Dose levels in paediatric CT in Scotland

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Introduction

▪ What is the Medical Physics Network (MPNET)?
▪ Why assess paediatric CT doses across Scotland?
▪ How was the benchmarking of paediatric doses achieved?
▪ Benchmarking results
▪ Looking to the future
What is MPNET?

MPNET intends to influence the delivery of high quality, technologically focussed patient care in Scotland by bringing together professionals from across the country to work in a coordinated manner to ensure the provision of effective, efficient and equitable Medical Physics and Clinical Engineering services.

- MPNET is not funded, it is supported on a consultancy basis
- Aims to share best practice, innovation and improvement throughout;
  - Clinical engineering, MRI physics, Nuclear Medicine physics, Radiation Protection, Diagnostic Radiology physics, Radiotherapy physics and Rehabilitation engineering
- The Scottish Radiation Protection Adviser’s Group (SRPA) sits within MPNET
  - Its membership includes every RPA in Scotland
Why assess paediatric doses across Scotland?

- Radiographer colleagues at Ninewells hospital had expressed concerns about the optimisation of paediatric CT examinations.
- Radiation physics could not find reliable data against which to compare.
- The issue was discussed at the SRPA group; other sites had similar concerns.
- For non-specialist hospitals or departments, the optimisation of paediatric CT is complicated by low patient throughput and a lack of comparative data.
- But IRMER 2017 requires optimisation of examinations, and that special attention be paid to examinations of children.
- It was agreed that a Scotland wide optimisation approach would be adopted.
- Phase one was the benchmarking of current practice.
Benchmarking approach

- The Royal Hospital for Sick Children, Edinburgh, lent the group 2x CIRS anthropomorphic phantoms (a 5yo and a 10yo)
- Central funding allowed for the purchase of a third (1yo)
- Individual department’s goodwill funded protective travel cases
- It was agreed that each of these would be taken to as many CT scanners as possible around Scotland by physics staff
- Head and Chest examinations would be undertaken at each by local staff
- All data pertaining to dosimetry and image quality for each examination would be recorded; a thorough and detailed protocol was devised and followed to ensure relevant comparison
Data acquisition

- Data was received for at least one phantom from 50 CT scanners
- 49 for the 1 year old
- 25 for the 5 year old
- 20 for the 10 year old
- 2 specialist children’s hospitals (3 scanners)
Observations during acquisition

- The physics team reported three distinct approaches by radiographer colleagues;
- Where available, the appropriate site paediatric protocol was used; or
- A manufacturer default paediatric protocol was used; or
- The adult protocol was selected and adjusted for the paediatric phantom
Results – dosimetry
Results – image quality

- For each examination on each phantom, Signal to Noise Ratio (SNR) [HU / Std Dev] was measured at pre-defined locations;

- For head scans, these were three different locations in the brain;

- For the chest, these were in the lung, heart and abdomen;

- However; a long established limitation of optimisation using anthropomorphic phantoms is that quantitative image quality results are difficult to interpret;

- Further, we cannot interpret image quality in isolation of patient dose, or vice versa;

- So, we devised a Figure of Merit, defined as; $\frac{|SNR|}{DLP}$
Results – figure of merit

Box plots showing the figure of merit (FoM) for different time periods and examination types. Each box represents the distribution of FoM measurements, with the red line indicating the median, the box indicating the interquartile range, and the whiskers showing the range of data points.

- **1yr head**: FoM values range from 0.01 to 0.08, with a median around 0.05.
- **5yr head**: FoM values range from 0.01 to 0.07, with a median around 0.05.
- **10yr head**: FoM values range from 0.01 to 0.08, with a median around 0.05.

- **1yr chest**: FoM values range from 3 to 7, with a median around 5.
- **5yr chest**: FoM values range from 3 to 7, with a median around 5.
- **10yr chest**: FoM values range from 3 to 7, with a median around 5.

The box plots indicate that the FoM varies depending on the time period and examination type, with the chest examinations generally showing higher FoM values than the head examinations.
Analysing deeper

- A number of specific research questions were formulated to determine the reasons for the variability of performance;
- Protocol choice – which is best; existing paediatric protocol, manufacturer default paediatric protocol or modified adult protocol?
- The poorest performance in general was associated with the manufacturer defaults (4 highest DLPs, 3 lowest FoM)
- Existing local paediatric protocols were the best optimised (lowest DLP for 3, 3 highest FoM)
- Modified adult protocol was least predictable – just as likely to have the highest DLP as the lowest – why?
- The answer was related to the auto-mA system
Auto-mA performance

- CT scanners use auto-mA to vary the mA throughout the examination and deliver a consistent image quality throughout the scan length by varying the dose.

- The protocol must define some indicator of image quality (parameter varies with CT scanner manufacturer) and then a maximum and minimum mA value.

- In-depth investigation reveals that where auto-mA was utilised for modified adult protocols, the minimum mA was not adjusted at any site.
Analysing deeper

- Is it better to use mA modulation or a fixed examination mA?
- Intuitively, the use of mA modulation should always result in a lower patient dose; this was not the case however, for the reasons already identified.
- For some examinations, in particular for the 1yo phantom, the use of a fixed mA gave a better performance for both dose and FoM – this is known to be because of a poorly selected minimum mA however.
- This analysis also identified variations in the selection of image quality parameter throughout Scotland however; this may be justified but it is likely that a better consensus is possible.
Analysing deeper

- What examination kVp should be used?
- The majority of examinations for both head and chest used 120kVp
- It is known that almost all adult protocols use 120kVp
- The evidence suggests that examinations undertaken at a lower kVp can reduce patient dose whilst maintaining image quality
- This is especially true of chest examinations
Technological factors

- Analysis compared protocols employing filtered back projection against iterative reconstruction.
- Not all scanners are capable of iterative reconstruction, those that are used it.
- For all combinations of examination and phantom age, iterative reconstruction resulted in the lowest DLP and the highest FoM.
- Iterative reconstruction resulted in an average dose reduction of 36% for the head and 50% for the chest.
Looking to the future

- All results and recommendations have been shared widely throughout Scotland
- Optimisation of local paediatric protocols should be undertaken by a multi-disciplinary team (radiologist, radiographer, physicist and, where available, paediatric specialists)
- A decision must be taken as to the level of image quality required
- CT scanners should be equipped with locally created paediatric protocols (not manufacturer default or modified adult protocols)
- Protocols should be individually optimised for different patient sizes
- Where available, iterative reconstruction should be used
- mA modulation should be used but with particular care to the selection of appropriate minimum mA values
- Consideration should be given to reducing the examination kVp
- Protocols should be audited and protocols and results shared throughout Scotland
The importance of collaboration

- The results to provide the information necessary for local optimisation were not achievable for any site working independently
- In this endeavour, as in so many others, a collaborative approach has been key

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