		CT Protocol
Title:	**Pediatric CT Scanning Guidelines and Protocols**	
Issuing Department/ Committee/Body:	Pediatric Radiology Section	Effective From 24 November 2014 Until Next Updated
Policy Owner:	Clinical Science Specialist (CSS) for CT	
Approval:	Pediatric Section Head	

POLICY

All technologists providing imaging care to patients under the age of 18 years are required, at minimum, to demonstrate competency and a basic operating proficiency with the Image Gently™ guiding concepts of pediatric dose awareness, management, and the operating principles of their respective CT scanning equipment and its dose management and dose reduction capabilities. Technologists are also expected to have signed the Image Gently pledge.

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GUIDELINES

These guidelines are designed to give basic guidance for the performance of common CT examinations in the Pediatric population. Due to variations among different types of scanners, it is not possible to document every parameter, but critical parameters are included and should be adhered to unless otherwise approved by the supervising radiologist.

1. READ THE ENTIRE CONTENTS OF THIS DOCUMENT BEFORE ATTEMPTING TO SCAN ACCORDING TO THESE GUIDELINES. IMPORTANT GLOBAL INFORMATION THAT COULD NOT BE INCLUDED IN EACH PROCEDURE IS CONTAINED IN DOCUMENT AND SECTION PREFACE PAGES.
2. Shielding of patients is actively discouraged based on present knowledge and evidence on exposure management. Local facility policy should be followed. Shielding may be provided for patients if they are insistent provided it doesn't interfere with the examination to be performed. Shielding (if used) for CT should always completely encompass the area to be shielded. All other persons that remain in the room during scanning must wear appropriate personnel shielding and should ideally remain as far away from the gantry aperture as possible while still being able to perform any required duties or care. Care should be taken to ensure that applied shielding does not encroach into the scan plane. This is particularly important if the gantry is being angled.
3. IV contrast dosing guidelines for pediatrics are included below. For intravenous contrast, a concentration of 300 LOCM is the preferred concentration based on literature and clinical evidence. Full guidelines for the use and administration of iodinated intravenous contrast material are contained within a separate document (Uniform Guidelines for Use of Iodinated Contrast Materials for RIA staffed hospitals and Invision sites).
4. Exposure and scanning guidelines contained within this procedure document were developed based on evidence-based techniques, Image Gently guidelines, ACR dose limit recommendations, peer-reviewed journal publications, and with the consultation and review of board-certified pediatric radiologists and board-certified medical physicists.
5. Adult versus Pediatric Protocol Selection: Because of differences in size and attenuation, manufacturers have created specific reference protocols for children where technical parameters have been adjusted according to the physical characteristics of children. Thus, it is recommended that users select pediatric reference protocols when scanning children, rather than selecting adult reference protocols and simply scaling technique factors (e.g. kV, mAs).

BASIC OPERATING REQUIREMENTS

- Scan operators must be familiar with and able to employ the principles and guidance of the Image Gently™ Program and also with all ACR recommendations of the CT Accreditation Program if you are bound by that.
- Reconstruction kernels/algorithms/filters are specific to each machine and vendor. The most commonly used will be those recommended either specifically for pediatric imaging, or those typically recommended by the vendor for routine imaging of the body area under examination.
- Reformatted images must be produced from image data reconstructed at the thinnest slice available based on scanner performance, usually between 0.5 and 0.625mm (must be <2.0mm).
    1. Slice spacing should be ideally contiguous (same as slice thickness).
    2. Rendering mode for all reformats should be either "average" or "MPR". MIP rendering is only performed when specifically directed in the procedure.
    3. Coronal series should always run from posterior to anterior and sagittals from left to right.

- The required images indicated in each scanning protocol (including all scouts and dose reports) must be sent to PACS, this includes any and all scout scans performed. No images/series should be deleted or not sent based on tech decisions. If your scanner produces an "intermediate" series used solely for the purpose of generating coronal and sagittal reformats, this series does NOT need to be sent as long as you are sending a set of 1.0-1.5mm axial scans.
- Any series that are missing or could not be obtained must be documented in notes visible to the radiologist at the time of reading.
- No full scans should EVER be repeated without radiologist direction, exceptions are short segment repeats due to gross patient motion or small range additional scans to include missed anatomy.
    1. If contrast timing results in a missed bolus, the study must be checked with a radiologist before repeating.
    2. Reasonable efforts on the part of the technologist should be made to minimize patient movement in accordance with facility policy on patient restraint.
    3. Patients who are not holding still enough to produce a diagnostic scan should not be exposed without conferring with a radiologist first. This is particularly important in the pediatric setting where unnecessary exposure should be particularly avoided.
    4. If a patient moves significantly during a scan, contact a radiologist to have them review the images and make a determination if any of the imaging needs to be re-acquired.
- Pediatric patients (any patient under 18 years of age) should not be imaged using unadjusted adult guidelines. Making size-specific adjustments to protocols specifically designed for pediatrics which incorporate pediatric-specific dose management features and beam filtering is the recommended mechanism for building pediatric scan protocols on each machine.
    1. Staff should be familiar with Image Gently guidelines on how to manage dose and tailor scanning techniques to pediatrics. This includes but is not limited to size- and exam-based kVp optimization, mA modulation, and beam filtration options.
    2. Questions about imaging pediatric patients should be directed to a radiologist BEFORE exposing the patient.
    3. Multiple phase scanning on pediatric patients should be performed ONLY with specific direction from the radiologist.
    4. NO scans through the pelvis of pediatric male (<18 years of age) patients should expose the scrotal region (gonads) EXCEPT in the setting of pelvic trauma affecting the ischia or unless specifically directed by a radiologist. The name of the radiologist requesting this additional coverage must be documented. In all other cases the scanning range should terminate with inclusion of the symphysis pubis.
- All CT technologists should be familiar with basic quality requirements for scans which include, but are not limited to:
    1. Patient positioning.
    2. Adequacy of oral and IV contrast enhancement.
    3. Basic image quality requirements (noise, reconstruction algorithm/filter, slice thickness and spacing, and anatomic inclusion). Additionally, all CT operators must have a clear and complete understanding of CT Dose parameters, how they relate to patient exposure, and how your CT technical exposure factors impact them during scanning.
    4. Scan and reformat plane alignment.
    5. Completeness of submitted scans.

6. Function and dependencies of automatic dose modulation (Auto mA, CareDose, Sure Exposure, DoseRight ACS/DDOM/Z-DOM) on your individual machines.
7. Function and appropriate use of scanner-integrated noise management software (ASIR/V, Safire/ADMIRE, AIDR/3D, iDose/iMAR).
8. Inputting scan parameters into the scanner based on guidelines contained within this document and supporting guidelines from Image Gently, the AAPM, and the ACR, including the selection of exposure parameters required to produce the dose ranges indicated and optimal diagnostic image quality.

CRITICAL INFORMATION REGARDING PEDIATRIC DOSE REFERENCE LEVELS

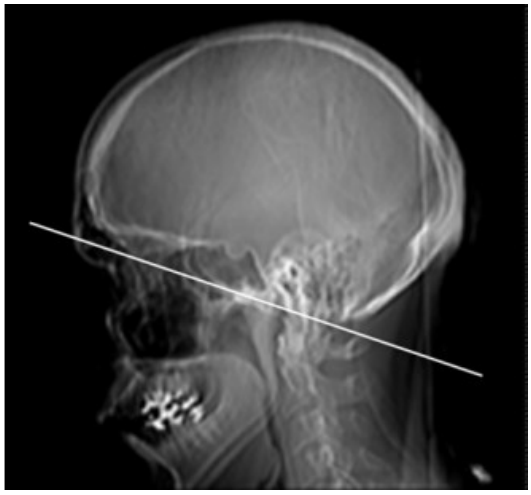
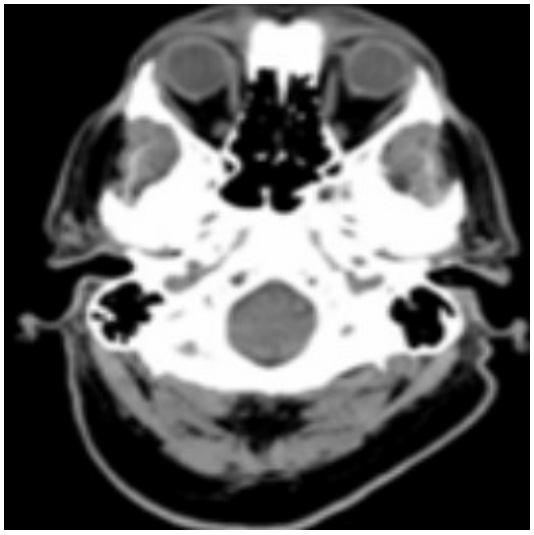
A critical element to consider and understand when imaging pediatrics is that dose values (CTDIvol most often) can be reported and measured based on two different dosimetry phantoms; keeping the context of the measurements is of paramount importance as there is a difference of a factor of two between these two measurement phantoms (the 16cm phantom dose equivalent is twice that of the 32cm phantom). Therefore, you MUST assure that you are aware of which phantom your scanner uses to calculate and report doses on pediatric patients. For reference, it is accepted practice that all doses for head imaging are reported and measured with a 16cm phantom. Pediatric body doses have long been reported and measured with a 16cm phantom as well, but a shift is in progress to report and measure all body dose with a 32cm phantom. In this document, great care was taken to assure that the DRL and dose information is provided IN CONTEXT of the phantom used to report and measure it. Furthermore, it is incumbent upon the technologist to have a functional understanding of the most basic dosimetric values such as CDTIvol and DLP and how these influence dose and how they are influenced by scan parameter selection. The best resource for further information and training on this is your qualified medical physicist.

General Dose issues in Pediatric CT:

- Concerns about exposure levels on already completed exams should be addressed through facility channels and brought to the attention of the radiologist as soon as possible after occurrences.
- Operator identification (initials or full name) must be entered into the scanner in the appropriate dedicated field at the start of the scan.
- Patient height and weight will be documented for the radiologist on ALL scans performed.
- Preferred means of documentation is entering the data into dedicated fields on the patient registration screen on the scanner so that it populates the DICOM header.
- Contrast type, volume, and flow rate will be documented for the radiologist on ALL scans where contrast media are administered. Preferred means of entering this information is in dedicated fields on the scanner so that it populates the DICOM header.
- Dose reports (also referred to as patient procedure screens or summary pages) must be sent to PACS on all patients exposed in CT whether the exposure resulted in diagnostic information or not.
- Dose reference values (CTDIvol) in the guidelines to follow are given based on a “per series” value, not accumulated values unless otherwise indicated.

HEAD

- Head (Brain) CT scans should ideally be performed with the angulation parallel to a line intersecting the upper 3rd of the orbit and the foramen magnum. (see below for example of ideal angulation and slice positioning). This will help to reduce direct dose to the lens of the eye. Please note that this angulation represents the expected angle under ideal circumstances and may not always be possible due to patient position, body posture or gantry angle limitations.
- Angulation for CT scanning of the brain should focus on avoiding direct scans through the lens of the eye. Images and guidance below should help you to achieve the optimal angulation on most patients who do not have hyperextended necks.

	The lateral localizer image to the left demonstrates the preferred angulation for brain CT scans. It is acknowledged that this angulation may not be possible in SOME cases due to patient factors, however it should be attempted wherever possible to avoid exposure to the lens of the eye.
	The axial image to the left is an example of an ideally angled “first” slice through the brain. Slices taken below this level risk direct exposure to the lens of the eye and do not yield any diagnostically useful information.

- Scans are to begin at the foramen magnum and continue through the vertex at the slice thickness optimized for your machine and should be contiguous.
- Scans MAY be performed routinely as standard 360 degree axial scans, unless your scanner is optimized and approved for helical scanning of the brain. Either way, the dose should be comparable between either techniques and should fall at or below the recommended dose reference levels.
- Scanning below the foramen magnum (sinuses, upper cervical spine) as part of a head/brain CT study should not be performed as this does not constitute part of a brain CT scan and imparts an unnecessarily high dose to the face, eyes and thyroid.
- If artifact or motion severe enough to obscure anatomical or pathological detail occurs during scanning, it is expected that a reasonable effort will be made to repeat the scans through the area of motion.
- Scanning of the brain on all CT scanners should be performed in the head holder unless otherwise impossible. At all times, scanning of the brain on all scanners should be performed with the optimized “HEAD” SFOV (or comparable corresponding bowtie filter or optimization) to optimize visualization of the interface of the brain and inner table of the skull. This is in part due to the bowtie filter that is employed when using the “HEAD” SFOV which corrects for the cupping artifact that can occur at the brain/skull interface and can mimic subdural hematomas.
- The practice of combining scans of the brain and face, brain and sinuses or brain and cervical spine should be AVOIDED and each of these exams should be scanned separately with its own appropriate scanning guidelines, technique, and dose appropriately selected for the anatomy and pathology under examination. Exceptions may be made on an individual facility basis for trauma situations, EXPLICITLY at the approval of the radiologist.
- Brain CT scans on pediatrics (17 years and under) should be performed with age-appropriate dedicated pediatric scanning parameters consistent with scanner manufacturer recommended settings.
- Any orders for WITHOUT –and- WITH on patients under 18 should be reviewed with a radiologist before scanning.

ROUTINE BRAIN/HEAD WO (OR W: CONTRAST DELAY SHOULD BE AT LEAST 2 MINUTES POST INJECTION)	
DX: HEADACHES, HEAD TRAUMA, CONCUSSION, DIZZINESS, CONFUSION, CHILD ABUSE, CRANIOSYNOSTOSIS/ PLAGIOCEPHALY, CALVARIAL BONE LESIONS (LANGERHANS CELL HISTIOCYTOSIS, NEUROBLASTOMA, ETC.), SUSPECTED ACUTE INTRACRANIAL HEMORRHAGE, IMMEDIATE POSTOPERATIVE EVALUATION FOLLOWING BRAIN SURGERY (EVACUATION OF HEMATOMA, ABSCESS DRAINAGE, ETC), SUSPECTED SHUNT MALFUNCTIONS, OR SHUNT REVISIONS IF RAPID BRAIN MRI IS NOT AVAILABLE, INCREASED INTRACRANIAL PRESSURE, ACUTE NEUROLOGIC DEFICITS, SUSPECTED ACUTE HYDROCEPHALUS, BRAIN HERNIATION, SUSPECTED MASS OR TUMOR, NON-FEBRILE SEIZURES, DETECTION OF CALCIFICATION	
PREP: NONE	
Localizer(s) (LOW DOSE)	**LATERAL AND FRONTAL**
Scan Series	**BRAIN**
Scan Phase	NONCONTRAST (UNLESS CONTRAST ORDERED)
Instructions	-
Contrast agent (IF USED)	300 preferred
Volume/ rate	Volume and flow rate should be appropriate for size/weight of patient. 1.0-3.0ml/sec is a typical flow rate range
Contrast Delay	AT LEAST 2 MINUTES
Start	FORAMEN MAGNUM
End	VERTEX
Angulation	PLANE ALIGNED FROM FORAMEN MAGNUM TO FRONTAL FOSSA (SUPRAORBITO-MEATAL LINE) *See above for angulation guidelines*
Scan type	AXIAL/SEQUENTIAL or HELICAL IF APPROVED
kVp	70-120 (as recommended by vendor)
Important dose information!	See reference at bottom for target dose levels
Target CTDIvol: 1 year old (ACR)	<35 mGy
Max CTDIvol: 1 year old (ACR)	<40 mGy
Max scan time	30 SEC
Detector/Slice	Parameter should be set to the thinnest slice the detector can generate is used so that high-quality sagittal and coronal MPRs can be generated
Pitch	N/A
DFOV	14.0-25.0 (to encompass entire skull)
Send to PACS	AX 1 X 1 mm UP TO 1.5 x 1.5 mm BONE
	AX 1 X 1 mm UP TO 1.5 x 1.5 mm SOFT
	COR 3X3 SOFT- PERPENDICULAR TO AXIAL ACQUIRED PLANE
	SAG 3X3 SOFT- PARALLEL TO MIDLINE

Radiation Dose Considerations:

- The best place to start for developing your scanner-specific pediatric protocols is the vendor-provided default protocol library. The pediatric protocols contained within that library are developed by the vendor in consultation with pediatric imaging specialists and are designed to maximize the dose-saving capabilities of the respective scanner. It is also advised to consult the Image Gently ACR/AAPM/SPR Alliance's most recent release of protocol guidance (https://www.aapm.org/pubs/CTProtocols/) for vendor- and scanner-specific guidance on dose as the mA and kVp recommendations as well as the dose-modulation recommendations vary widely from vendor to vendor, and it is beyond the practical scope of this document to account for all the potential scanners and their unique dose response.
- CTDI limit recommendations established by the ACR for ADULT brain CT scans state that a recommended dose reference limit of 75 mGy should not be exceeded for routine scanning of the brain. Typically, diagnostic scans of the brain in children can easily be obtained at doses (CTDI) between 30 and 66 mGy. Under no circumstances should dose values (CTDI or DLP) for pediatric brain CT scans exceed those of adult scans.
- Ideally, a routine scan of the head or brain should produce an effective dose (DLP) between 400 and 900 mGy---cm. This reflects appropriate selection of technical exposure factors (mA, kVp) as well as appropriate scanning techniques (start and end locations). DLPs for studies where it is necessary to repeat scans will be higher because of the additional scanning.
- Routine, uncomplicated scans of the brain where the DLP approaches or exceeds 1200 mGy---cm should be examined for opportunities to improve scanning technique or exposure factors.

- CTDIvol DRLs from the ACR CT Accreditation Program Clinical Imaging Guidance (see table below) for pediatric head CT are for a 1-year-old child and are 35 mGy as a recommended maximum and 40 mGy as an absolute maximum. For older/larger patients, a CTDIvol greater than the 1-year-old DRL but less than the adult recommended maximum of 75 mGy is reasonable. Similarly, a CTDIvol less than the 1-year-old recommended maximum of 35 mGy is expected for patients younger/smaller than 1 year of age.

Pediatric Head	
Technique Parameters	
Required Series	Non-enhanced
Reconstructed Slice Width	≤ 5 mm
Reconstruction Algorithm	Standard or equivalent
Scan FOV	"Head" or equivalent
$CTDI_{vol}$	Reference value: 35 mGy; Pass/Fail criteria: 40 mGy ($CTDI_{vol}$ values are based on a 1-year-old age)
Anatomical Coverage	
Coverage	Base of the skull through the vertex
Lens Exposure	Lens exposure should be avoided

Source: *https://accreditationsupport.acr.org/support/solutions/articles/11000049640-technique-parameters-and-anatomic-coverage-ct-pediatric-head-and-neck-module*

- The AAPM provides guidance in terms of achievable dose levels in their document: **Pediatric Routine Head CT Protocols Version 1.1 12/14/2015,** which can be reviewed at: **https://www.aapm.org/pubs/CTProtocols/documents/PediatricRoutineHeadCT.pdf.** For single source scanners using either axial or helical scanning, the pediatric head CTDIvol DRLs by age of patient, range as follows:
  - 0-1 yr: 21.2 to 26.5 mGy
  - 1-2 yr: 26.5-32.5 mGy
  - 2-6 yr: 34.6-42.9 mGy
  - 6-16 yr: 44.3-54.8 mGy
  - 16+ yrs: 56-69 mGy
  - **NOTE: All volume CTDI values are for the 16-cm diameter CTDI phantom!**
  - Note also that kVp recommendations vary across vendors, however that does not preclude the use of a lower kVp in concert with an mAs adapted commensurately to produce a CTDIvol comparable to those provided above as reference.

- Data from the National Radiology Dose Index Registry (NRDIR) provides additional guidance on dose levels for pediatric head CT:

Table 3: Age-based Achievable Doses and Diagnostic Reference Levels

Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Head without contrast material							
0 to <1	66 307	19	23	NA	NA	267	344
1 to <2	42 462	22	27	NA	NA	350	440
2 to <6	108 808	25	31	NA	NA	409	518
6–18	593 573	46	55	NA	NA	748	910

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

FACIAL BONES & PARANASAL SINUSES

FACE-FACIAL BONES-PARANASAL SINUSES WO CONTRAST	
DX: SINUSITIS, SINUS CONGESTION, FACIAL TRAUMA	
**SCAN AXIAL ACQUISITION AND REFORMAT CORONAL AND SAGITTAL PLANES*	
Localizer(s)	**FRONTAL AND LATERAL**
Scan	**AXIAL PARANASAL SINUSES**
Phase	NON-CONTRAST
Instructions	-
	-
Additional requirement	****BB MARKER MUST BE PLACED ON RIGHT CHEEK ALIGNED WITH PUPIL OF RIGHT EYE JUST ABOVE THE NOSTRIL****
Volume/ rate	[redacted]
Contrast Delay	
Start	BELOW HARD PALATE (INCLUDE MANDIBLE FOR FACE)
End	ABOVE FRONTAL SINUSES (ABOVE VERTEX FOR STEALTH)
Angulation	SCANS SHOULD BE PARALLEL TO HARD PALATE
	TRY TO POSITION HEAD CAREFULLY SO THAT FACE IS PARALLEL WITH FLOOR
Scan type	HELICAL
kVp	70-120 (as recommended by vendor)
Target CTDIvol	SEE DRL GUIDANCE BELOW
Max CTDIvol	SEE DRL GUIDANCE BELOW
Max scan time	10 SEC
Pitch	1.0-1.5:1
DFOV	15-17
Send to PACS	AX 1 mm CONTIGUOUS STANDARD
	AX/COR/SAG 1 mm BONE

Radiation Dose Considerations:

- The best place to start for developing your scanner-specific pediatric protocols is the vendor-provided default protocol library. The pediatric protocols contained within that library are developed by the vendor in consultation with pediatric imaging specialists and are designed to maximize the dose-saving capabilities of the respective scanner. It is also advised to consult the Image Gently ACR/AAPM/SPR Alliance's most recent release of protocol guidance (https://www.aapm.org/pubs/CTProtocols/) for vendor- and scanner-specific guidance on dose as the mA and kVp recommendations as well as the dose-modulation recommendations vary widely from vendor to vendor, and it is beyond the practical scope of this document to account for all the potential scanners and their unique dose response.
- The ACR does not provide dose reference values for this examination, however scanning guidance from the ACR CT Accreditation Program are shown in the table below, and DRL guidance may be obtained from the National Radiology Dose Index Registry (NRDIR) data below. While no DRL values are provided by the ACR, it is logical to expect that in all cases, the dose levels will be well below the DRLs for an adult examination. The use of kVp values greater than 100 kVp should not be necessary except in cases where a large quantity of metal may be present. This is generally quite rare in the pediatric population. **Note that our approach to scanning is to acquire in the axial plane and reformat to the other planes.**

Pediatric Sinus	
Technique Parameters	
Required Series	Coronals - May be reconstructed from axial images
Reconstructed Slice Width	≤ 3 mm from the frontal through the anterior ethmoid sinuses ≤ 5 mm from the posterior ethmoid through the sphenoid sinuses
Reconstruction Algorithm	Detail or other high spatial frequency
Scan FOV	"Head" or equivalent
$CTDI_{vol}$	There are no reference values for this examination
Anatomical Coverage	
Coverage	Frontal through the ethmoid sinuses

Source: *https://accreditationsupport.acr.org/support/solutions/articles/11000049640-technique-parameters-and-anatomic-coverage-ct-pediatric-head-and-neck-module*

- Data from the National Radiology Dose Index Registry (NRDIR) provides guidance on dose levels for pediatric facial and sinus CT:

Table 3: Age-based Achievable Doses and Diagnostic Reference Levels

Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Sinuses without contrast material							
0 to <1	…	…	…	NA	NA	…	…
1 to <2	…	…	…	NA	NA	…	…
2 to <6	2234	6.7	12	NA	NA	94	219
6–18	25606	14	22	NA	NA	209	377
Maxillofacial area without contrast material							
0 to <1	917	6.3	12	NA	NA	103	155
1 to <2	413	7.0	15	NA	NA	127	286
2 to <6	2488	11	23	NA	NA	196	472
6–18	33743	24	34	NA	NA	480	647

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

CERVICAL SPINE

CERVICAL SPINE WO CONTRAST	
DX: TRAUMA, FRACTURE, BONY DISEASE, SPINAL STENOSIS, CONGENITAL ABNORMALITY	
PREP: NONE	
Localizer(s) (LOW DOSE)	**FRONTAL AND LATERAL**
Scan Series	**CERVICAL SPINE**
Scan Phase	NONCONTRAST
Instructions	DON'T SWALLOW
Contrast agent	-
Volume/ rate	-
Contrast Delay	-
Start	FORAMEN MAGNUM
End	THROUGH T1 VERTEBRAL BODY
Scan type	HELICAL
kVp	70-120 (140 for very large patients over 15 can be used)
Target CTDIvol	SEE DRL GUIDANCE BELOW
Max CTDIvol	SEE DRL GUIDANCE BELOW
Max scan time	15 SEC
Pitch	0.8-1.75:1
DFOV	9-14
Send to PACS	AX 1-1.25MM CONTIGUOUS BONE
	AX 1-1.25MM CONTIGUOUS STANDARD OR DETAIL
	SAG 1X1 BONE-ALIGNED TO SPINE
	COR 1X1 BONE-ALIGNED TO SPINE
	SAG 1 x 1 STANDARD – ALIGNED TO SPINE

Radiation Dose Considerations:

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- The ACR does not provide dose reference values for this examination, however scanning guidance from the ACR CT Accreditation Program are shown in the table below, and DRL guidance may be obtained from the National Radiology Dose Index Registry (NRDIR) data below. While no DRL values are provided by the ACR, it is logical to expect that in all cases, the dose levels will be well below the DRLs for an adult examination. The use of kVp values greater than 120 kVp should be avoided unless the size of the patient requires it in order to produce diagnostic images. This should only occur with patients at the higher end of the age range.

Pediatric C-Spine	
Technique Parameters	
Required Series	Axial with sagittal and coronal reformations
Reconstructed Slice Width	≤ 3 mm
Reconstruction Algorithm	Bone
$CTDI_{vol}$	There are no reference values for this examination
Anatomical Coverage	
Coverage	Cranio-cervical junction to the T_1 vertebrae
Display FOV	9-14 cm

Source: *https://accreditationsupport.acr.org/support/solutions/articles/11000049640-technique-parameters-and-anatomic-coverage-ct-pediatric-head-and-neck-module*

- Data from the National Radiology Dose Index Registry (NRDIR) provides guidance on dose levels for pediatric cervical spine CT:

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Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Cervical spine without contrast material							
0 to <1	617	5.1	17	NA	NA	81	260
1 to <5	4010	4.7	11	NA	NA	67	179
5 to <10	5691	6.7	12	NA	NA	121	241
10 to <15	18798	13	24	NA	NA	284	490
15–18	62103	19	34	NA	NA	425	707

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

SOFT TISSUE NECK

SOFT TISSUE NECK WITHOUT *OR* WITH CONTRAST	
DX: LARYNGEAL TRAUMA, AIRWAY COMPROMISE, MASS, SWELLING, CELLULITIS, INFECTION	
PREP: NONE	
Localizer(s)	**FRONTAL AND LATERAL**
Scan series	**NECK**
Phase	NONCONTRAST
Instructions	DO NOT SWALLOW
Contrast agent (if used)	300 preferred
Volume/ rate	Volume and flow rate should be appropriate for size/weight of patient. 1.0-3.0ml/sec is a typical flow rate range
Contrast Delay	25 sec for larger patients, shorten delay for smaller
Start	EXTERNAL AUDITORY MEATUS
End	LUNG APICES
Angulation	NONE
Scan type	HELICAL
kVp	70-120 (as recommended by vendor)
Target CTDIvol	SEE DRL GUIDANCE BELOW
Max CTDIvol	SEE DRL GUIDANCE BELOW
Max scan time	10 SEC
Pitch	0.9-1.5:1
DFOV	14-20cm (WILL VARY WITH PATIENT SIZE)
Send to PACS	AX 1.0-1.25mm CONTIGUOUS BONE
	AX 2-2.5 mm CONTIGUOUS STANDARD
	COR 2X2 STANDARD
	SAG 2X2 STANDARD

Radiation Dose Considerations:

- The best place to start for developing your scanner-specific pediatric protocols is the vendor-provided default protocol library. The pediatric protocols contained within that library are developed by the vendor in consultation with pediatric imaging specialists and are designed to maximize the dose-saving capabilities of the respective scanner. It is also advised to consult the Image Gently ACR/AAPM/SPR Alliance's most recent release of protocol guidance (https://www.aapm.org/pubs/CTProtocols/) for vendor- and scanner-specific guidance on dose as the mA and kVp recommendations as well as the dose-modulation recommendations vary widely from vendor to vendor, and it is beyond the practical scope of this document to account for all the potential scanners and their unique dose response.
- The ACR does not provide dose reference values for this examination, however scanning guidance from the ACR CT Accreditation Program for C-spine CT are shown in the table below, and DRL guidance may be obtained from the National Radiology Dose Index Registry (NRDIR) data below. While no DRL values are provided by the ACR, it is logical to expect that in all cases, the dose levels will be well below the DRLs for an adult examination. The use of kVp values greater than 120 kVp should be avoided unless the size of the patient requires it in order to produce diagnostic images. This should only occur with patients at the higher end of the age range.

Pediatric C-Spine	
Technique Parameters	
Required Series	Axial with sagittal and coronal reformations
Reconstructed Slice Width	≤ 3 mm
Reconstruction Algorithm	Bone
$CTDI_{vol}$	There are no reference values for this examination
Anatomical Coverage	
Coverage	Cranio-cervical junction to the T1 vertebrae
Display FOV	9-14 cm

Source: *https://accreditationsupport.acr.org/support/solutions/articles/11000049640-technique-parameters-and-anatomic-coverage-ct-pediatric-head-and-neck-module*

- Data from the National Radiology Dose Index Registry (NRDIR) provides guidance on dose levels for pediatric neck CT:

Table 3: Age-based Achievable Doses and Diagnostic Reference Levels

Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Neck soft tissue with contrast material							
0 to <1	743	2.5	3.8	NA	NA	41	58
1 to <5	7502	3.4	4.4	NA	NA	65	88
5 to <10	6971	4.6	6.3	NA	NA	98	137
10 to <15	6491	7.8	11	NA	NA	198	270
15–18	16421	10	14	NA	NA	300	385

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

CHEST

ROUTINE CHEST WO (NODULE)	
DX: EVALUATE POSSIBLE NODULE OR FOLLOW UP KNOWN NODULE OR ROUTINE CHEST ORDERED WITHOUT CONTRAST, F/U PNEUMOTHORAX	
PREP: NONE	
Localizer(s) (LOW DOSE)	**Frontal (lateral if required)**
Scan Series	**Chest/lungs**
Scan Phase	Non-contrast
Instructions	Inspiration
Contrast Agent	-
Volume/Rate	-
Contrast Delay	-
Start	Apices
End	Below adrenals
Scan Type	Helical
kVp	70-120 (as recommended by vendor)
Target CTDIvol	See reference data below
Max CTDIvol	See reference data below
Max Scan Time	10 sec
Pitch	0.9-1.75:1
DFOV	To body wall
Send to PACS	AX 1x1* standard (*1.0-1.5mm x 1mm is acceptable depending on scanner config.)
	COR 2x2 standard
	SAG 3x3 standard

ROUTINE CHEST W	
DX: SOB, EV PLEURAL FLUID/EFFUSION, MEDIASTINAL/HILAR ADENOPATHY, LYMPHOMA, LUNG CA, LUNG MASS (OTHER THAN NODULE), F/U KNOWN AA OR DISSECTION, CA STAGING	
PREP: NPO 1-4 HOURS PRIOR IF POSSIBLE	
Localizer(s) (LOW DOSE)	**Frontal (lateral if required)**
Scan Series	**Chest/Lungs**
Scan Phase	Late arterial
Instructions	Inspiration
Contrast Agent	300 preferred
Volume/Rate	Volume and flow rate should be appropriate for size/weight of patient. 1.0-3.0ml/sec is a typical flow rate range
Contrast Delay	25 sec for larger patients, shorten delay for smaller
Start	Apices
End	Below adrenals
Scan Type	Helical
kVp	70-120 (as recommended by vendor)
Target CTDIvol	See reference data below
Max CTDIvol	See reference data below
Max Scan Time	10 sec
Pitch	0.9-1.75:1
DFOV	To body wall
Send to PACS	AX 1x1* standard (*1.0-1.5mm x 1mm is acceptable depending on scanner config.)
	COR 2x2 standard
	SAG 3x3 standard

Radiation Dose Considerations:

- The best place to start for developing your scanner-specific pediatric protocols is the vendor-provided default protocol library. The pediatric protocols contained within that library are developed by the vendor in consultation with pediatric imaging specialists and are designed to maximize the dose-saving capabilities of the respective scanner. It is also advised to consult the

Image Gently ACR/AAPM/SPR Alliance's most recent release of protocol guidance (https://www.aapm.org/pubs/CTProtocols/) for vendor- and scanner-specific guidance on dose as the mA and kVp recommendations as well as the dose-modulation recommendations vary widely from vendor to vendor, and it is beyond the practical scope of this document to account for all the potential scanners and their unique dose response.

- The ACR does not provide dose reference values for this examination, however scanning guidance from the ACR CT Accreditation Program are shown in the table below, and DRL guidance may be obtained from the National Radiology Dose Index Registry (NRDIR) data below. While no DRL values are provided by the ACR, it is logical to expect that in all cases, the dose levels will be well below the DRLs for an adult examination. Based on the very low achievable doses for adult chest CT (specifically the low-dose lung screening techniques) the DRLs shown in the NRDIR data below should provide good guidance on achievable dose ranges.

Pediatric Chest	
Technique Parameters	
Required Series	Non-enhanced
Reconstructed Slice Width	≤ 5 mm
Reconstruction Algorithm	Standard or high spatial frequency
$CTDI_{vol}$	There are no reference values for this examination
Anatomical Coverage	
Coverage	Lung apex to below the lung bases

Source: https://accreditationsupport.acr.org/support/solutions/articles/11000049641-technique-parameters-and-anatomic-coverage-ct-pediatric-chest-module

- The AAPM protocol guidance (available at https://www.aapm.org/pubs/CTProtocols/) suggest that ranges based on lateral measurements correlating loosely to weight can produce predictable, reasonable target ranges for CTDIvol, but stop short of endorsing them as DRLs. These values are in the chart below, but should be used in the context of the document from which they originated.

Lateral dimensions (cm)	Approx. Weight (kg)	Approx. Weight (lbs)	CTDI-vol (mGy) 32 cm CTDI phantom*
7-11	6	13	1.9-2.5
12-18	12	27	2.4-3.4
19-23	18	40	2.7-4.3
24-28	32	71	3.5-5.7
29-33	54	119	5.2-8.8

*To convert this CTDIvol to an estimate for the 16 cm phantom, multiply by 2

- Data from the National Radiology Dose Index Registry (NRDIR) provides guidance on dose levels for pediatric chest CT. **Note that the dose values in the data below are normalized to a 32cm phantom as in the table above, so if your machine reports pediatric dose based on a 16cm phantom, you must multiply the values below by 2.** The reference values in the article are stratified by patient age rather than size, so it can be helpful to correlate the dose values in the table below to the dose values above based on patient size.

Table 3: Age-based Achievable Doses and Diagnostic Reference Levels

Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Chest without contrast material							
0 to <1	884	1.2	1.7	2.9	3.8	22	27
1 to <5	3110	1.7	2.2	3.3	3.9	35	49
5 to <15	3862	2.1	2.5	3.7	4.6	57	70
10 to <15	6639	3.4	4.1	5.1	6.2	107	128
15–18	9980	5.9	7.4	7.7	9.3	202	257
Chest with contrast material							
0 to <1	2653	1.4	1.6	3.0	4.1	23	31
1 to <5	7650	1.8	2.4	3.6	4.5	43	58
5 to <10	7264	2.3	2.9	3.8	5.1	64	95
10 to <15	9992	4.6	7.2	6.3	9.1	146	272
15–18	19453	8.8	14	11	16	364	596

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

ABDOMEN AND PELVIS

- Multiple phase scanning on pediatric patients should be performed ONLY with specific direction from the radiologist.
- NO scans through the pelvis of pediatric male (<18 years of age) patients should expose the scrotal region (gonads) EXCEPT in the setting of pelvic trauma affecting the ischia or unless specifically directed by a radiologist. The name of the radiologist requesting this additional coverage must be documented. In all other cases the scanning range should terminate with inclusion of the symphysis pubis.

ROUTINE ABDOMEN OR ABDOMEN/PELVIS WO (RENAL STONE STUDY, ER NON-CON ABDOMEN/PELVIS)	
DX: EVALUATE FOR RENAL STONES, FLANK PAIN (SPECIFICALLY ORDERED AS STONE STUDY). ANY INDICATION REQUESTED BY ER WITHOUT ORAL OR IV CONTRAST	
PREP: NONE	
Localizer(s) (LOW DOSE)	**Frontal (Lateral if required)**
Scan Series	**Abdomen/Pelvis**
Scan Phase	Non-contrast
Instruction	Inspiration
Contrast Agent	-
Volume/Rate	-
Contrast Delay	-
Start	Above diaphragms
End	Bifurcation for Abdomen only, Symphysis pubis if Abdomen+Pelvis
Scan Type	Helical
kVp	70-120 (as recommended by vendor)
Target CTDIvol	<15 mGy **(16cm phantom)
Max CTDIvol	<20 mGy **(16cm phantom)
Max Scan Time	15 sec
Pitch	0.9-1.75:1
DFOV	To body wall
Send to PACS	AX 1x1 standard
	COR 2x2 standard
	SAG 3x3 standard

ROUTINE ABDOMEN/ ABDOMEN+PELVIS WITH IV CONTRAST ONLY	
DX: SUSPECTED ACUTE APPENDICITIS, ANY ABDOMINAL PAIN, FUO, WEIGHT LOSS, BOWEL OBSTRUCTION, NAUSEA/VOMITING/DIARRHEA, PANCREATITIS, ELEVATED LIPASE/AMYLASE, EPIGASTRIC PAIN, PSEUDOCYST, ELEVATED LFTS, FOLLOW-UP AAA	
PREP: NONE	
Localizer(s) (LOW DOSE)	**Frontal (Lateral if required)**
Scan Series	**Abdomen/Pelvis**
Scan Phase	Portal venous
Instruction	Inspiration
Contrast Agent	300 preferred
Volume/Rate	Volume and flow rate should be appropriate for size/weight of patient. 1.0-3.0ml/sec is a typical flow rate range
Contrast Delay	50-80 sec
Start	Above diaphragms
End	Bifurcation for Abdomen only, Symphysis pubis if Abdomen+Pelvis
Scan Type	Helical
kVp	70-120 (as recommended by vendor)
Target CTDIvol (40-50lb child)	<15 mGy **(16cm phantom)
Max CTDIvol (40-50 lb child)	<20 mGy **(16cm phantom)
Max Scan Time	15 sec
Pitch	0.9-1.75:1
DFOV	To body wall
Send to PACS	AX 1x1 standard
	COR 2x2 standard
	SAG 3x3 standard
[To convert this CTDIvol to an estimate for the 32 cm phantom, divide by 2]**	

Radiation Dose Considerations:

- The best place to start for developing your scanner-specific pediatric protocols is the vendor-provided default protocol library. The pediatric protocols contained within that library are developed by the vendor in consultation with pediatric imaging specialists and are designed to maximize the dose-saving capabilities of the respective scanner. It is also advised to consult the Image Gently ACR/AAPM/SPR Alliance's most recent release of protocol guidance (https://www.aapm.org/pubs/CTProtocols/) for vendor- and scanner-specific guidance on dose as the mA and kVp recommendations as well as the dose-modulation recommendations vary widely from vendor to vendor, and it is beyond the practical scope of this document to account for all the potential scanners and their unique dose response.
- CTDIvol DRLs from the ACR CT Accreditation Program Clinical Imaging Guidance (see table below) for pediatric head CT are for a 1-year-old child and are 35 mGy as a recommended maximum and 40 mGy as an absolute maximum. For older/larger patients, a CTDIvol greater than the 1-year-old DRL but less than the adult recommended maximum of 75 mGy is reasonable. Similarly, a CTDIvol less than the 1-year-old recommended maximum of 35 mGy is expected for patients younger/smaller than 1 year of age.
- CTDIvol DRLs from the ACR CT Accreditation Program Clinical Imaging Guidance (see table below) for pediatric abdominal CT are as follows: For single source scanners using helical scanning, the pediatric REFERENCE value is 15 mGy and the Pass/Fail criteria is 20 mGy (as reported by the scanner using a 16 cm phantom. If your scanner reports values using a 32 cm phantom, then approximate limits would be 7.5 mGy and 10 mGy). The CTDIvol is based on a 40-50 lb. patient size.

Pediatric Abdomen	
Technique Parameters	
Required Series	IV Contrast Enhanced
Reconstructed Slice Width	≤ 5 mm
Reconstruction Algorithm	Standard or soft tissue (or appropriate body kernel)
Oral Contrast	It is recommended oral contrast material be present with barium or neutral (water) contrast agents
$CTDI_{vol}$	Reference value: 15 mGy; Pass/Fail criteria: 20 mGy (As reported by the scanner using a 16 cm phantom. If scanner reports values using a 32 cm phantom, then approximate limits would be 7.5 mGy and 10 mGy. The $CTDI_{vol}$ is based on a 40-50 lb. patient size.)
Anatomical Coverage	
Coverage	Diaphragm to pubic symphysis

Source: https://accreditationsupport.acr.org/support/solutions/articles/11000049642-technique-parameters-and-anatomic-coverage-ct-pediatric-abdomen-module

- The AAPM protocol guidance (available at https://www.aapm.org/pubs/CTProtocols/) suggest that ranges based on lateral measurements correlating loosely to weight can produce predictable, reasonable target ranges for CTDIvol, but stop short of endorsing them as DRLs. These values are in the chart below, but should be used in the context of the document from which they originated.

Lateral dimensions (cm)	Approx. Weight (kg)	Approx. Weight (lbs)	CTDI-vol (mGy) 32 cm CTDI phantom*
7-13	6	13	2.5-3.5
14-16	12	27	3.5-4.6
17-22	18	40	4.2-5.9
23-27	32	71	4.9-6.7
28-32	54	119	6.6-11.2

*To convert this CTDIvol to an estimate for the 16 cm phantom, multiply by 2

- Data from the National Radiology Dose Index Registry (NRDIR) provides additional guidance on dose levels for pediatric abdomen/pelvis CT. **Note that the dose values in the data below are normalized to a 32cm phantom as in the table above, so if your machine reports pediatric dose based on a 16cm phantom, you must multiply the values below by 2.** The reference values in the article are stratified by patient age rather than size, so it can be helpful to correlate the dose values in the table below to the dose values above based on patient size.

Table 3: (continued) Age-based Achievable Doses and Diagnostic Reference Levels

Examination Type and Age (y)	No. of Examinations*	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy · cm)	
		AD	DRL	AD	DRL	AD	DRL
Abdomen and pelvis without contrast material							
0 to <1	…	…	…	…	…	…	…
1 to <5	1278	2.2	2.6	4.5	5.4	69	95
5 to <10	5058	3.4	4.8	5.9	7.9	124	171
10 to <15	11048	6.2	8.1	8.9	11	277	367
15–18	43747	8.4	11	11	14	408	510
Abdomen and pelvis with contrast material							
0 to <1	1886	1.8	2.4	4.2	5.3	49	60
1 to <5	14470	2.4	2.9	4.6	5.9	79	100
5 to <10	49323	3.3	4.6	5.8	8.0	126	170
10 to <15	99433	6.2	7.9	8.9	11	276	358
15–18	208728	8.3	11	11	14	402	511

Source*: U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. Kanal et al. Radiology 2021; 000:1-11. https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241*

IV IODINATED CONTRAST MEDIA GUIDANCE

- Guidelines for the use and administration of iodinated intravenous contrast material are contained within a separate document (Uniform Guidelines for Use of Iodinated Contrast Materials for RIA staffed hospitals and Invision sites).
- Contrast dosing: 2 ml/kg of a 300 concentration low osmolality contrast medium is recommended.
- Any IV hydration should only be ordered by the referring physician.
- Strongly consider alternative imaging methods in the rare case of children with contrast or iodine allergy. Any steroid pre-treatment must be ordered by a pediatrician. Contrast should only be given to pediatric patients with contrast allergies when a PALS certified provider is on site and available.
- 24-gauge angiocatheters in a peripheral location can be safely power injected using a maximum flow rate of approximately 1.5 ml/sec and a maximum pressure of 150 psi. When access is thought to be tenuous, hand injection of contrast medium should be strongly considered to minimize risk of vessel injury and extravasation. Since many currently used central venous catheters are not approved for power injection, one should always verify in advance that any catheter to be utilized for bolus contrast material injection can tolerate the anticipated injection. It is also important to ensure that the pressure used does not exceed the catheter's pressure rating.
- Thyroid dysfunction in high-risk young children: The FDA recommends that thyroid function be evaluated in high-risk young children (0-3 years of age, especially in term and preterm neonates, with risk factors including prematurity, very low birth weight, and underlying medical conditions) within 3 weeks following exposure to iodinated contrast media. Thyroid dysfunction characterized by hypothyroidism or transient thyroid suppression has been reported after both single exposure and multiple exposures to iodinated contrast media. Among patients 0 to 3 years of age exposed to iodinated contrast media, thyroid dysfunction has been reported in 1% to 15% depending on the age of the patient and the dose of the iodinated contrast agent. Younger age, very low birth weight, prematurity, and the presence of other conditions, such as, admission to neonatal or pediatric intensive care units, and cardiac conditions are associated with an increased risk. Pediatric patients with cardiac conditions may be at the greatest risk given that they often require high doses of contrast during invasive cardiac procedures, such as catheterization and computed tomography. Pediatric patients 0 to 3 years of age warrant closer monitoring because an underactive thyroid during early life may be harmful for motor, hearing, and cognitive development and may require transient T4 replacement therapy.

ORAL IODINATED CONTRAST MEDIA GUIDANCE

- A major concern with administering ionic iodinated oral contrast to the pediatric population is the potential for the contrast mixture to be prepared incorrectly, resulting in it being hypertonic. If an incorrectly prepared, hypertonic solution is administered, it can result in fluid imbalance, hypovolemia, and hypotension with the potential for circulatory collapse or shock. For this reason, specifically, when ionic iodinated oral contrast is administered, **critical attention must be paid to the condition of the patient foremost, and also the concentration of the contrast mixture *(dilution with whatever diluent you use: water, Breeza, juice).** Failure to follow the dilution guidelines can result in a solution that can pose or increase the risk to the patient. **To help mitigate the potential for this risk, most patients are candidates for scanning without oral contrast.** In the setting where oral contrast may be requested or needed, it is *strongly* advised to consult with a radiologist (pediatric if available) to determine if the use of water as a neutral agent may be acceptable, or if a positive agent such as diluted Gastrografin/GastroView or Omnipaque is required.

- Gastrografin dilution: 0.025 x desired total volume = Volume of Gastrografin to add to water. E.g. 0.025 x 500 ml = 12.5 ml Gastrografin diluted in 500 ml water.
- Omnipaque 350 dilution: 0.02 x desired total volume = Volume of Omni 350. E.g. 0.02 x 500 ml = 10 ml of Omnipaque 350 diluted in 500 ml water.
- Volume of oral contrast to give by weight:

1-7 Kg	40-60 mL
8-11 Kg	110-160 mL
12-15 Kg	165-240 mL
16-42 Kg	250-360 mL
Over 42 Kg	480 mL +

- A 90 minute delay after the consumption of the contrast is recommended for adequate bowel opacification before scanning.

REFERENCES

- Bracco Isovue product insert
- U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations (Kanal, KM: Radiology https://pubs.rsna.org/doi/epdf/10.1148/radiol.2021211241).
- Image Gently ACR/AAPM/SPR Alliance most recent release of protocol guidance https://www.aapm.org/pubs/CTProtocols/.

REVIEW/REVISION HISTORY

Review/Revision	Summary of Review/Revision	Effective Date (month/day/year)
Original	Original document titled, "Image Gently Development of Pediatric CT Protocols 2014".	11/24/2014
Revision	1. Added information from the separate document titled, Pediatric CT Imaging Guidelines".	03/06/2015
Revision	1. Added the information from the separate document titled, "Pediatric IV Contrast Dosing for CT".	06/27/2016
Revision	1. Transferred draft revisions contents into the BOD-approved template.	03/20/2023
Revision		