

How to Develop CT Protocols for Children

Introduction

Prior to 2001 the vast majority of CT imaging of children was conducted using the same or similar techniques used for adult imaging. In 2001, several articles (1-3) received considerable media attention by pointing out that this approach was not necessary and resulted in estimated radiation doses to the smallest children as much as three times that given to an adult. Since then, considerable work has been published in the literature on protocols to reduce dose to children undergoing CT examinations (4-17). However, many of these protocols are scanner specific and not transferable to other CT units.

These instructions provide guidance in either developing CT protocols for children or verifying that your current protocols are appropriate. ***This document is only intended as a guide and the technique parameters provided are only suggestions that primarily apply to the use of manual techniques. The interpreting radiologist, in consultation with a medical physicist, must evaluate any changes to the practice's techniques that reduce radiation dose so that the adequate diagnostic information is available.***

Technique reduction factors were developed from radiation measurements obtained with ionization chambers and anatomical pediatric CT phantoms (18). These phantoms range in size from infant to large adults and consist of tissue equivalent plastic that has a CT number of "0". The abdomen phantoms have a tissue equivalent spine; the thorax phantoms have tissue equivalent spine and lung tissue; and the head phantoms have tissue equivalent skull bone.

In order to use these reduction factors, the radiologist should first work with the CT technologist to be familiar with techniques used for both adults and children. You must then verify that your adult technique factors do not deliver estimated radiation doses ***larger*** than those recommended by the American College of Radiology's (ACR) CT Accreditation Program (19,20). No universal CT technique can be used with all vendors' CT equipment for the adult patient. Differences in CT scanner design (e.g. bow tie filters, focal spot-to-detector distance, detector efficiency, etc.) make it impossible to estimate patient radiation dose based on technique factors alone. Consequently, you must have a Qualified Medical Physicist (21,22) (i.e., one who is board certified in diagnostic radiological physics) measure the radiation output from your CT scanner in order to estimate the dose and help you establish appropriate adult abdomen and head techniques. Any Qualified Medical Physicist who has assisted other facilities in obtaining accreditation of their CT scanners should be familiar with this test protocol (23).

Your adult abdomen and head techniques will become your baseline techniques. Using these baselines, Tables I and II allow you to estimate appropriate reductions in mAs for children based on their age or PA thickness. Ideally, the PA thickness of the pediatric patient should be measured with calipers. If you cannot obtain the child's PA thickness, Tables I and II list an "average" age that corresponds to the thicknesses in the first column. The resulting techniques should provide a radiation dose that is approximately

equal to or less than your estimated adult CT dose for the same procedure. (Again, your medical physicist should assist with this.)

These instructions assume all technique factors (other than tube current and/or gantry rotation time) remain fixed as techniques are adjusted for pediatric patients. Although several authors have advocated changing other parameters (i.e., kVp) in order to reduce dose (24-28), these instructions will not apply if parameters other than mAs are changed. You need to work closely with your medical physicist in these situations to insure image quality is maintained while your desired dose reductions are achieved.

The data in the two tables list reduction factors for the “mAs” provided you are using manual techniques. If you are using the automatic exposure control (AEC) features of your CT scanner for imaging, the AEC system should automatically reduce techniques for children provided the adult baseline is set up properly. In this case, you should follow part A of the procedure to verify that the dose estimate from your baseline technique does not exceed recommended adult values. Place your baseline “mAs” values in the provided spreadsheet to obtain the correct pediatric techniques for your scanner. You can verify that the AEC system on your CT scanner is properly functioning by comparing the mAs values listed on your CT images with the appropriate value listed in Tables 1 & II. If the mAs values listed on your CT images are less than or equal to the corresponding value in Tables I & II, your pediatric radiation doses are less than or equal to your estimated adult radiation doses.

Reducing patient dose in CT increases the quantum mottle or background “noise” in your images. Since increased quantum mottle affects low contrast image quality more than high contrast image quality, dose reductions for low contrast images may be limited. For example, soft tissue differentiation (low contrast) requires lower noise in the image than studies of bony detail or lung parenchyma (high contrast). These instructions should provide adequate image quality for your pediatric soft tissue studies since the dose will be similar to adult techniques and the noise level should not change. You may be able to reduce doses to a greater degree for high contrast studies.

Procedure

A. Establish baseline techniques for an adult head and abdomen CT.

1. Your medical physicist should determine the $CTDI_{vol}$ for an adult body phantom and an adult head phantom using the FDA 32 and 16 cm $CTDI$ PMMA phantoms (29) respectively.
2. If the measured $CTDI_{vol}$ of the adult abdomen or head phantoms exceed the ACR CT Accreditation Program recommended upper values of 25 and 75 mGy respectively (20), work with your medical physicist to reduce either the tube current (mA) or rotation time (sec) to lower the doses.

- Record the final tube voltage (kVp), tube current (mA), rotation time (sec), pitch and bow tie filter settings in Tables I and II as your baseline techniques for the adult abdomen and head.

B. Determine the appropriate mAs for a pediatric thorax, abdomen and head CT.

- Multiply the baseline (abdomen or head) mAs by the indicated Reduction Factor to determine the appropriate pediatric mAs and write this in the table for all patient PA thicknesses/ages or use attached Excel spread sheet to automatically perform these calculations.)
- The other techniques in your protocol (kVp, pitch, and bow tie filter) must remain the same. ***You should verify with your CT manufacturer that the bow tie filter in the scanner does not change if the FOV is reduced for pediatric patients.***
- If the pitch of your thorax and abdomen scans is different, ask your medical physicist to calculate the correct Thorax Baseline from your Abdomen Baseline. Alternatively, the attached Excel spread sheet automatically performs this correction if you enter the different pitch values in the spreadsheet.
- When examining pediatric patients, find the mAs Reduction Factor from the completed tables that corresponds to the applicable PA thickness/age.
- The mAs ratios in Tables I and II assume that the kVp used for a pediatric examination is the same as the kVp used to determine the baseline mAs for either the head or the abdomen.** If you elect to use a reduced kVp for pediatric examinations, the suggested mAs ratios in these tables do not apply.

Table I: mAs Reduction Factors for the Pediatric Abdomen and Thorax

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 II: mAs Reduction Factors for the Pediatric Head

Head Baseline:	kVp=	mA=	Time= sec
	Pitch=		

PA Thickness (cm)	Approx Age	Head	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF (<i>fill in</i>)
12	newborn	0.74	
16	1 yr	0.86	
17	5 yr	0.93	
19	med adult	Baseline (BL)	

Example Calculations

1. An adult thorax is examined at a technique of 120 kVp, 0.5 sec scan time, 200 mA, pitch = 1, and FOV = 35 cm. What is the appropriate technique for a five year old thorax at a pitch of 1?

Abdomen Baseline:	kVp= 120	mA= 200	Time= 0.5 sec	Pitch Abdomen= 1	Pitch Thorax = 1
PA Thickness (cm)	Approx Age	Abdomen		Thorax	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF (<i>fill in</i>)	mAs Reduction Factor (RF)	Estimated mAs = BL x RF (<i>fill in</i>)
9	newborn	0.43	43	0.42	42
12	1 yr	0.51	51	0.49	49
14	5 yr	0.59	59	0.57	57
16	10 yr	0.66	66	0.64	64
19	15 yr	0.76	76	0.73	73
22	small adult	0.90	90	0.82	82
25	med adult	Baseline (BL)	100	0.91	91
31	large adult	1.27	127	1.16	116

Table I suggests a reduction factor of 0.57 for a five year old. Since the baseline mAs is 100 mAs (200 mA x 0.5 sec), the adjusted pediatric mAs is 57. The resulting technique would be 120 kVp, 0.5 sec, 114 mA (200 mA x 0.57), pitch = 1, FOV = 25 cm.

2. An adult head is examined at a technique of 140 kVp, 0.5 sec scan time, 400 mA, pitch = 1, and FOV = 25 cm. What is the appropriate technique for a one year old head?

Head Baseline:	kVp= 140	mA= 400	Time= 0.5 sec
PA Thickness (cm)	Approx Age	Head	
		mAs Reduction Factor (RF)	Estimated mAs = BL x RF (<i>fill in</i>)
12	newborn	0.74	148
16	1 yr	0.86	172
17	5 yr	0.93	186
19	med adult	Baseline (BL)	200

Table II suggests a reduction factor of 0.86 for a one year old. Since the baseline mAs is 200 mAs (400 mA x 0.5 sec), the adjusted pediatric mAs is 172. The resulting technique would be 140 kVp, 0.5 sec, 344 mA (400 mA x 0.86), pitch = 1, FOV = 20 cm.

Please note that since the baseline mAs was established at 140 kVp, the pediatric technique estimated from the table needs to remain at the same kVp. If the baseline mAs is established at 120 kVp, the estimated pediatric mAs technique is only correct for 120 kVp.

Summary

This two-step approach should result in CT radiation dose estimates no greater than the corresponding adult doses regardless of the patient's size. But first, you are encouraged to reduce your current adult techniques and doses if they are high. If you have not previously reduced your pediatric techniques to the recommended levels of Tables I and II, these images will be noisier than those you are accustomed to viewing. However, you are encouraged to take this step.

The Alliance acknowledges that the above reductions in pediatric CT doses are less aggressive than those that some institutions have currently achieved. If your current pediatric protocols use mAs that are lower than those derived from Tables I and II, your pediatric doses are currently less than your adult doses. You are commended for achieving this reduction and encouraged to continue with your current program.

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