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
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
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 knowledge 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)
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, personneel 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)
What can be found in the report..

- 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...

- 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)

https://www.aapm.org/pubs/ctprotocols/
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 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 reconstruction) has become more and more tailored 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.

### 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).

<table>
<thead>
<tr>
<th>Head scans</th>
<th>kV</th>
<th>Body scans, dimension</th>
<th>kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paediatric 0–2 y</td>
<td>70–80</td>
<td>Paediatric; &lt; 44 cm</td>
<td>70–80</td>
</tr>
<tr>
<td>Paediatric 2–6 y with contrast</td>
<td>80–100</td>
<td>Paediatric and adult; 44–60 cm</td>
<td>100</td>
</tr>
<tr>
<td>Paediatric 2–6 y no contrast</td>
<td>100–110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult with contrast</td>
<td>100–120</td>
<td>Medium and large adults; 60–80 cm</td>
<td>120</td>
</tr>
<tr>
<td>Adult CT perfusion</td>
<td>80–90</td>
<td>Extra large adults; 80 cm</td>
<td>140</td>
</tr>
<tr>
<td>Adult no contrast</td>
<td>100–120</td>
<td>Adult upper thorax through shoulders</td>
<td>120</td>
</tr>
</tbody>
</table>

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!
Some take home messages...

➢ Successful 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 acquisition 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.