group that they need to put in place.

C: Basic Level

- Requests for CT scans include reason for referral and clinical history of patient.
- CT radiographers trained by vendor applications specialist.
- Clinical protocols agreed for imaging of all key body regions
- Separate paediatric protocols based on patient age (head) or body weight (trunk)
- Standard anatomical references used to set scan limits.
- ATCM settings provide appropriate modulation for patients of all sizes.
- Basic tube voltage selection based on indication, patient size and use of contrast
- Reconstruction filters specified for common types of examination in use.
- If available, IR implemented for selected procedures with adjustment of exposure factors, after agreement with radiologists.
- Acknowledgement of dose display and using DRLs (published or national) at least for the most general examinations (head, chest, abdomen).
- Regular (daily tube wam-up and air calibration) constancy checks performed by radiographers (QC).
- CT scanner QC tests to characterise scanner performance carried out regularly, at least annually.

- Depending on your resources and specific circumstances on your site, you can optimise your CT practice.
- ICRP TG108 has proposed 3 levels of development (C-basic, B-intermediate, A-advanced)

What other organizations propose…

Home | Directory | Career Services
Continuing Education | BBS | Contc

AMERICAN ASSOCIATION *of* PHYSICISTS IN MEDICINE

THE ALLIANCE FOR QUALITY COMPUTED TOMOGRAPHY

Purpose | FDA Award | Questions | Role of the QMP | CT Dose-Check | Protocols | Lexicon | CT Dose Education | CT AEC Education

Available Protocols

Adult Protocols

- CT Colonography (added 11/30/2017) [Give Feedback]
- Lung Cancer Screening CT (updated 07/24/2019) [Give Feedback]
- Routine Adult Chest-Abdomen-Pelvis CT (added 02/20/2014) [Give Feedback]
- Routine Adult Chest CT (updated 05/04/2016) [Give Feedback]
- Routine Adult Abdomen/Pelvis CT (updated 08/07/2015) [Give Feedback]
- Routine Adult Head CT (updated 03/01/2016) [Give Feedback]
- Routine Adult Brain Perfusion (updated 03/01/2016) [Give Feedback]

Pediatric Protocols

- Routine Pediatric Chest CT (added 07/21/2017) [Give Feedback]
- Routine Pediatric Abdomen and Pelvis CT (added 07/21/2017) [Give Feedback]
- Routine Pediatric Head CT (updated 12/14/2015) [Give Feedback]

Your feedback regarding the content of this website is welcome. Feedback regarding this website will not be monitored daily. **Users experiencing problems in performing an exam should contact their service provider.**

https://www.aapm.org/pubs/ctprotocols/

- You can find some resources about reasonable CT protocols for some clinical indications in different websites, like the AAPM
- (incl. main CT vendors for some models)

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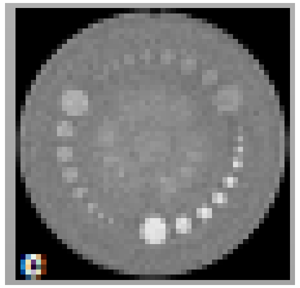
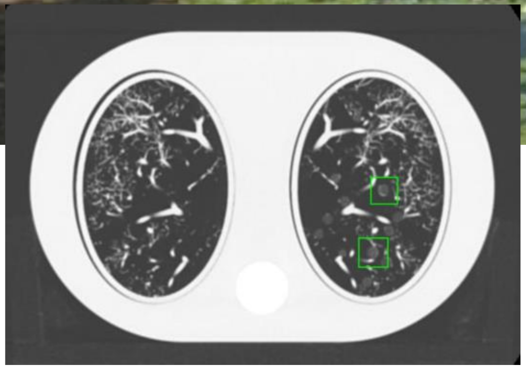
What does “good” diagnostic image quality mean?

Physicists



Technical measurements to check system’s performance (objective)

Radiographers/Technicians



Radiologists, oncologists, clinicians…

Depends highly on the clinical task (subjective) and on the experience, skills (even on tiredness…)

CAD/AI

Now we have not only human observers but also computer-based observers

CT protocol optimisation

- ❑ CT protocols should be developed with input from consultant radiologist(s), lead CT radiographer(s)/ technologist(s) and medical physicist expert.

  Image quality level, exposure factors, slice thickness, pitch, filters, iterative/Deep learning reconstruction level should be agreed among the professionals involved

  → Anthropomorphic phantom studies can help in these tasks

- ❑ What works to optimize your protocol for a specific clinical indication may not work for another!

- ➢ Example: Increasing rotation time (in certain step points depending on your manufacturer), can increase your spatial resolution:

  → Good for CT protocols without contrast where you need high spatial resolution like cochlear implants or inner ear imaging

  → Beware in CT protocols with contrast injection (like some cardiac-CT or thorax CT protocols) where your timing is crucial for the in-flow and out-flow of contrast on the organs or interest

Radiographers training

- Radiographers/technicians training is crucial wrt patient positioning for each clinical indication to avoid irradiating organs not relevant for it and for a correct performance of AEC in CT.

- The patient should be centred in the gantry before starting the examination (otherwise, ATCM and ATVS can be affected, impacting dose and image quality)

- Use anatomical markers to define scan start and stop positions, for consistency and also avoid irradiating organs not relevant for the clinical indication.

- Anthropomorphic phantoms can be very useful for radiographers training in positioning

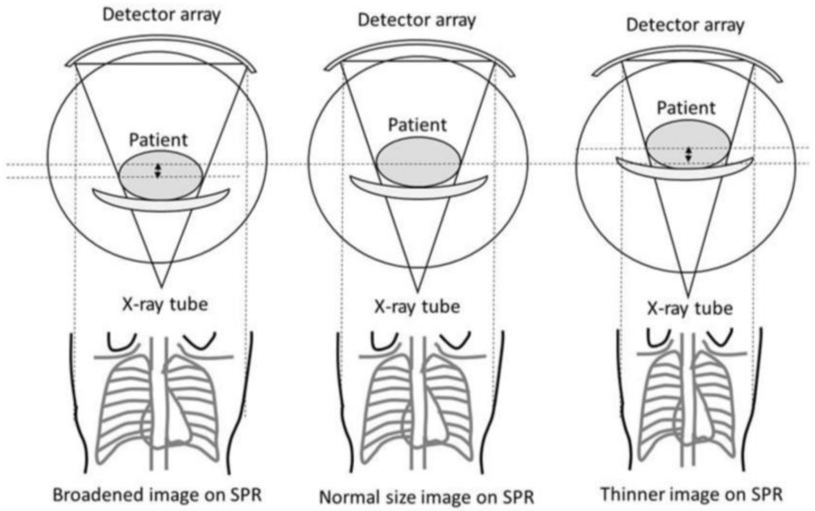
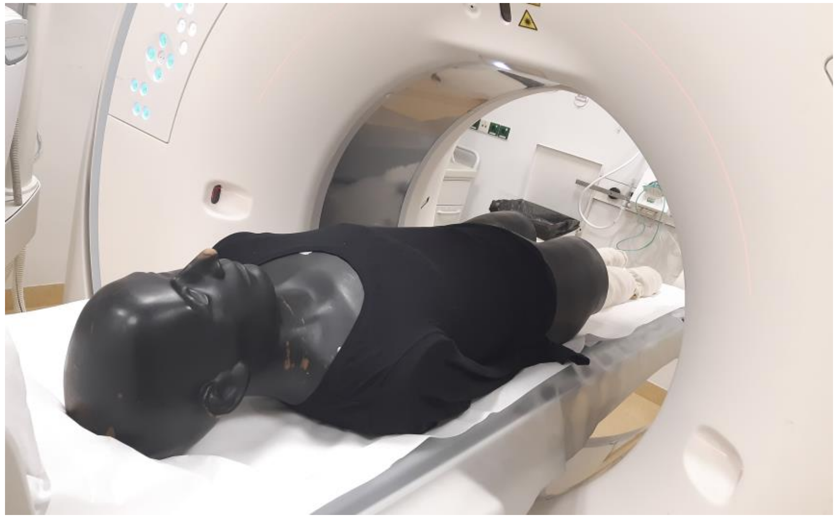
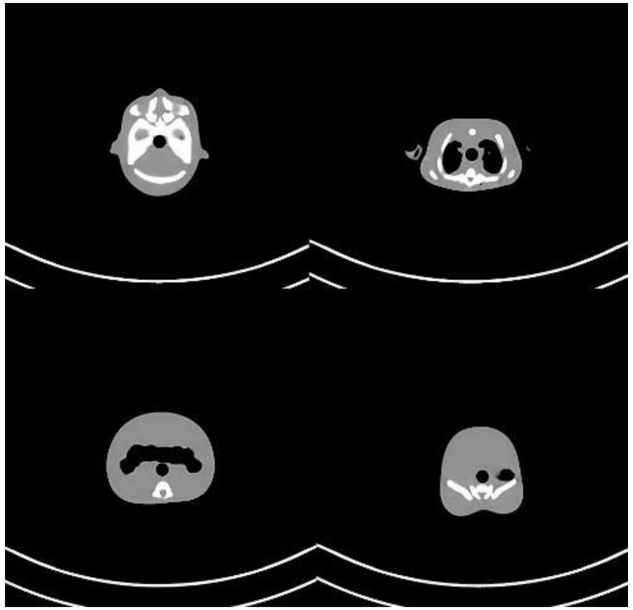


Fig. 4.4. Diagrams showing how height of the couch can affect the apparent patient dimension on an SPR recorded with a PA projection. When patients are lower (left) the image is magnified, while when they are higher (right) the image is reduced. (Colin Martin, University of Glasgow).

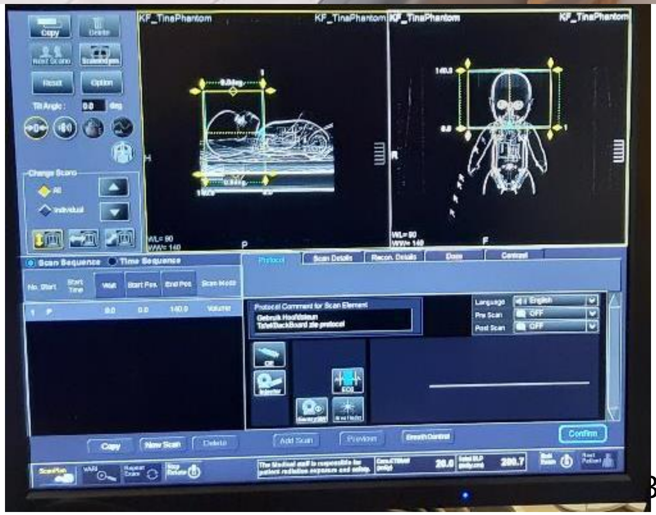


Anthropomorphic phantoms in optimisation

Anthropomorphic phantoms are very useful for protocol optimisation and image quality assessment



But if you cannot get access to them, consider alternatives… (especially for training of personeel in patient positioning)



- CT technology (especially wrt image reconsctruction) has become more and more taylored by design to render images of the human body (DLR trained only with patient images) → Anthropomorphic phantoms need to be included in our QA and optimisation processes.

https://www.kyotokagaku.com/en/products_data/ph-50b/

What can be found in the report...

Box 4.2. Choosing the tube potential for a CT scan

The optimum tube potential depends on body size and use of low tube potentials is more advantageous for examinations using iodine contrast. Recommended tube potentials are given here in terms of the sum of AP and lateral body dimensions in cm (Ranallo, 2013; AAPM, 2022).

Head scans	**kV**	**Body scans, dimension**	**kV**
Paediatric 0–2 y	70–80	Paediatric; < 44 cm	70–80
Paediatric 2–6 y with contrast	80–100	Paediatric and adult; 44–60 cm	100
Paediatric 2–6 y no contrast	100–110		
Adult with contrast	100–120	Medium and large adults; 60–80 cm	120
Adult CT perfusion	80–90	Extra large adults: 80 cm	140
Adult no contrast	100–120	Adult upper thorax through shoulders	120

N.B. These values provide guidance, but will not be universally appropriate, because of differences in CT scanner models. The inherent filtration varies with the CT scanner, so the x-ray spectra will also vary. Moreover, some new scanners have the capability to generate tube currents over 1000 mA with lower kilovoltages, enabling their use with larger patients, when appropriate.

CT protocol development and maintenance

Box 4.5. Guidance for CT protocol development and maintenance

- Standard clinical protocols should be agreed by the core team and communicated within each facility.
- There should be sufficient indication-specific CT protocols available and maintained to provide an efficient and comprehensive optimisation imaging process.
- The process of protocol optimisation should involve evaluation of clinical image quality and technical measurements of image quality in phantoms as a part of regular QA.
- Analysis of dose performance in scans of phantoms performed in parallel can be useful, together with measurements of noise, limiting resolution and contrast visualisation.
- Changes to protocols should be made in stages, checks made to confirm that the desired changes have been achieved and a dose audit performed at an early stage.
- Protocol development should be a continuing process with measurements being made of the impact of changes and the whole process repeated.
- Radiologists, radiographers and medical physicists should all feed into protocol development; other stakeholders (clinicians and vendor application specialists) may also add information to the local optimisation process.

- ❑ Scan protocols should be reviewed periodically and protocol development be a continuous process. Measurements should be performed to track the impact of changes
- ❑ New protocols need to be tested against old ones, and phantoms used if required
- ❑ Be very careful if “copying” CT protocols between scanners
- ❑ Beware of potential changes in your CT protocols after a vendor software upgrade!

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Some take home messages...

- Succesful MDCT in clinical practice is complex, the image quality required depends highly on your clinical task.

- The required image quality for a specific clinical task depends on patient related factors (morphometry, anatomy, disease stage) and CT system (both technical and operational) related factors

- In CT, many acquistion and reconstruction parameters are involved that affect patient dose and image quality and they are intertwined. There exist a wide variation in doses among regions and even between systems of the same vendor and model for equivalent clinical tasks.

- Learn how your own CT devices operate to make the most of their capabilities. Personnel training is crucial.

- CT protocol setup, tracking and optimization is a team effort. Depending on your resources, ideally you need the involvement and close collaboration between clinicians/radiologists, medical physicists, radiographers/technicians and IT.

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