The ROYAL MARSDEN
NHS Foundation Trust

Evaluation and optimisation of low dose neck CT for SPECT

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CTUG meeting
18 October 2024

NHS

Context and Background

Who are we?

What do we do?

What was the problem?

Context & background: Who are we?

DR Physics Team at the RMH

- 6.2 clinical scientists:
  - Three MPEs
  - Two trainee MPEs
  - One vacancy
  - One RT/DR clinical scientist (0.2 WTE)
- Two trainee clinical scientists
- 19 CT scanners across 6 sites
  - Including PET/SPECT-CT
- Specialisms across all sites:
  - Oncology
  - Heart and lung (Royal Brompton Hospital)

Context & background: dose surveys

Routine dose surveys for various procedures are conducted in our department approximately every three years to **review and update** LDRLs as needed.

IR(ME)R 2017 Reg. 13[1]: <u>Estimates of population doses</u>

The employer must collect **dose estimates** from medical exposures for radiodiagnostic and interventional procedures, taking into consideration the distribution by age and gender of the exposed population.

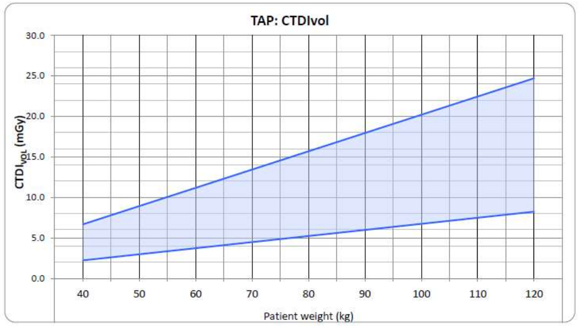
Diagnostic Radiology Physics Group — Royal Marsden NHS Foundation Trust

Individual Diagnostic Reference Levels

Protocol:TAP

Hospital: Royal Marsden Hospital	**Data collection period:** Sep-22 to Sep-23
Unit: SOMATOM Definition Edge and Flash (both sites)	**Date of issue:** 01/11/23
Exam: Thorax^TAP	**Issued by:** Gibril Kallon

The $CTDI_{VOL}$ and DLP for a given patient weight should fall within the shaded blue area on the relevant graph below.
Any $CTDI_{VOL}$ or DLP that does not satisfy this condition should be reported to the Superintendent Radiographer.



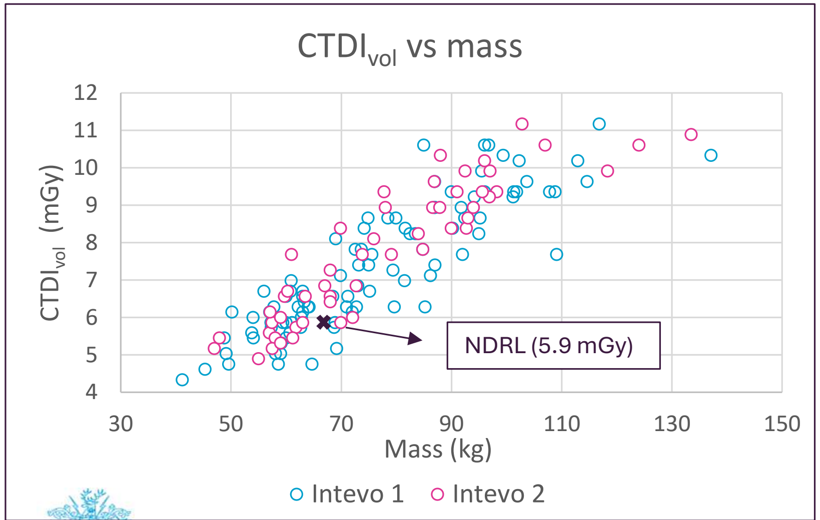
exam	proposed local DRLs	
	$CTDI_{vol}$ (mGy)	DLP (mGycm)
brain	50	1600
NTAP	6, 7	620
TAP	8	547
TA	6	320
T	6	220
AP	8	420
CTPA (100 kV)	5	160
CTPA (120 kV)	7	210
DIEP	9	360
Urogram (KUB & 15 min AP)	7,4	470

Context & background: the problem

Recent dose survey for low-dose neck CT procedures for SPECT exceeding the NDRLs:

- About 30% for $CTDI_{vol}$,
- About 50% for DLP.

Dose indicator	Intevo 1	Intevo 2	NDRL[2]
$CTDI_{vol}$ (mGy):	7.4±1.8	7.7±1.9	5.9
DLP (mGy.cm):	300±75	320±80	210



- Meeting with NM physics and consultants:
  - No justifiable reason
  - Multidisciplinary optimisation task group put in place.

What did we do:
the journey to the right protocol

What did we do?

Dosimetry and Imaging Performance Report (16-slice configuration)

CARE Dose4D

CARE Dose4D automatically adapts the tube current to the patient's body size and shape.

Using the patient's topogram, CARE Dose4D evaluates two profiles of the patient's X-ray attenuation in the a.p. and lateral directions.

Base on these profiles, the mAs value is adapted to the patient during the subsequent CT scans. The adaption follows an adaptation curve, which determines the correlation between X-ray attenuation and tube current. The adaptation curve has been derived from the clinical optimization for constant diagnostic image quality.

The adaptation curve is based on following three parameters:

- A reference X-ray attenuation, related to a typical adult patient size of approximately 70-80 kg (for adult protocols) respectively a pediatric body size of a 5 year old child with approximately 20kg (for pediatric protocols), which is internally stored in the CT system for the considered organ characteristic and depending on the selected protocol.

- Brochures;
- Communication with Siemens apps specialists.

- Datasheets;
- System Owner Manual;

The curve below shows the theoretical adaptation curve for a cylindrical body shape. Depending on the individual patient geometry, the curve may deviate from this theoretical function. Moreover, the curve may be cut depending on the system's power limits.

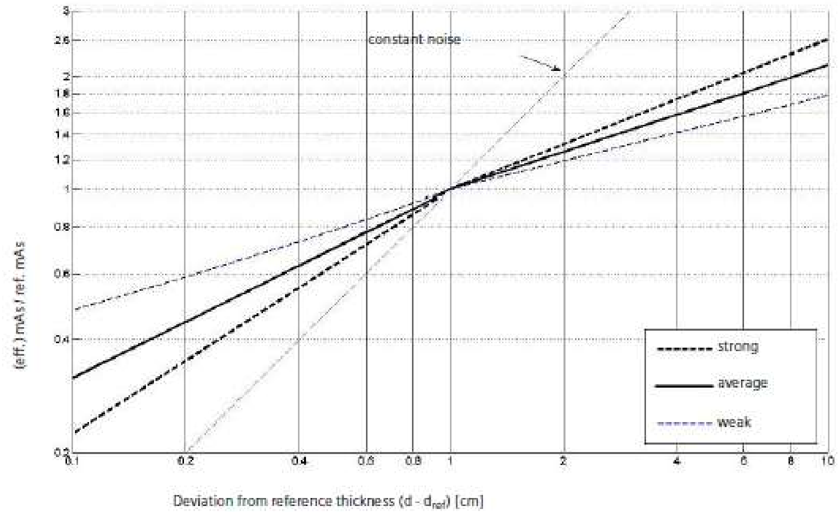


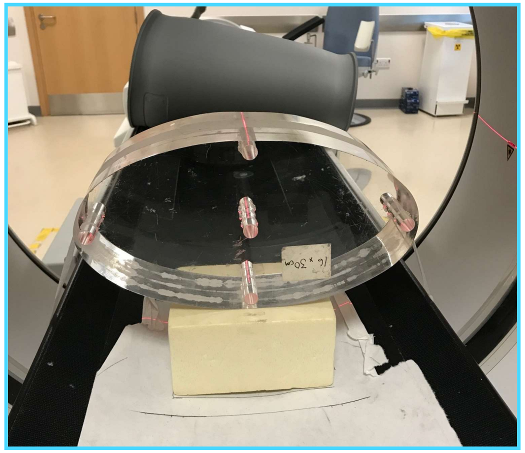
Fig. 6: Adaption of mAs to patient attenuation with adjustable strengths

What did we do?

- SPECT-CT scanners:
  - Siemens Symbia Intevo
  - Siemens Symbia Intevo Bold

- Assessment of tube current modulation
  - Patients
  - Phantom
- Phantom work
  - Topogram direction
  - Organ characteristic
  - kV
  - Pitch
  - Rotation time
  - Quality reference mAs.

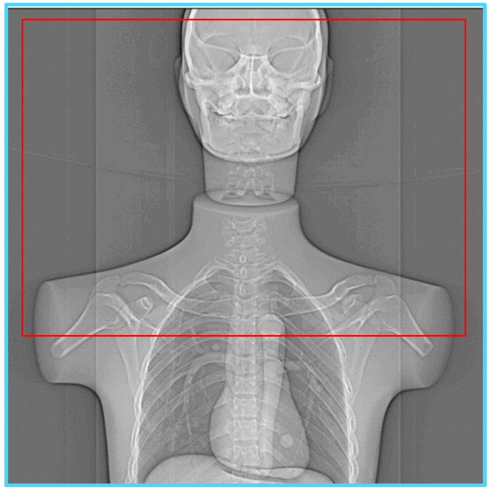
Phantoms



Protocol changes

Parameters of existing protocol:

- Topogram direction: AP
- 130 kV
- Quality reference mAs: 35
- Organ characteristic: Neck
- Pitch: 0.8
- Rotation time: 1 second



Parameters to test:

Organ characteristic: Neck, shoulders, chest, abdomen

kV: 130, 110

Topogram direction: AP, LAT

Pitch: 0.8, 1.1, 1.2, 1.5

Rotation time: 0.6 s, 1 s

Quality reference mAs: 28, 35

Lots of possible combinations, not all of them good/worth trying!

Results

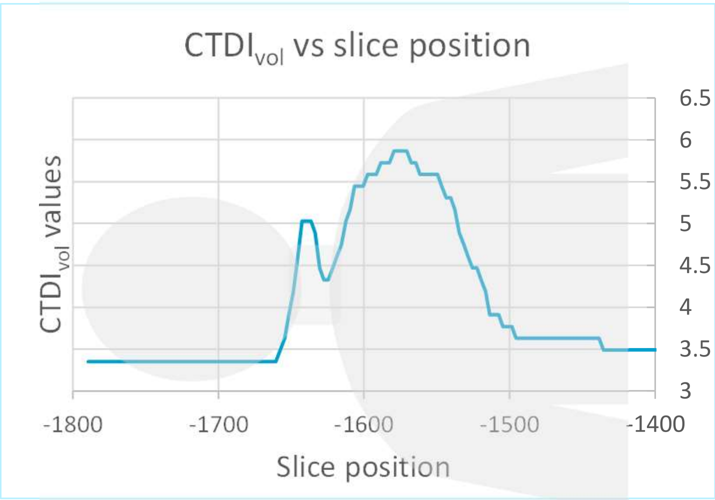
What we learned
(and what we did about it)

Results: mAs analysis vs slice position

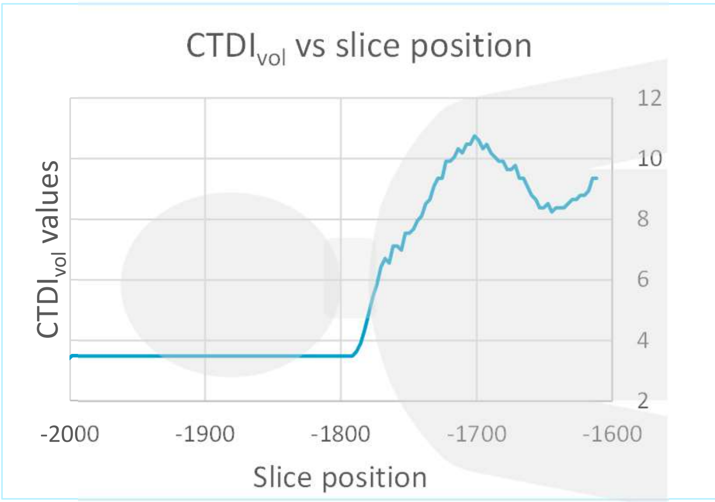
41 kg patient

72 kg patient

102 kg patient



Head → Neck/ Shoulders → Thorax/ abdomen



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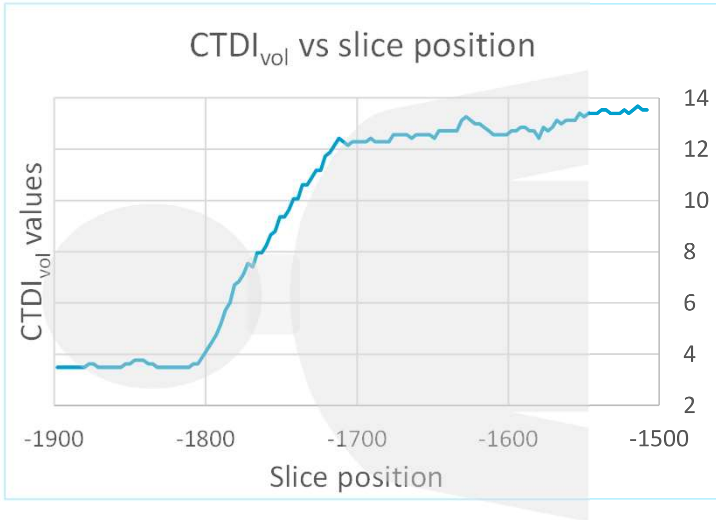


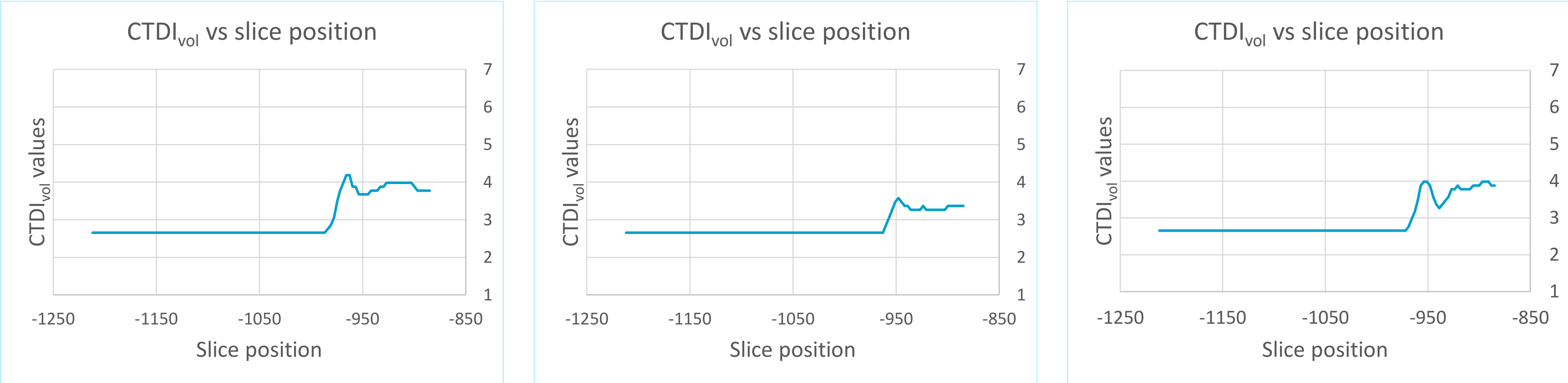
Head → Neck/ Shoulders → Thorax/ abdomen

Results: mAs analysis vs slice position: phantom

Tube current reaching **minimum** value:

- No modulation regardless of OC used.
- Chest and Shoulders OC examples below:
  - NB: other parameters (kV, Q_{ref} mAs, pitch) unchanged in these charts.

Neck OC | Shoulders OC | Chest OC



What we learned so far

Feedback from Siemens:

- It makes no difference if you use a LAT or AP topogram;
- The lateral topogram is preferred if scanning the spine as you can see the vertebrae better;
- Shoulders are extremely dense in the lateral projections;

"It's one of those CT protocols that doesn't really fit a standard CT protocol.

In the CT world they would most likely scan the neck and chest separately, but this sits somewhere between the two and as you know the organ characteristic influences the dose curves."

Initial results from experiments:

- Minimum mAs delivered by the scanner: 32
- Q_{ref} mAs: 35

- **Option 1:** keep 130 kV, change OC to chest
  - 16% dose reduction ✓
  - **No modulation** along the head ✗

- **Option 2:** change kV to 110, keep neck as OC
  - 30% dose reduction ✓
  - Change in contrast ?
  - **Still no modulation** ✗
  - Potential issue for large patients ?

- **Option 3:** more tests at 130 kV, varying other parameters (OC, pitch, rotation time).

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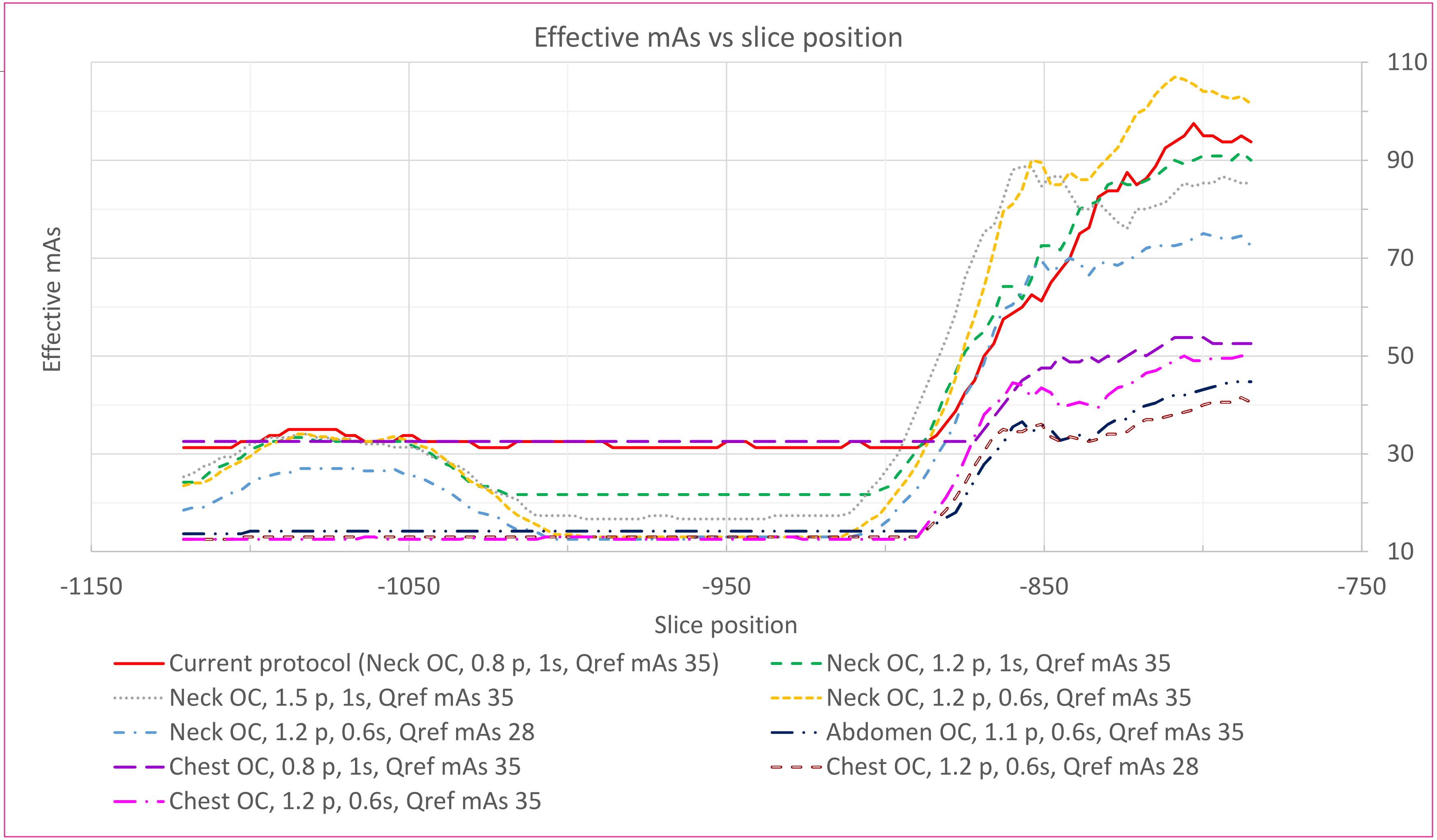
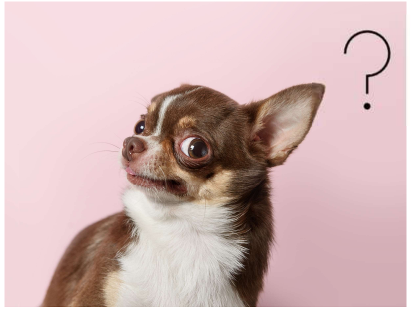
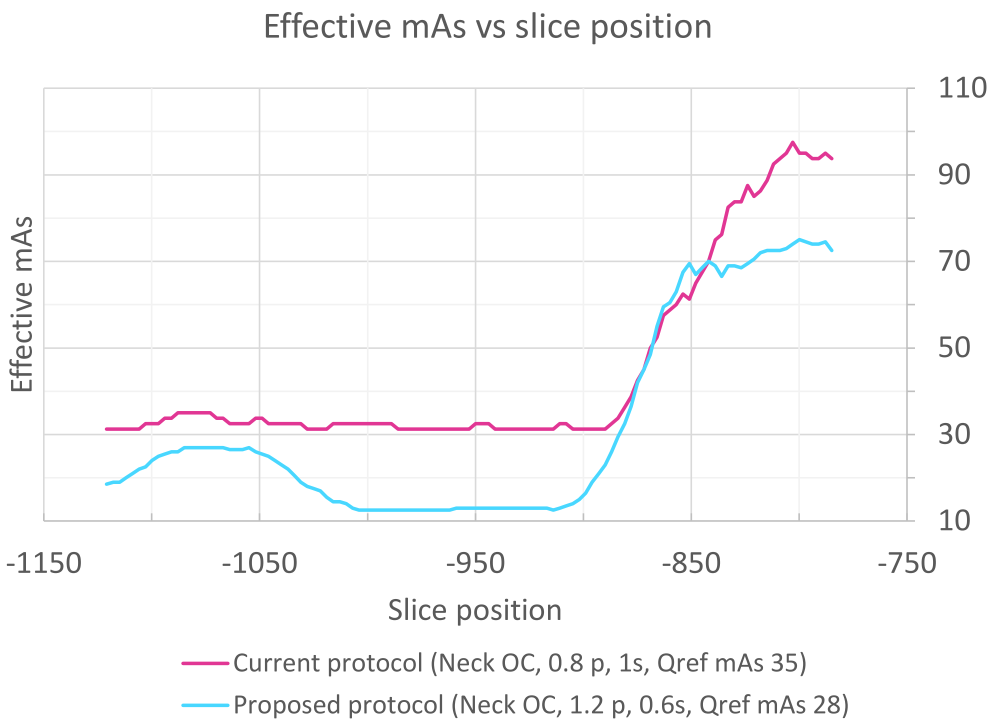
Results: 130 kV protocol





Results: 130 kV protocol

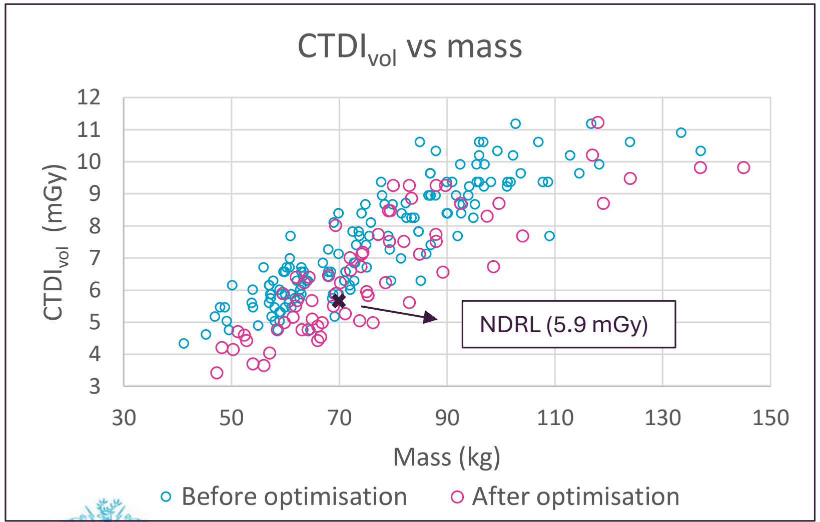
Organ characteristic	Pitch	Rotation time (s)	Q_{ref} mAs	Post-scan eff mAs	Post-scan $CTDI_{vol}$
Neck	0.8	1	35	48	4.96
Neck	1.2	1	35	45	4.60
Neck	1.5	1	35	44	4.49
Neck	1.2	0.6	35	44	4.55
Neck	1.2	0.6	28	35	3.58
Abdomen	1.1	0.6	35	22	2.34
Chest	0.8	1	35	41	4.20
Chest	1.2	0.6	28	21	2.20
Chest	1.2	0.6	35	24	2.45



Where are we at now?

Where are we at now?

- Data collection period after optimisation: 20/04/2023 – 19/02/2024
- Compared to NDRLs, differences are:
  - About 5% for $CTDI_{vol}$,
  - About 20% for DLP.



Dose indicator	Intevo 1	Intevo 2	NDRL
$CTDI_{vol}$ (mGy):	6.2±2.2	6.2±1.9	5.9
DLP (mGy.cm):	260±100	250±80	210

RMH scanning length:

- Minimum: 235 mm
- Median: 430 mm
- Maximum: 450 mm

NDRL scanning length:

- Minimum: 180 mm
- Median: 350 mm
- Maximum: 430 mm

Conclusions and lessons learned

Conclusions and lessons learned

Conclusion:

After about one year, we **successfully** reduced the representative dose indicators to **align** with the published **NDRLs**.

Image quality was still deemed **acceptable** and adequate for the **required clinical task**.

Lessons learned:

- These neck CT scans often **extended beyond the neck**;
- Not solely used for localisation and attenuation correction:
  - Radiologists still required **diagnostic image quality** for the **lung portion** of the scan.

More lessons:

- Better understanding of scanner and protocols;
- Joint effort required (NM physicists, technologists, clinicians, apps specialists)
  - E.g., change in rotation time and pitch inevitably led to **faster** scans
  - Fast scans are good for DR, but was it ok with NM?

And a bit more:

- Various protocol options available
  - Professional judgement to choose one.
- Strengthening collaboration across different modalities
- Optimisation: **ongoing process**
  - Further changes to be discussed.

References

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2. Iball, G.R. et al. A national survey of computed tomography doses in hybrid PET-CT and SPECT-CT examinations in the UK. Nuclear Medicine Communications. 2017;38(6):459 to 470
3. Siemens Symbia Intevo Data Sheet. (Siemens)
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Acknowledgements

- Diagnostic Radiology Physics group - The Royal Marsden NHS Foundation Trust
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Thank you!

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Life demands excellence