Measuring CT dose: lessons from an optimization project

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Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Queensland Government
Queensland Health

The Royal Australian and New Zealand College of Radiologists

Background

Expanded clinical applications / utilization of multi-detector computed tomography (MDCT) associated with substantial increase in population cumulative effective dose and stochastic risk (1-5)

Project Aims

- Collect baseline data for radiation dose delivered at 10 volunteer CT practices for range of common adult and pediatric scan protocols
- To test methodology for an optimization program including:
  - web – based audit tool for collection and dose calculation
  - feedback workshop + academic detailing and re-audit methodology as tools for optimization training

Project Funding and IRB

- Supported through grant from the Australian Government Department of Health and Ageing to the RANZCR's Quality Use of Diagnostic Imaging (QUDI) program
- Requirement for IRB approval waived due to de-identification of patient data and satisfaction of Australian National Health and Medical Research Council criteria for a quality improvement project
- Local technical support in Queensland, Australia funded by Queensland Health
  - Radiation physicist
  - Medical Imaging Technologist

Project Team

- Radiologist project leader (interstate)
- Medical Imaging Technologist project leader
  - Funded by Queensland Health
- Site radiologist and medical imaging technologist X 10
- Radiation physicists X 4
  - Local (Hospital based)
  - National expert
  - Representative of Australian Radiation Protection and Nuclear Safety Agency
  - Representing Queensland Health

Timelines

- August to Oct 2008
  - Protocols and scope were developed
  - Web based audit tool developed
- November 2008 – January 2009
  - Baseline survey data collection
  - Pediatric phantom scanning
- Feb 2009
  - Feedback workshops / academic detailing
- March to May 2009
  - 2nd survey data collection
- June 2009 to present
  - Data analysis and reporting to participating sites

Scan types - Adult

- Non-contrast Brain
- CT Pulmonary Angiogram (CTPA)
- Lumbar Spine
- Urogram or Kidneys, Ureters and Bladder (KUB)

Scan types - Pediatric

- Non contrast brain – trauma
- Chest – HRCT for lung disease
- Chest - for ?tumor mass
- Chest / Abdo / Pelvis – cancer staging
- Temporal bones – sensorineural hearing loss
- Cervical spine – trauma
- Abdomen - generalized pain?, trauma
- Sinuses - sinusitis

Participants

- All 25 practices contracted by Queensland Health to provide CT services (public and private sector) sent letter of invitation
- 10 agreed to participate voluntarily
- No payment for radiologist / MIT
- Travel and accommodation to workshop paid
- Data collection support funded

Data collected

- Date of scan
- Patient initials
- Scan type
- Parameters
  - kVp
  - mAs
  - Pitch
  - Collimation
  - Scan length
  - Dose modulation (z , rotational, size)
  - Scanner generated DLP, $CTDI_{VOL}$

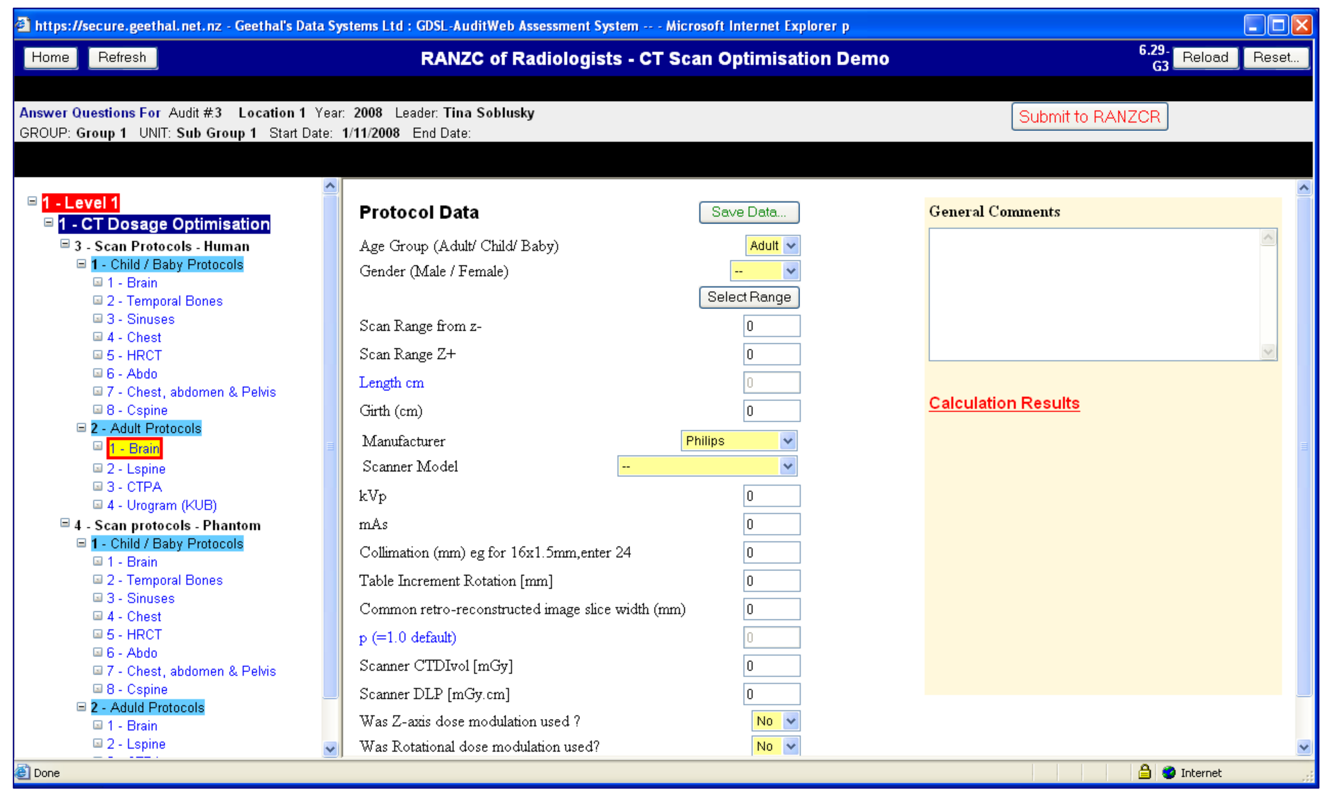
Data Collection Methods

- Data collection by technologist on paper form at the scanner
- Transferred (by technologist project leader) to web based tool

Dose calculation

- Web – based audit tool purpose built for the project
  - was linked to CT Expo[6]
- Used to validate scanner generated DLP

Web-based Data Collection Tool



Workshop

- 2 x one day off site workshops held on weekend (Sat and Sun)
- Attendees: radiologist and radiographer at each site as well as lead radiologist, radiation physicist, MIT, QLD health and QUDI staff
- Didactic review of CT radiation physics, dosimetry and risks - 1 hours
- Display, discussion and review of data – 2 hours
- MDCT Technology and Optimization – 1.5 hours
- Afternoon panel discussion
- Step by Step "how to do it" optimization instruction sheet to take home (see link below)
- Individual site data de-identified
- Sites
  - Compared with one another for dose and other parameters
  - Detailed discussion about likely sources of high dose (in terms of scanning parameters) for those sites at top end of range
  - MDCT Optimisation Advice (Available on the QUDI website): http://www.insideradiology.com.au/pages/radiologists_ctDose.php

Pediatric abdomen - ? Liver mass

	A	B	C	D	E	F	G	H	I	J
Eff.Dose	**5.3**	**8.7**	**8.9**	**16.3**	**3.3**	**4.6**	**6.8**	**11.0**	**2.4**	**2.1**
kVp	120	120	120	120	120	120	120	100	120	120
mAs	32	58	62	184	53	48	59	244	34	39
pitch	1	0.48	0.83	0.89	1.1	1.4	0.94	1.2	0.89	1
mAs(effective)	32	120	75	207	48	34	63	203	38	39
Collimation	40	40	32	40	24	20	16	38.4	40	19.2
Scan Length	28	24	26	28	24	25	26	25	25	19
Zmod	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes
Rot Mod	Yes	No	Yes	No	Yes	No	No	Yes	No	Yes
Size Mod	Yes	No	Yes	No	Yes	No	No	Yes	Yes	Yes
Consistent with clinical data	no data	Yes	no data	Yes	Yes	no data	no data	no data	Yes	no data

Table 1: Data from participating sites (A – J) for paediatric abdomen liver mass protocol

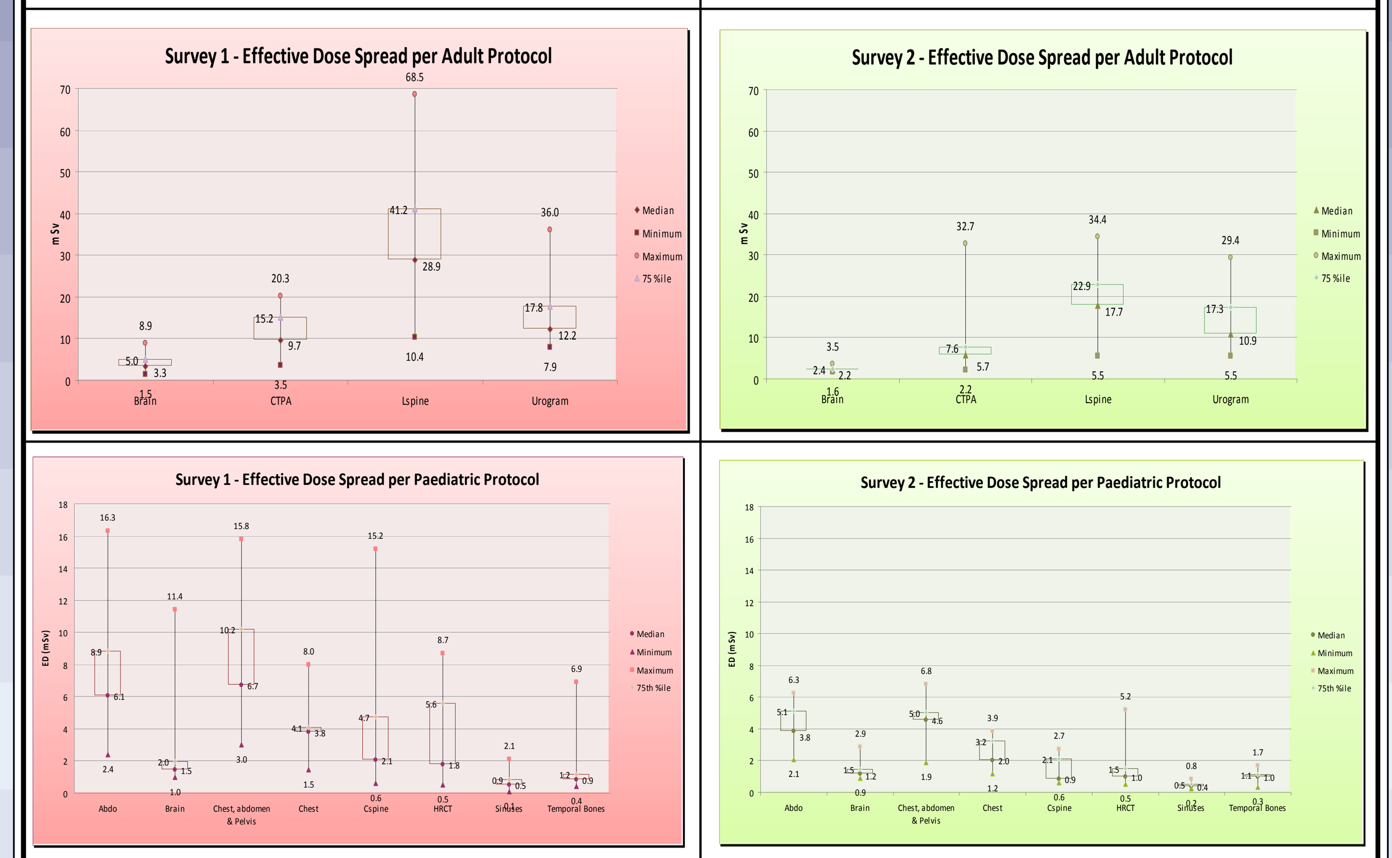
Data collection issues

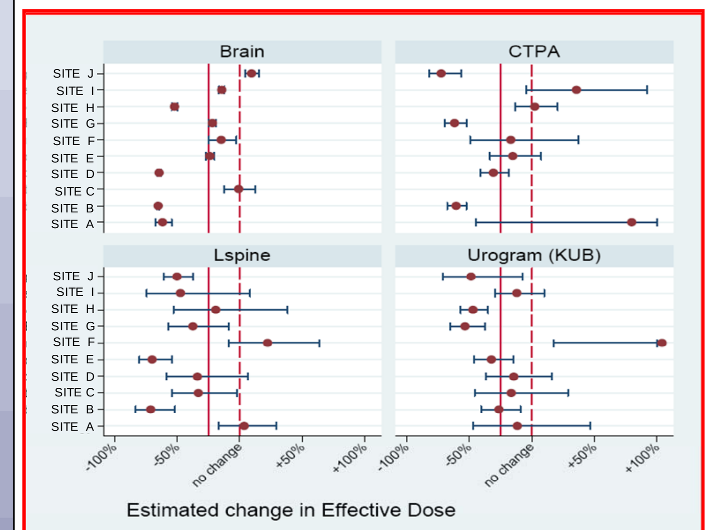
- Problems encountered with inter-scanner variation in terminology and displayed data
  - mAs vs. mAseff
  - Pediatric body DLP – platform variations relating to scan FOV influence on calculated DLP
  - CT Expo program written before dose modulation
  - Workaround (which was different for each scanner platform) was needed to generate a mean mAs from which dose could be calculated

Results – Key Points

- 1144 scans were submitted for baseline survey
- 1226 scans for post intervention
- A decrease in effective dose was achieved with all scan protocols
- 6-7 fold variation in dose for adult protocols at baseline
- Hard to collect real patient data for pediatric scans except head due to small scan numbers
- Relied on data from an anthropomorphic phantom equivalent to a 5 year old child

Pre-intervention	Post-intervention





Estimated change in geometric mean ED, with 95% confidence intervals, by site and protocol.

Broken vertical red lines = point of no change;

Solid vertical red lines = median dose reduction of 25%

Manufacturer Chosen Reference Phantom (160 mm or 320 mm perspex) for $CTDI_W$

	Pediatric		Adult	
	Head	**Body**	**Head**	**Body**
Siemens	160 mm	320 mm	160 mm	320 mm
Philips	160 mm	320 mm	160 mm	320 mm
GE	160 mm	**160 mm**	160 mm	320 mm
Toshiba	160 mm	**160 mm**	160 mm	320 mm

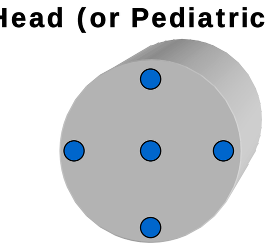
Use of smaller phantom approximately doubles DLP!

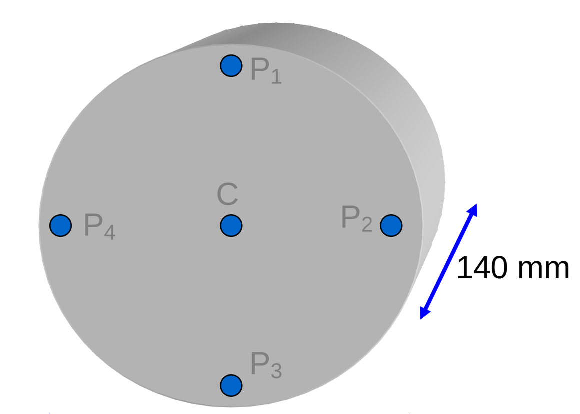
- Toshiba and GE can appear to deliver double the dose for a pediatric body scan compared to Siemens and Philips for the same acquisition parameters
- Issues with the reference phantom can create the same effect in some adult scans eg Lumbar Spine when a small field of view has been utilized

CTDI Phantoms

$$CTDI_W = 1/3\ CTDI_{100,C} + 2/3\ CTDI_{100,P}$$

Head (or Pediatric body?)





Use of adult data for child scans

kV	Collimation (mm)	System CTDIvol/100mAs	Pitch (1 if mAseff)	System CTDIw/100mAs	CTExpo CTDIw/100mAs (child)	CTExpo CTDIw/100mAs (adult)
120	40	5.92	1	5.92	11	5.7
120	40	11.44	1	11.44	11	11
120	40	6.67	1	6.67	11	5.7
120	40	5.85	1	5.85	11	5.7
120	40	6.83	1	6.83	11	5.7
120	40	5.87	1	5.87	11	5.7
120	25	11.4	1	11.4	12	12

Table 2: Results from scans on an anthropomorphic phantom equivalent to a 5 year old child at known mAs – Philips BR64 system

Other problems.....

- Post workshop optimization using Philips scanners particularly challenging
  - Difficult to determine how dose modulation worked
  - Difficult to obtain an understanding of this from applications specialist or vendor
  - mAs seemed to depend on most recent previous scans and whether scanner generated parameters had been overridden in the past by technologist

What helped us succeed?

- Hot topic
- National DLP survey for CT funded 2010 by Australian Government Department of Health
- RANZCR initiative
  Would government initiated alone work?
- Face to face workshop
  Compare with peers (without the threat) due to de-identification of sites
  ....but would it work on – line?
- Volunteer practices
  ....but would it work with conscripts?

Summary

- Survey – Workshop – Re-Survey approach successful
  - Clinically important median dose reduction
  - Range of doses reduced
- Pediatric dosimetry challenges
- Labor intensive
  - Partnership between radiologist and MIT dedicated to the project over many weeks
  - Access to internal or external medical physics support
  - ALL must have excellent understanding of what contributes to dose
  - Support from vendors to help find scan parameters and understand how dose modulation / noise index works for particular scanner essential

Simplifications for single scanner adult optimization.......

- Do not need CT Expo dose calculation program
- Use paper spreadsheet to collect scan data for a small number of scans
- Use scanner generated DLP as indicative metric (**may not be comparative if FOV changed and Toshiba or GE scanner)
- Change one parameter at a time and monitor change to:
  - Subjective appearance
  - ROI in standard location on image ; SD in ROI is indicative of noise
  - In an "average sized" patient to avoid confounding effect on dose of very large or very small patient

Bibliography

1. Brenner DJ, Hall EJ. Computed Tomography - An Increasing Source of Radiation Exposure. New England Journal of Medicine 2007; 357:2277-2284.;
2. Ghotbi N, Ohtsuru A, Ogawa Y, et al. Pediatric CT scan usage in Japan: results of a hospital survey. Radiat Med Huda W, Vance A. Patient radiation doses from adult and pediatric CT. AJR Am J Roentgenol 2007; 188:540-546;
3. Linton OW, Mettler FA, Jr. National Conference on Dose Reduction in CT, with an Emphasis on Pediatric Patients. Am. J. Roentgenol. 2003; 181:321-329.;
4. McLean D, Malitz N, Lewis S. Survey of effective dose levels from typical paediatric CT protocols. Australasian Radiology 2003; 47:135-142.;
5. Moss M, McLean D. Paediatric and adult computed tomography practice and patient dose in Australia. Australasian Radiology 2006; 50:33-40.
6. Stamm H, Nagel HD. CT-Expo. In. Ver. 1.6 ed. Hannover, 2007

Acknowledgements

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