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Paediatric CT Practice - How safe is imaging in different countries?

Paediatric CT practice in a tertiary hospital

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Part 1

1. How radiation protection is promoted and practised during CT imaging of children in your facility

This is achieved by working within the strict guidelines of the Ionising Radiation (Medical Exposure) Regulations 2000. Radiation protection is a priority and taken very seriously in our practice at GOSH. The use of empirical paediatric imaging protocols developed specifically, in house, to assist in the delivery of the lowest possible radiation dose whilst ensuring that images are of diagnostic quality.

2. How radiation protection of children undergoing CT imaging is practised

A good knowledge of presenting pathology is achieved based on which selection of the most appropriate imaging protocol in order to limit radiation dose is achieved. In addition, the use of low kVp for all body imaging (80 or 100kV), and limiting coverage strictly to the area of interest only, is advocated. Multiphase scans are no longer necessary, as with optimal contrast timing, both arterial and venous phases are defined. Within cardiac imaging, prospective ECG-gated cardiac imaging is preferred (compared to retrospective gating) as a means to reduce radiation dose.

3. Assessment of the number of paediatric CT examinations that lack in appropriateness

At GOSH we have weekly multidisciplinary meetings with clinicians to discuss and educate clinicians into the optimal imaging techniques used to image specific conditions and also specific clinical dilemma facing individual patients? This helps to encourage clinicians to favour techniques such as ultrasound and MR where appropriate and available.
Both the technologists and the sessional radiologists vet all CT requests. Examinations are triaged to MRI if this is thought appropriate. We reject or redirect a mean 10% of requests (235 of 2,358 in 12 month period over 2011-2012)

4. Data on the percentage dose reduction in CT of children

With the implementation of each new model of CT scanner, and the associated improved technology and radiation saving features, an overall average reduction of 50% (range 48-52%) reduction in radiation dose has been achieved with each successive generation of CT scanner, see Table. Regular audit of image quality and imaging parameters is carried out to monitor patient exposure to ensure imaging parameters are optimised.

		Data Source	Multi-Detector CT 2003	Single Source CT 1996
Up to 15kg	Decrease 46%	1.0 CTDIvol mGy 0.8 mSv	0.98 CTDIvol mGy 1.0 mSv	1.9 CTDIvol mGy 1.5 mSv
16 to 24kg	Decrease 54%	1.27 CTDIvol 1.0mSv	1.25 CTDIvol 1.3 mSv	2.7 CTDIvol 2.2 mSv
25 to 35kg	Decrease 57%	1.50 CTDIvol 1.2 mSv	1.75 CTDIvol 1.6 mSv	2.8 mSv
36 to 45kg	Decrease 50%	1.76 CTDIvol 1.4 mSv	2.68 CTDIvol 2.9 mSv	3.5 CTDIvol 2.9 mSv

5. How we child size our CT imaging

Imaging parameters have been developed and optimised to encompass the range of patients (from 1 day old to 17years) seen within the CT department. Protocols are set according to patient weight dependent on body parts being examined.

In brain imaging, patients are separated into three age groups: up to 1 year, 1 to 6 years and over 6 years. Whilst for body imaging, parameters are set according to six different patient weight ranges. These are up to 7kg, 7 to 15kg, 16 to 25kg, 26 to 35kg, 36 to 45kg and over 46kg. In addition, ultra low dose protocols may be used for the same body part depending on the presented pathology, e.g. the assessment for hydrocephalus does not require the same spatial resolution as for a routine head imaging, and in the evaluation of for e.g. pectus excavatum, a low dose chest CT is adequate to define the bony structures[1].

6. Paediatric CT referrals that are reviewed by radiologists before giving appointments

All requests (ie 100%)body imaging (approx. 1,100 patients per annum) are vetted and justified by a consultant radiologist prior to appointment scheduling. Requests for abdominal imaging are referred to MRI in the first instance especially in the younger children, and in particular for the diagnosis and staging of tumours where further regular diagnostic follow up imaging is necessary during treatment.

7. Table of facility's CTDI and DLP for children from different age groups

Imaging Protocols

Table 1: Routine Chest CT imaging parameter guidelines

Scan Mode	Helical			
Scan Parameter	**kV**	**QmAs**	**CTDIvol mGy**	**DLP mGy.cm**
Up to 7kg	80	60	0.8	16
7 - 15kg	100	30	1	22
16 - 25kg	100	38	2	38
26 - 35kg	100	42	3	77
36 - 45kg	100	48	4	111
Tube Rotation	0.5sec			
Tube Collimation	64 x 0.6mm			
Scan Pitch	1			
Dose Modulation	On			
Recon Slice Width	1mm			
Recon Kernel	1st recon - medium-soft B30, on mediastinum setting 2nd recon - sharp B60, on lung parenchyma setting			
Contrast Media	1.5 - 2mls/kg up to maximum 100mls			
Scan Delay	20-30secs			

Table 2: CT Angiography imaging parameter guidelines

Scan Mode	Helical			
Scan Parameter	**kV**	**QmAs**	**CTDIvol mGy**	**DLP mGy.cm**
Up to 7kg	80	60	0.9	12
7 - 15kg	100	30	0.9	18
16 - 25kg	100	38	2	44
26 - 35kg	100	42	3	84
36 - 45kg	100	48	5	114
Tube Rotation	0.5sec			
Tube Collimation	64 x 0.6mm			
Scan Pitch	1			
Dose Modulation	On			
Recon Slice Width	1mm			
Recon Kernel	1st recon - medium-soft B30, on mediastinum setting 2nd recon - sharp B60, on lung parenchyma setting			
Contrast Media	1.5 - 2mls/kg up to maximum 100mls			
Scan Delay	20-30secs			

Table 3: Retrospective ECG-Triggered Cardiac CT imaging parameter guidelines

Scan Mode	Helical			
Scan Parameter	**kV**	**QmAs**	**CTDIvol mGy**	**DLP mGy.cm**
Up to 7kg	80	80	3	38
8 - 15kg	80	150	2	31
16 - 25kg	100	120	3	66
26 - 35kg	100	136	5	108
36 - 45kg	100	152	6	150
Over 46kg	100	170	8	209
Tube Rotation	0.33sec			
Tube Collimation	64 x 0.6mm			
Pitch	0.3 to 0.5 dependent on heart rate			
ECG-trigger phase	End-systolic phase			
Dose Modulation	Off for children up to 7kg On for all other children			
Recon Slice Width	0.75mm with 0.5mm overlap 1st recon diastolic phase 2nd recon systolic phase 3rd recon 10 – 100% cardiac phase			
Recon Kernel	Soft B26			
Contrast Media	1.5 - 2mls/kg up to maximum 150mls			
Scan Delay	Bolus tracked with ROI placed outside body area and with manual scan initiation			

Table 4: Prospective ECG-Triggered Cardiac CT imaging parameter

Scan Mode	Helical			
Scan Parameter	**kV**	**QmAs**	**CTDIvol mGy**	**DLP mGy.cm**
Up to 7kg	80	62	1	11
7 - 15kg	80	112	0,6	7
16 - 25kg	100	106	2	28
26 - 35kg	100	118	3	66
36 - 45kg	100	132	4	88
Over 46kg	100	148	6	140
Tube Rotation	0.33sec			
Tube Collimation	64 x 0.6mm			
Table Feed	17mm			
ECG-trigger phase	End-systolic phase - 200ms			
Dose Modulation	Off for children up to 7kg On for all other children			
Recon Slice Width	0.75mm with 0.5mm overlap			
Recon Kernel	Soft B26			
Contrast Media	2mls/kg up to maximum 150mls			
Scan Delay	Bolus tracked with ROI placed outside body area and with manual scan in			

Table 5: Routine Abdomen CT imaging parameter

Scan Mode	Helical			
Scan Parameter	**kV**	**QmAs**	**CTDIvol mGy**	**DLP mGy.cm**
Up to 15kg	100	60	2	44
15 to 25kg	100	65	3	106
26 to 35kg	100	70	5	192
36 to 45kg	100	75	6	238
Over 46kg	100	80	7	315
Tube Rotation	0.5sec			
Tube Collimation	Under 15kg - 64 x 0.6mm Over 16kg - 24 x 1.2mm			
Scan Pitch	1			
Dose Modulation	On			
Recon Slice Width	1mm			
Recon Kernel	Medium-soft B30			
Contrast Media	2mls/kg up to maximum 150mls			
Scan Delay	40 - 50secs			

These protocols are in current use at Great Ormond Street Hospital for Children, London. The CTDIvol and DLP data were collected in collaboration in collaboration with the Health Protection Agency, Medical Dosimetry Group, Didcot, UK . To date, I do not believe this data has been published.

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Part 2

8. Imaging Protocols with consequent results on CTDI/DLP

CT Chest Routine

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Up to 7kg	0.4 (±0.3)	5.3 (±1.6)	13.2 (±1.2)	10.4 (±1.3)	0.9 (±0.2)	14 (±3.7)
7 to 15kg	3.3 (±1.9)	12.1 (±1.9)	16.8 (±1.5)	12.4 (±1.1)	1.2 (±0.2)	22 (±3.7)
16 to 35kg	6.7 (±3.7)	21.1 (±7.6)	21.5 (±3.0)	14.8 (±1.4)	2.3 (±0.7)	51 (±20.9)
36 to 50kg	11.7 (±1.9)	40.5 (±2.7)	26.7 (±1.3)	18.0 (±1.4)	4.3 (±0.6)	109 (±20.9)

CT Chest Angiography

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Up to 7kg	0.2 (±0.3)	4.3 (±1.7)	12.2 (±1.9)	9.8 (±1.5)	0.9 (±0.3)	12 (±3.7)
7 to 15kg	1.8 (±1.4)	10.3 (±2.2)	16.0 (±1.9)	11.9 (±0.9)	0.9 (±0.2)	20 (±8.0)
16 to 35kg	7.2 (±3.3)	29.0 (±5.7)	24.1 (±6.0)	16.1 (±2.0)	2.7 (±1.7)	65 (±37.2)
36 to 50kg	11.1(±1.9)	40.3 (±5.3)	27.1(±2.5)	18.7 (±1.0)	4.0 (±1.1)	101 (±27.7)

CT ECG-Gated Prospective Cardiac Imaging

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Up to 7kg	0.2 (±0.2)	3.3 (±1.1)	10.6 (±1.0)	8.9 (±0.8)	1.1 (±0.2)	11 (±2.0)
7 to 15kg	1.5 (±0.9)	10.5 (±2.6)	16.8 (±1.2)	11.7 (±1.1)	0.6 (±0.1)	8 (±1.9)
16 to 35kg	7.7 (±3.0)	21.7 (±6.3)	20.5 (±2.3)	15.1 (±1.5)	1.9 (±0.8)	39 (±19.5)
36 to 50kg	14.0 (±3.1)	43.4 (±4.7)	28.1 (±1.4)	17.9 (±1.9)	4.78 (±1.5)	111(±37.8)

CT ECG-Gated Retrospective Cardiac Imaging

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
8 to 15kg	1.3 (±0.6)	8.5 (±1.7)	16.4 (±1.0)	12.2 (±0.6)	1.9 (±0.6)	31 (±6.0)
16 to 35kg	12.1 (±5.1)	25.6 (±5.4)	22.6 (±2.6)	15.6 (±1.7)	4.12 (±1.3)	90 (±29.6)
36 to 50kg	14.1 (±0.2.6)	41.4 (±4.5)	27.4 (±2.5)	17.8 (±1.6)	6.58 (±1.6)	165 (±41.1)

CT Abdomen/Pelvis
32 x 0.6mm collimation
24 x 1.2 collimation

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Under 7kg	n/a					
8 to 15kg	1.6 (±0.9)	11.2 (±2)	16.8 (±2)	12.6 (±2)	1.6 (±0.3)	46 (±10)
16 to 35kg	7.4 (±3)	23.2 (±3)	20.7 (±2)	15.2 (±2)	3.6 (±1)	131 (±42)
36 to 50kg	13.5 (±2)	42.9 (±5)	25 (±2)	17.8 (±2)	5.9 (±1)	251 (±79)

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Up to 7kg	0.5 (±0.3)	5.1 (±1)	14.2 (± 2)	11.0 (±0.9)	1.6 (±0.4)	34 (±8)
8 to 15kg	2.3 (±2)	12 (±3)	17.9 (±3)	13.3 (±3)	2.11 (±1)	58 (±19)
16 to 35kg	6.2 (±2)	19.3 (±4)	20.6 (±0.2)	13.9 (±1)	3.2 (±0.2)	114 (±21)
36 to 50kg	14.7(±2)	43.3 (±6)	25.6(±2)	18.1 (±2)	6.7 (±2)	278 (±57)

CT Head Routine
Sequence acquisition, 24 x 1.2mm collimation

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Under 7kg	0.2 (±0.2)	4.1 (±4)	10.6 (±1)	12.5 (±1)	12.8 (±1)	146 (±25)
8 to 15kg	2.1 (±2)	12.1 (±2)	13.7 (±1)	16 (±2)	19.6 (±3)	288 (±51)
16 to 35kg	7.3 (±2)	24.9 (±7)	14.5 (±1)	18 (±1)	31.7 (±8)	477 (±115)
36 to 50kg	13.2 (±3)	41.5 (±5)	15 (±1)	18.7 (±1)	39.2 (±5)	607 (±125)

CT Head Hydrocephalus
Sequence acquisition, 1 x 10mm collimation

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Under 7kg	0.3 (±0.2)	4.8 (±1)	10.8 (±1)	13.5 (±1)	8.12 (±1)	100 (±21)
8 to 15kg	1.8 (±1)	11.6 (±2)	13.0 (±1)	16.5 (±1)	12.4 (±1)	179 (±23)
16 to 35kg	5.8 (±2)	21.6 (±5)	14.2 (±1)	17.9 (±2)	17.2 (±4)	259 (±65)
36 to 50kg	13.0 (±2)	44.8 (±6)	14.3 (±1)	18.6 (±1)	22.9 (±2)	338 (±38)

CT 3D Head
Helical acquisition, 32 x 0.6mm collimation

	Age yrs	Weight kg	Lateral Diameter cm	AP Diameter cm	CTDIv mGy	DLP mGy.cm
Under 7kg	0.4 (±0.2)	5.6 (±1)	12.1 (±1)	13.2 (±2)	2.6 (±1)	50 (±8)
8 to 15kg	1.7 (±1)	10.5 (±3)	13.1 (±1)	15.6 (±2)	2.9(±0.2)	64 (±10)
16 to 35kg	7.6 (±4)	21.6 (±5)	14.5 (±1)	17.6 (±1)	4.4 (±1)	105 (±37)
36 to 50kg	13.4 (±3)	43.3 (±4)	15.2 (±1)	18.0 (±2)	5.7 (±1)	145 (±23)

This data was collected at Great Ormond Street Hospital for Children, London, between the period January 2011 to December 2011 in collaboration with the Health Protection Agency, Medical Dosimetry Group, Didcot, UK.

Poster References:

1. Young C, Owens CM. Paediatric Computed Tomography Imaging Guideline. Acta Radiologica 2013; 0:1-9
2. Young C, Xie, Cheng, Owens CM. Paediatric Multi-Detector Row Chest CT: What You Really Need To Know. Insights into Imaging 2012; 3:229-46