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Pediatric CT imaging: The issues and how I do it

Abstract

Philips CT Clinical Science • Philips Healthcare

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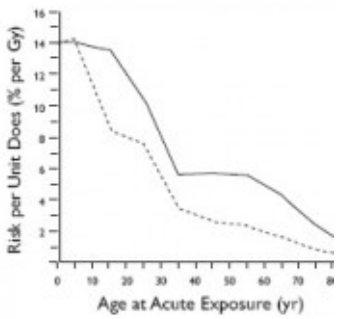
Multidetector CT scanning (MDCT) MDCT, due to shorter scan times, has enabled imaging with reduced motion and breathing artifacts, particularly in children. The need for sedation is confined to very young children. Thinner image slices results in greater spatial resolution which is useful in the evaluation of complex areas such as the inner ears. Isotropic image data collection allows for multiplanar reconstructions and 3-D rendering.

There is reduced Z-axis geometric efficiency of MDCT in comparison to single slice CT scanners. This is due to the irradiated tissue slice being greater than the detector width. The loss of efficiency is worse at narrow collimations. Thus the dose to the patient may well be increased with the use of MDCT, especially when acquiring data with very narrow collimation.



Dose Reduction

The most pertinent difference between CT imaging of adults and children is that children are more susceptible to the ill-effects of radiation. If the imaging parameters (e.g. KVp and mAs) are not reduced from adult settings, the dose to the child is much increased due to their smaller size and reduced beam attenuation. Children have increased organ sensitivity to radiation induced damage. They also have a longer lifetime in which to manifest radiation induced cancers. Thus there is an obligation on the radiologist to minimize radiation exposure when scanning children.

The greatest dose reduction is achieved when the study is not performed - the

Abstract

abdomen, Body, Cardiac, dose reduction, Head, IAC, MDCT Users Meeting, Neck, Neuro, Pediatric, pediatric abdomen, pediatric cardiac, pediatric ear, pediatric head, pediatric neck, pediatric thorax, spatial resolution, Thorax, thyroid, Z-DOM

radiologist must satisfy themselves that it is required and that other non-radiation modalities cannot suffice (Justification). If the scan is to be undertaken then the principles of 'As Low As Reasonably Achievable' should be adhered to (ALARA). The dose parameters should be tailored to the size/age of the child and the clinical indication. The aim is not for optimal image quality but for a diagnostic study. Dose reduction without compromising diagnostic accuracy is possible. It is generally best to image with a standard KVp (usually 120 KVp) and pitch and attempt to reduce the mAs as much as is tolerable. An advised or 'planned' mAs will be suggested automatically by the scan console based on the attenuation during acquisition of the scout image, taking into account patient size and thickness. Depending on the clinical indication this advice may be followed or manually over-ridden to reduce the mAs further. Follow-up scans may be done at a lower mAs as 'noisier' images are generally more tolerable in this instance. The mAs can usually be significantly reduced when imaging areas of high inherent contrast such as the chest, bone and for CT angiograms. Automatic Exposure Control (Z-Dom) should be enabled where possible to allow for further dynamic mAs reduction in the Z plane during scanning, e.g. when going from the shoulder region to the chest. Multiphase imaging is rarely required in children i.e. pre- and post-contrast phase or delayed post-contrast images. The area to be scanned should be kept to a minimum. Shielding should be routinely used in all children regardless of age or gender e.g. bismuth breast shields, thyroid and eye shields. These need to be applied after the scout image is acquired as the planned mAs for the study is based on the attenuation of the scout image.

It is good policy to note the estimated Dose Length Product ($CTDL_{vol}$ x scan length) for each paediatric scan and to observe how it may be reduced by adopting the above recommendations. The DLP can be accessed via the 'Information' icon on the 'Quick Review' screen of the scout image where the cut lines are shown. In order to express it as an estimated Effective Dose in mSv, the DLP value needs to be multiplied by a 'conversion factor' as per the following table.

Normalised values of effective dose per dose-lenght product (DLP) over various body regions and (standard) patient age

Region of body	Effective dose per DLP (mSv (mGy cm)$^{-1}$) by age				
	0[a]	1y[a]	5y[a]	10y[a]	Adult[b]
Head & neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen & pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

[a] All data normalised to $CTDI_w$ in the standard head CT dosimetry phantom.
[b] Data for the head & neck regions normalised to $CTDI_w$ in the standard head CT dosimetry phantom; data for other regions normalised to $CTDI_w$ in the standard body CT dosimetry phantom.

Patient Preparation

We do not routinely fast patients for CT, even if they are going to receive IV contrast. We do, of course, fast young children if they are for oral sedation. We

give oral contrast for most abdominal scans except if done immediately post trauma. A 4% solution of iodinated contrast is used (20 mls of 300 mg/ml iodinated contrast in 500 mls water), flavored with fruit squash if required. The suggested volumes are as follows, given over one-two hours with perhaps a top-up volume just prior to the scan especially if the area of interest is the duodenum or pancreas.

< 1 year <200 mls
1-5 years 200-360 mls
6-12 years 360-550 mls
>12 years 550-600 mls

To achieve sedation, we only use oral medication by means of chloral hydrate. We do not administer IV sedation. We give 50 mg/kg chloral hydrate to infants less than one year and 75 mg/kg to young children up to the age of three-and-a-half years. We do not sedate over this age group or body weight over 20 kg. A top up dose of 25 mg/kg may be given to either age group if the first dose fails to sedate adequately. Fasting prior to sedation is for six hours from food, four hours from milk and two hours from clear fluids. Sedation is administered approximately 30 minutes prior to the CT examination by experienced pediatric nurses with the supervision of a radiologist. Children between the ages of three months and approximately two-and-a-half years often require sedation for the CT exam. Older children can often be encouraged to cooperate without the use of sedation. Infants in the first few months of life may often be settled by feeding, wrapping warmly and perhaps using a 24% sucrose solution - a few drops orally or on the soother. If IV access is required for a contrast enhanced scan, it is established prior to sedation. If clothes with metal fasteners need to be removed for the scan, this should also be done prior to giving sedation. We have a colourful wall mural with many familiar children's characters to soften the clinical environment of the scan room. Additionally, we have a lighting scheme with constantly changing hues and intensities. These often succeed in catching a child's interest long enough to ensure cooperation. We encourage parents to come into the scan room with their child, either behind a lead screen or wearing a lead coat.

In all children requiring contrast enhancement, the IV cannula should be inserted well in advance of the scan to avoid distress just prior to scanning. Ideally, the cannula should be either 22 or 20 gauge. We use 2 ml/kg of nonionic iodinated contrast at a concentration of 300 mg/ ml. We generally use a hand injection if the volume to be given is less than 20 mls. It is preferable to use the pump injector for volumes greater than this to optimize timing of the injection and subsequent scanning. We use 1-1.5 ml/sec for a 22 gauge and up to 2 ml/sec for a 20 gauge cannula. The maximum flow rates used for these cannulas are 2 ml/sec and 3 ml/sec respectively and for certain indications such as CTPA we may increase the flow rate if we are confident of the peripheral access site. We commence scanning within ten seconds after termination of contrast administration for Chest CT, but leave a scan delay of approximately 50-60 seconds after the onset of contrast administration for CT of the abdomen for the portal venous phase of enhancement. We place lead aprons outside the imaging field e.g. over the abdomen in children for CT of the chest. As mentioned, we use Bismuth latex shields for the breast and thyroid in boys and girls of all ages. In very young children, we tend not to use these shields as they have to be placed

after acquiring the scout image, and generally, this would involve disturbing a child we have already taken time to settle in the scanner. We acquire images during quiet breathing in young children and sedated children. Generally children older than five-six years cooperate with a single breath hold for the duration of the scan.

Contrast Media and Asthma/Allergies

Most data in relation to this topic relates to adult populations. Dillman, et. al, in 2007 reported on a large group of paediatric patients and found the incidence to be 0.18%, lower than reported in many adult groups. 80% of the reactions were mild and no deaths occurred. Apparent risk factors for developing reactions included a history of prior reaction to iodinated contrast material, a history of multiple allergies and asthmatic attacks, particularly if described as recent, frequent or severe. They advised premedication with oral steroids and antihistamines prior to imaging these groups. The regimen for premedication advised was as follows. Many users also find it helpful to use the following tables with suggested reduction factors to be applied to a baseline study in a medium sized adult. When acquiring the paediatric scan, it is important to use the same KVp and pitch as used in the baseline adult scan and only reduce the mAs.

Drug	Timing	Paediatric Dose
Prednisone	13, 7 and 1 hour prior to sca	0.5-0.7 mg/kg orally
Diphenhydramine	1 hour prior to scan	1.25 mg/kg orally

Scan Parameters

We use the following scan parameters routinely in our paediatric scanning. We often reduce the mAs below the suggested value advised based on the attenuation during acquisition of the scout image. Additionally, activating the Z-DOM will reduce the actual mAs further dynamically when acquiring the images through narrower portions of the body part.

	Collimator width	Slice thickness	Slice increment	Pitch	KVp	mAs	Z-DOM
Chest CT	64 x 0.625	2mm	1mm	1.08	120	as planned based on scout	Yes
HRCT Chest	2 x 0.625	1.25mm slices axial, non helical			120	as planned based on scout	No
Abdominal CT<40kg	64 x 0.625	3mm	1mm	0.89	80	as planned based on scout	Yes
Abdominal CT 40kg	64 x 0.625	3mm	1mm	0.89	120	as planned based on scout	Yes
Head CT 0-18 mts	16 x 0.625	2.5mm slices axial, non helical			120		No
Head CT 18 mts-6yrs	16 x 0.625	2.5mm slices axial, non helical			120		No
Head CT >6 yrs	16 x 0.625	2.5mm slices axial, non helical			120		No

Abdomen Baseline	kVp=	mA=	Time= sec	Pitch Abdomen=	Pitch Thorax=
PA Thickness (cm)	Approx Age	Abdomen		Thorax	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF (fill in)	mAs Reduction Factor (RF)	Estimated mAs= BL x RF (fill in)
9	newborn	0.43		0.42	
12	1 yr	0.51		0.49	
14	5 yr	0.59		0.57	
16	10 yr	0.66		0.64	
19	15 yr	0.76		0.73	
22	small adult	0.90		0.82	
25	med adult	Baseline (BL)		0.91	
31	large adult	1.27		1.16	

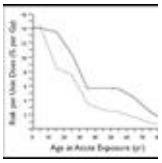
Table I mAs Reduction Factors for the Pediatric Abdomen and Thorax

Head Baseline:	kVp= Pitch	mA=	Time=
PA Thickness (cm)	Approx Age	Head	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF (fill in)
12	newborn	0.74	
16	1 yr	0.86	
17	5 yr	0.93	
19	med adult	Basline (BL)	

Table II mAs Reduction Factors for the Pediatric Head

Further Reading

1. *Estimated risks of radiation-induced fatal cancer from pediatric CT.* Brenner DJ et al. AJR 2001;176:289-296
2. *Helical CT of the body: Are settings adjusted for pediatric patients?* Paterson et al AJR 2001;176:297-301
3. *Minimizing radiation dose for pediatric body applications of single-detector helical CT: Strategies at a large children's hospital.* Donnelly LF et al AJR;176:303-306
4. *Dose reduction in pediatric CT: A rational approach. Boone JM et al Radiology 2003;228:352-360 www.imagegently.org* The Alliance for Radiation Safety in Pediatric Imaging.
5. *Incidence and severity of acute allergic-like reactions to IV non-ionic iodinated contrast material in children.* Dillman JR et al AJR 2007;188:1643-1647



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This abstract from a presentation given by Dr. Eilish Twomey (Children's University Hospital in Dublin) at the 6th Philips MDCT Users Meeting provides details on issues and techniques in pediatric imaging.

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