Overview of Resources Available for CT Protocol Optimization

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Disclosure

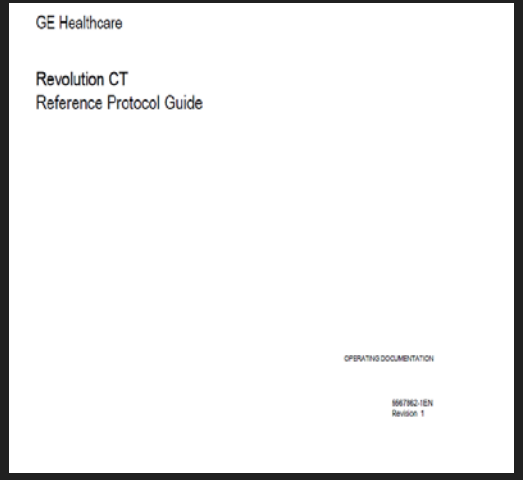
- Receives an equipment grant and supplies CT protocols to GE Healthcare
- Consultant, GE Healthcare
- Founder, protocolshare.org

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

Reference CT Protocols

- All of the major CT vendors have scanners that come with CT protocols for major indications
  - Usually they will also publish a booklet to go along with the protocols
  - Usually some applications specialist time is devoted to “tweaking” these protocols to a specific institutions preferences or expanding the list of covered indications

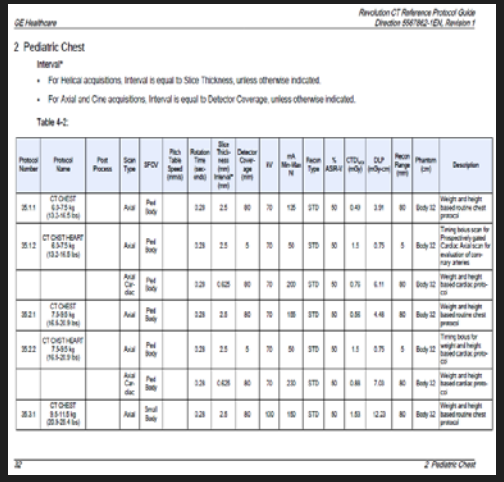


GE Healthcare

Revolution CT
Reference Protocol Guide

OPERATING DOCUMENTATION

5667962-1EN
Revision 1



2 Pediatric Chest

Interval*

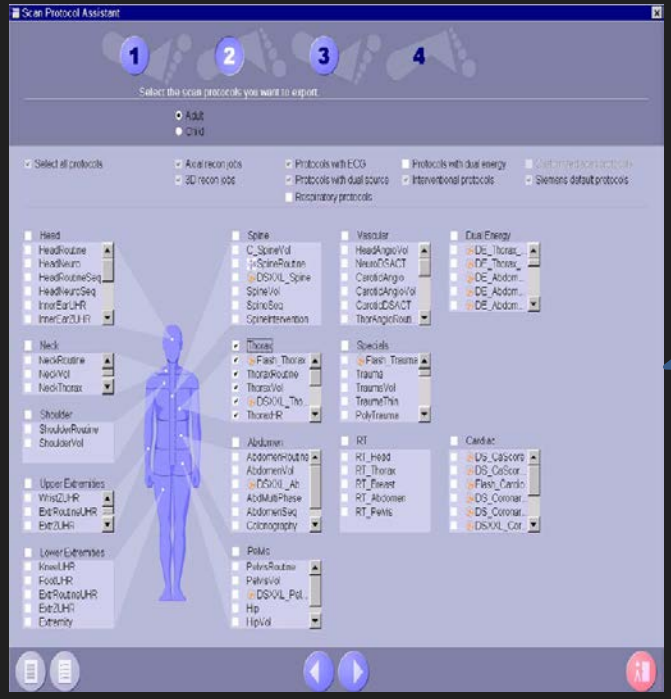
- For Helical acquisitions, Interval is equal to Slice Thickness, unless otherwise indicated.
- For Axial and Cine acquisitions, Interval is equal to Detector Coverage, unless otherwise indicated.

Table 4-2:

Protocol Number	Protocol Name	Post Process	Scan Type	SFOV	Pitch Table Speed (mm/s)	Rotation Time (sec-onds)	Slice Thick-ness (mm) Interval* (mm)	Detector Cover-age (mm)	kV	mA Min-Max NI	Recon Type	% ASiR-V	$CTDI_{vol}$ (mGy)	DLP (mGy-cm)	Recon Range (mm)	Phantom (cm)	Description
35.1.1	CT CHEST 0.3-7.5 kg (0.2-16.5 lbs)		Axial	Ped Body		0.29	2.5	80	70	125	STD	50	0.49	3.91	80	Body 32	Weight and height based routine chest protocol
35.1.2	CT CHEST-HEART 6.3-7.5 kg (13.2-16.5 lbs)		Axial	Ped Body		0.29	2.5	5	70	50	STD	50	1.5	0.75	5	Body 32	Timing bolus scan for Prospectively gated Cardiac Axial scan for evaluation of coronary arteries
			Axial Cardiac	Ped Body		0.29	0.625	80	70	200	STD	50	0.75	6.11	80	Body 32	Weight and height based cardiac protocol
35.2.1	CT CHEST 7.5-50 kg (16.5-20.9 lbs)		Axial	Ped Body		0.29	2.5	80	70	155	STD	50	0.86	4.48	80	Body 32	Weight and height based routine chest protocol
35.2.2	CT CHEST-HEART 7.5-50 kg (16.5-20.9 lbs)		Axial	Ped Body		0.29	2.5	5	70	50	STD	50	1.5	0.75	5	Body 32	Timing bolus for weight and height based cardiac protocol
			Axial Cardiac	Ped Body		0.29	0.625	80	70	230	STD	50	0.86	7.03	80	Body 32	Weight and height based cardiac protocol
35.3.1	CT CHEST 50-110 kg (20.9-32.4 lbs)		Axial	Small Body		0.28	2.5	80	100	150	STD	50	1.53	12.23	80	Body 32	Weight and height based routine chest protocol

Reference CT Protocols

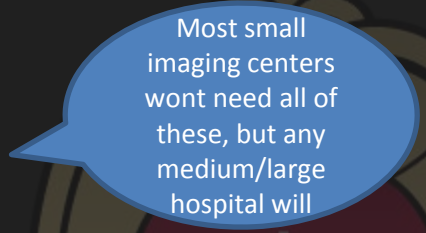
- All of the vendors will allow some kind of organization on the scanner to identify user and vendor supplied protocols



Example of a Siemens scanner protocol manager view, here the view is filtered to show only the default protocols

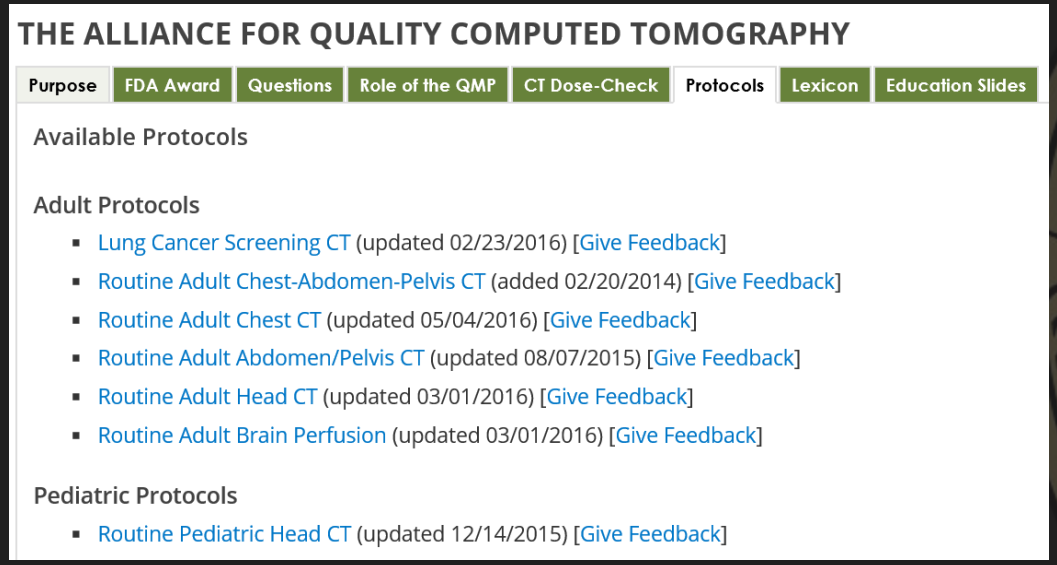
Reference CT Protocols

- Don’t expect the default protocols documentation to suffice for the occasional CT technologist or new CT technologist (CT vendors do not want to play doctor…too much liability so their instructions will be pretty laconic)
- Don’t expect esoteric protocols for rare indications
- Don’t expect protocols for devices
  - Orthopedic implants
  - Vascular implants (valves, flow diverters, etc.)
- Don’t expect protocols for CAD (chest)
- Screening protocols are becoming more common to be vendor supplied (as CMS supports screening, we will see more vendors offering such protocols)



Reference CT Protocols

- AAPM Protocols
  - http://www.aapm.org/pubs/CTProtocols/default.asp



Reference CT Protocols

- These are good protocols. They may require some site specific tweaking though
  - They are heavy on acquisition parameters and light on clinical advice.
  - These protocols are what you as a site's physicists wants to bring to the CT protocol optimization team meeting.
    - Let your lead tech modify/augment the patient preparation instructions, recon instructions, add reformat instructions, add billing/networking instructions, etc.
    - Let your radiologist add more phases, prescribe the contrast dosage strategy, modify the indication, etc.
  - They have GREAT introductions for the physicist to learn more about some of the clinical aspects of a protocol.

Reference CT Protocols

ADULT ROUTINE CHEST CT

Indications (include but are not limited to)
- Evaluation of findings on chest radiographs or other CT exams as seen on other imaging modalities;
- Evaluation of lung and other primary thoracic malignancies, and detection and evaluation of metastatic disease;
- Evaluation for thoracic manifestations of known extrathoracic diseases;
- Evaluation of chest infections;
- Evaluation of inflammations involving the chest;
- Evaluation of abnormalities within the chest; i.e. fluid or abscess
- Evaluation of the chest wall;
- Evaluation of pleural disease;
- Evaluation of the mediastinum and lymph nodes.

Diagnostic Tasks (include but are not limited to)
- Detect nodules or masses and characterize their size and shape and relationships to organs;
- Identify abnormal aeration or expansion of the lungs;
- Detect abnormal fluid collections in the chest;
- Identify abnormal air collections both in and around the lungs;
- Detect mediastinal and paravascular masses and nodules;
- Characterize chest wall masses;
- Detect calcifications in soft tissues or the mediastinum.

Key Elements
- Contrast enhancement;
- One breath-hold (motion is problematic);
- Can reconstruct additional images for high-resolution chest CT.

Contrast
- **Oral**: None.
- **Injected**: Certain indications require administration of intravenous contrast media.
- Intravenous contrast enhancement should be performed as directed by the supervising radiologist using appropriate injection protocols and in accordance with the ACR-SPR Practice Guideline for the Use of Intravascular Contrast Media and the ACR Manual on Contrast Media.

Patient Positioning
- Center the patient within the gantry; this is critical for proper functioning of AEC systems.
- Patient supine, arms above head;

Scan Range
- From top of lungs through the bottom of lungs. Instruct patient to hold breath at inspiration during entire scan.

Suspension of Respiration
- Patient should be instructed to hold his/her breath at end of inspiration.

Additional Image Reconstructions
- Certain indications may require that images be reconstructed in coronal and/or sagittal planes.
- Very thin images (approximately ≤ 1 mm) may need to be reconstructed to serve as source images for the sagittal and/or coronal reformatted images.
- Creation, use, and archival of these additional images are at the discretion of the supervising radiologist and/or departmental policy. Very large datasets may result from these additional reconstructions.

Radiation Dose Management
- AEC should be used whenever possible.
- Pay careful attention to the values selected to define the desired level of image quality (e.g., Noise Index, Quality Reference mAs, Standard Deviation).
- Each manufacturer will have recommendations unique to their systems and system features. Be sure to work with your CT equipment manufacturer and a qualified medical physicist to ensure safe and appropriate operation of AEC systems.
- If more than one CT localizer radiograph is acquired, AEC systems from different manufacturers can differ with respect to which one is used to determine mA and/or kV settings. Please refer to individual manufacturer protocol instructions.

Reference CT Protocols

Approximate Volume CT Dose Index (CTDIvol) Values

- Approximate values for CTDIvol are listed for three different patient sizes:

	Approx. Weight (kg)	Approx. Weight (lbs)	Approx. CTDIvol (mGy)
Small Patient	50-70	110-155	4-10
Average Patient	70-90	155-200	8-16
Large Patient	90-120	200-265	14-22

The approximate CTDIvol values are for reference only and represent a dose to the CT Dose Index phantom under very specific conditions. The CTDIvol displayed on the scanner for a patient of a given size should be similar, but not necessarily an exact match, to those listed in the above table. The provided values are all based on the 32 cm diameter "body" CTDI phantom.

It is essential that users recognize that the CTDIvol values reported on the user console prior to acquiring CT localizer radiographs on a particular patient do not represent the CTDIvol that will be delivered during that patient's scan. CT systems rely on the CT localizer radiograph to 1) estimate the patient's size, 2) determine the tube current settings for each tube angle and table position that will yield the requested level of image quality, and 3) calculate the average CTDIvol for the patient over the prescribed scan range. Until the CT localizer radiograph is acquired, the reported CTDIvol is not patient-specific, but is based on a generic patient size.

The CTDIvol values provided here are approximate, and are intended only to provide reference ranges for the user to consider. They are for a routine CT of an adult's chest for the general indications given at the beginning of this document. Other indications or diagnostic tasks may have different image quality and dose requirements, and hence reasonable ranges of CTDIvol may differ according to those requirements.

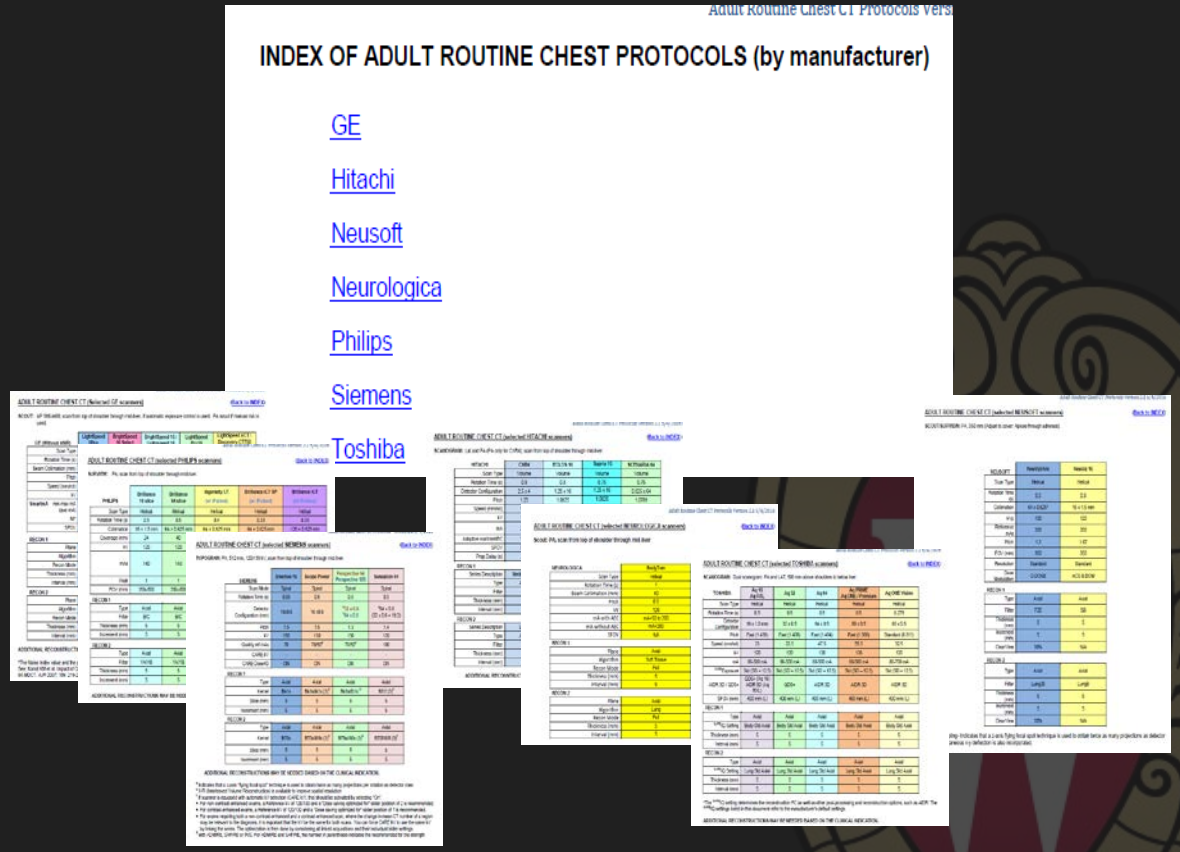
In this document, a small patient is considered to be approximately 50-70 kg (110-155 lbs), an average patient approximately 70-90 kg (155-200 lbs), and a large patient 90-120 kg (200-265 lbs). However, weight is not a perfect indication of patient size. A person's height, gender and distribution of weight across the body also must be taken into account. The thickness of the body over the area to be scanned is the best indication of patient size. Body Mass Index (BMI) may also be considered:

- Underweight = BMI <18.5
- Normal weight = BMI of 18.5–24.9
- Overweight = BMI of 25–29.9
- Obesity = BMI of 30 or greater

It is recognized that the median (50th percentile) patient size for adults in the USA is larger than 70 kg. However, the 70 kg patient represents the "Reference Man", as defined by the International Commission on Radiation Protection (ICRP), upon which AEC systems and tissue weighting factors (used for effective dose estimation) are based.

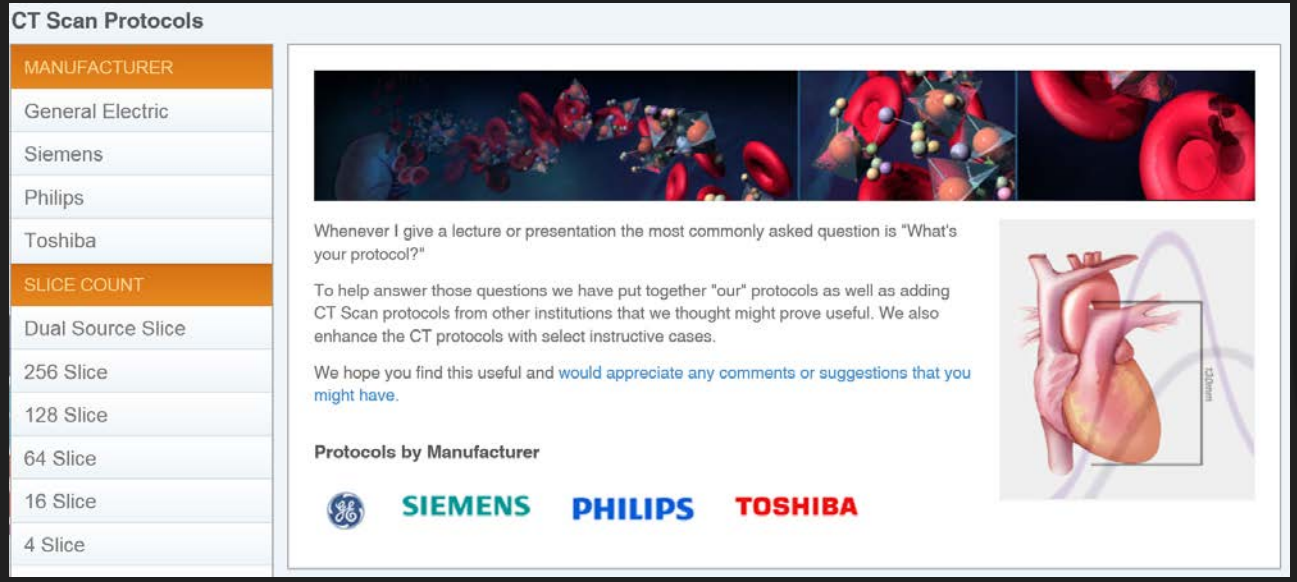
CTDI measurements and calculations

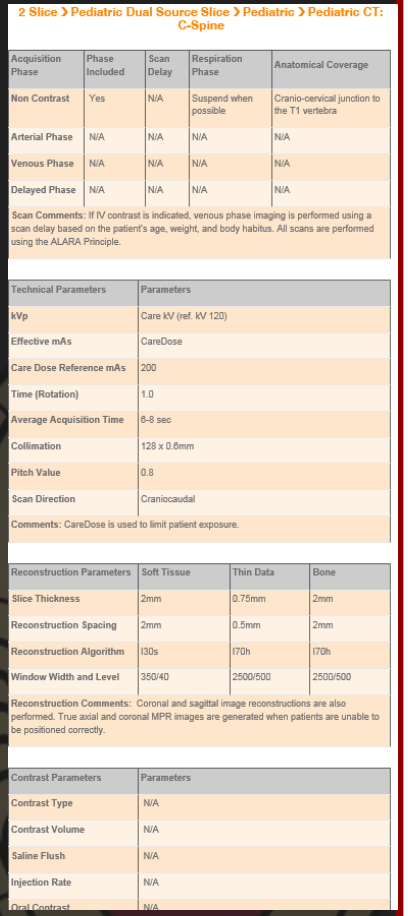
- Some manufacturers utilize a z-axis "flying focal spot", in which two unique projections are acquired at the same z-axis table position. When this technique is used, we identify it with **. The CTDIvol on the console accurately accounts for use of this feature.



Reference CT Protocols

- Go online!
  - Ctisus.com





Reference CT Protocols

- Try submitting a request for someone to send you a protocol on to the DXIMGMEDPHYS http://aapm.org/links/medphys/#lists
- Great place to have others with the same/similar equipment lend advice. This is a very active source of information in our community.

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

Reference Materials for CT scanners/protocols

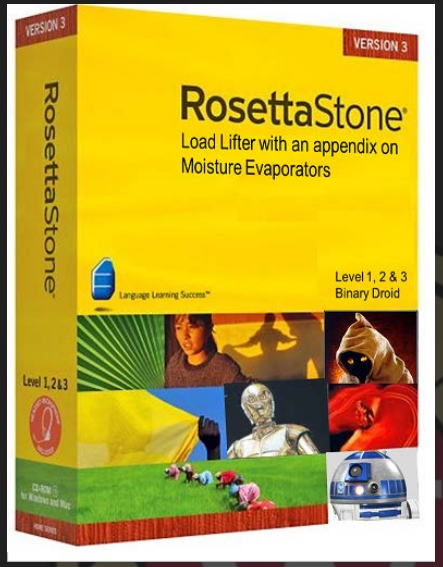
- Scanner to scanner verbiage
- What is a protocol

Reference Materials for CT scanners/protocols

- Vendor/Model to Vendor/Model verbiage
  - Vendors implement the same techniques and call them different things
    - “Scout/topogram/scanogram/surview” are all CT localizer radiographs
    - “Spiral/volume/Helical” are all acquisition modes with constant couch motion during data acquisition
  - Vendors implement different techniques to accomplish the same thing and call them different things
    - “Adaptive 4D spiral” versus “shuttle/jog” for perfusion data collection
  - Vendors implement different techniques to accomplish different things and call them the same thing
    - Good example is the use of the words “interval/increment” to basically be used to mean two different things by multiple vendors
      - Space between images AND the space between axial couch positions (this can get you in trouble if you prescribe an axial scan with a 2 cm beam and a 1 mm space between axial couch positions…)

Reference Materials for CT scanners/protocols

- AAPM has put together a lexicon that compares every button/knob and lever on our CT scanners
- “Rosetta stone” Of CT scanners
- Essential for a multi vendor environment to have technologists/physicists/radiologists familiar with this document



http://www.quarkquark.com/electronman/

Reference Materials for CT scanners/protocols

Table of Contents

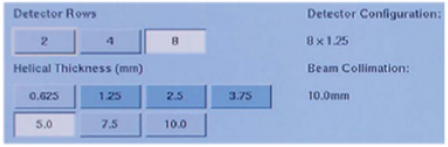
1. Scan acquisition and user interface basics							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
The portion of the **user interface** where scans are prescribed	Exam Rx	Scan Procedure	Examination	eXam Plan	Scan Protocol	Scan Procedure (Neuviz 16); Main Scan Interface (Neuviz DUAL)	Scan protocol
Other portions of the **user interface**, such as were reconstructed images are viewed	Desktop	Active viewer	Various "task cards", such as "Viewing"	Active display	Image Viewer	Image Display Area (Neuviz 16); Viewer (Neuviz DUAL)	Desktop
CT localizer radiograph (i.e. the scanned projection radiograph, often acquired by the CT system to allow the user to prescribe the start and end locations of the scan range)	Scout	Surview	Topogram	Scanogram	Scanogram	Surview	Scout
Axial scan mode: Data acquisition while the patient table remains stationary; the table position may be incremented between x-ray exposures to collect data over a longer z axis range.	Axial	Axial	Sequence	Scan & View, Scan & Scan, Volume, Wide Volume (Aquilion One)	Normal	Axial	Axial
Helical or Spiral scan mode: Data acquisition while the patient table is continuously moving along the z axis.	Helical	Helical	Spiral	Helical	Volume	Helical	Helical
Dynamic scan mode - single detector width: Data acquisition at multiple time points over the same anatomic location(s) while the patient table remains stationary; x-ray exposure can be continuous or intermittent	Cine or zero interval Axial	CCT (Continuous CT)	Dynamic (continuous) or Serio (intermittent); scan mode name: DynMulti or DynSerio.	Dynamic (Continuous or Intermittent)	Dynamic	CCT (Neuviz 16); N/A (Neuviz DUAL)	Dynamic
Dynamic scan mode - multiple detector widths: Data acquisition at multiple time points over the same anatomic location(s) while the patient table cycles back and forth between designated start and end locations in order image a region wider than the detector	Shuttle	Jog	Adaptive 4D Spiral; scan mode name: DynMulti4D or DynSerio4D (ECG triggered)	N/A	N/A	N/A	Dynamic
Interventional CT - Intermittent x-ray exposures	SmartStep	Single CCT	Model dependent: Biopsy or Intervention (i-Sequence/i-Spiral)	CT Fluoro (CTF)	guideShot	Single CCT (Neuviz 16); N/A (Neuviz DUAL)	CT Fluoro (CTF)

2. Dose modulation and reduction tools							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Automatic exposure control (AEC): A scanner feature that automatically adapts the x-ray tube current to the overall patient size to achieve a specified level of image quality	Available in AutomA and SmartmA	Available in DoseRight Automatic Current Selection (ACS)	Available in CARE Dose4D	Available in SURE Exposure	Available in IntelliEC	DoseRight, ACS (automatic current selection) [Neuviz 16]; DoseSave, ACS (automatic current selection) [Neuviz DUAL]	N/A
Angular tube current modulation	SmartScan (CT/i only)	D-DOM (Dose Modulation)	CARE Dose	not available as a separate item	Adaptive mA	D-DOM (Neuviz 16); N/A (Neuviz DUAL)	N/A
Longitudinal tube current modulation	AutomA	Z-DOM	not available as a separate item	SURE Exposure	n/a	Z-DOM (Neuviz 16); N/A (Neuviz DUAL)	N/A
Angular and longitudinal tube current modulation	SmartmA (x, y, z)	Work in progress	CARE Dose4D	SURE Exposure 3D (X, Y and Z Modulation)	IntelliEC	ACS+DOM (Neuviz 16); N/A (Neuviz DUAL)	N/A
ECG-based tube current modulation	ECG Modulated mA	DoseRight Cardiac	All features available in HeartView package (except (3), only available for SOMATOM Definition Flash) (1) Retrospective gated spiral mode: use "Pulsing" settings in Trigger card (2) Prospective triggered sequence: use "Adaptive Cardio Seq." and "Pulsing" settings in Trigger card. (3) Prospectively triggered spiral ("Flash" mode)	ECG Modulation	ECG Dose Modulation	N/A	N/A
Image quality reference parameter for AEC	Noise Index	Reference image	Quality reference mAs	Standard Deviation or standard, low-dose, or high-quality	Standard Deviation (%) or standard, low-dose, or high-quality	reference image	N/A

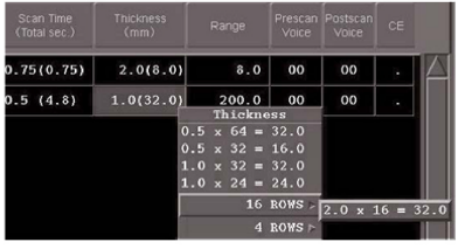
3. Multi-Slice Detector Geometry							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Multi-slice detector array design	Fixed	Model dependent: Fixed or Asymmetric	Model dependent: Adaptive or Fixed	Fixed (32 row and above); Adaptive (16 row and below)	Asymmetric-16 slice; Fixed-64 slice	Asymmetric (Neuviz 16); Fixed (Neuviz DUAL)	Fixed
Detector configuration	Detector Configuration	Collimation N x T (mm)	Detector Configuration or Aqu (Acquisition) on Exam Card	Detector Configuration	Detector Configuration	Collimation N x T (mm)	Detector Configuration

Detector Rows (N) and Slice Thickness (T) selection console screen images

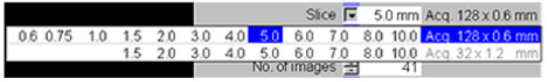
GE



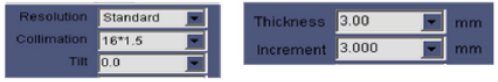
Toshiba



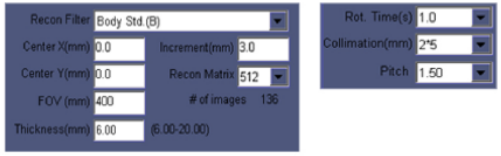
Siemens (N determined by the scan protocol)



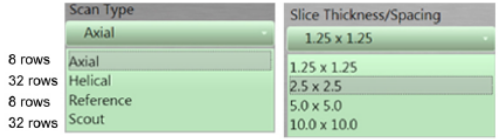
Neusoft (Neuviz 16)



Neusoft (Neuviz DUAL)

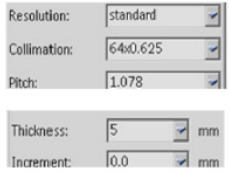


Neurologica



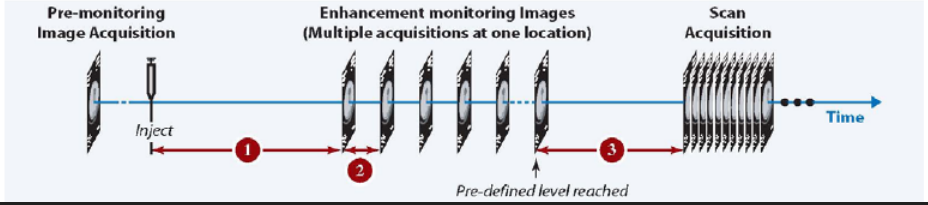
Hitachi

Philips



4. Image Reconstruction and Display							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Window width: Range of CT numbers (maximum - minimum) that are distributed over the viewable grey scale of the display device or film	Window Width	Window Width	Window width	Window width	Window Width	Window Width (Neuviz 16); WW Window Width (Neuviz DUAL)	Window width
Window center: The CT number in the center of the viewable grey scale	Window Level	Window Center	Window center	Window level	Window Level	Window Center (Neuviz 16); WL Window Level (Neuviz DUAL)	Window level
Reconstruction field of view: Width of the square region mapped to the reconstructed image matrix	Display Field of View (DFOV) (cm)	DFOV (mm)	FoV (mm)	DFOV (mm)	DFOV (mm)	FOV (mm) (Neuviz 16); Rec FOV (Neuviz DUAL)	FOV (cm)
Prescribing the reconstruction parameters prior to scan acquisition	Prospective recon	Recon and Additional Recons	Recon Job	Prospective recon	Multi Recon	Axial or helical reconstruction	Protocol
Prescribing the reconstruction parameters after scan acquisition	Retrospective recon	Offline Recon or Re-Recon	Recon Job	Retrospective or Raw data recon	Post Reconstruction	Offline reconstruction (Neuviz 16); Image Reconstruction (Neuviz DUAL)	Post Recon
Reconstruction property that determines sharpness or smoothness of image in the axial plane	Algorithm	Reconstruction Filter	Kernel	Filter convolution (FC)	Image Filter	Reconstruction filter (Neuviz 16); Recon Filter (Neuviz DUAL)	Kernel
Helical interpolation options to achieve a wider or narrower section sensitivity profile	Full (narrower) or Plus (wider) mode	Slice width independent of pitch	Slice width independent of pitch	Slice width independent of pitch	Slice width independent of pitch	Slice width independent of pitch (Neuviz 16); Thickness (Neuviz DUAL)	Slice width
Nominal width of reconstructed image along the z axis	Thickness (mm)	Thickness (mm)	Slice (mm)	Image thickness	Slice Thickness	Thickness	Slice thickness
Distance between two consecutive reconstructed images	Interval	Increment	Position increment	Reconstruction interval	Interval	Increment	Slice separation
Fast but lower-quality reconstructed images for rapid review of entire exam	QC Image Image Check	Evolving reconstructions	RT (Real-time reconstruction)	SUREScan	Real Time Reconstruction	Evolving mode (Neuviz 16); N/A (Neuviz DUAL)	Image Preview Image Check
Off-center reconstruction coordinates are called	RL Center; AP Center	Center x, center y	Center x, Center y	Center Position; (Vari Area)	Center x, y	Center x, center y	Center x, center y
Flip or rotate the image orientation is called	Flip/rotate	Flip/rotate	Mirroring (Flip in Viewing card); Rotate	Rotate/Mirror	Flip/Rotate	Flip/rotate	Flip/rotate
Image modifications to alter sharpness or smoothness (done in image space without reconstructing images)	Image Filters	Image enhancement filter	Evaluation > Image Manipulation (Viewing card)	Filter, QDS	Filter	IMAGE ENHANCE FILTER (Neuviz 16); DISPLAY MODE (Neuviz DUAL)	N/A

5. Contrast Media Tools							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Bolus tracking: Scanner feature to automatically initiate a prescribed axial, helical or dynamic scan when a threshold level of contrast enhancement is reached at a specified region of interest	Smart Prep	Bolus Tracking	CARE Bolus (includes Test Bolus and Bolus Tracking)	SUREStart	Predict Scan	Bolus Tracking	Bolus Tracking
Test Bolus: Scan mode used to measure the contrast transit time using a small injection of contrast media	Take axial scans at zero table feed and process with MIROI	Time Lapse	Test Bolus	Dynamic study	Not available	TIBT (Neuviz 16); Tracking layer (Neuviz DUAL)	Test Bolus
Time-attenuation curve (TAC): Graph of the contrast enhancement versus time	Smart Prep graph or MIROI graph	Time Lapse graph	Enhancement Curve	Time Density Curve	Monitoring Graph	Time Lapse Graph	Contrast curve
Threshold: CT number (HU) where bolus tracking tool will trigger the system to begin the scan	Transition ROI Threshold	Threshold	Level	Threshold ROI (HU)	Threshold	Threshold	CT threshold
Scanner feature used to quantitatively evaluate the TAC	MIROI (multiple image region of interest)	Tracker ROI Tools	DynEva (dynamic evaluation)	Real Time Monitoring	No special name	N/A	Algorithm
Monitoring delay: Time from injection to the start of monitoring scans (Time 1 in figure below)	Monitoring Delay	Post Injection Delay	Delay (on monitoring scan)	Delay (on SUREStart)	Scan Delay	(PIT) Post Injection Time	Time delay
Monitoring interval: Time between consecutive monitoring scans to (Time 2 in figure below)	Monitor ISD (InterScan Delay)	Cycle time	Cycle time	Real time monitoring or pulsed monitoring (seconds)	Monitoring Time	Cycle time (Neuviz 16); Bolus Timing (Neuviz DUAL)	Temporal resolution
Scan delay: Time from when threshold is reached and prescribed axial, helical or dynamic scan begins (Time 3 in figure below)	Diagnostic delay	Post Threshold Delay	Delay (on scan)	Delay (on helical)	Scan Delay	(PTD) Post Threshold Delay	Delay



6. Multi-planar formats and 3-D Processing							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Reformatted image at an oblique plane (not an axial, coronal, or sagittal)	Oblique reformat	Oblique	Oblique	Oblique	Oblique MPR	oblique/curved surface	Digital tilt
Saving images at various viewing angles about a volume or surface rendered object	Batch Loop	Cine	Radial Ranges	Key Frame Movie	Multi-Slice /Angle	Cine	Capture
Saving images at various planes through a volume	Batch Reformat	Batch MPR	Parallel Ranges	Batch MPR	Multi planar reformat	batch MPR	Capture
Surface-rendered object	3D	SSD 3D (Shaded Surface Display – 3D)	Shaded Surface Display (SSD)	ShadedVol (Shaded volume rendering (SVR))	Shaded Surface Display (SSD)	SSD (Shaded surface display)	3D
Volume-rendered object	Volume Rendered image (VR)	Volume Rendering	Volume Rendering Technique (VRT)	Shaded Vol	Volume Rendering	Volume Rendering (VR)	Volume Rendered image (VR)

7. Service and Application Tools							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
X-ray tube warm up	Tube Warm-up (tube warm up)	Tube conditioning	Check-up (calibrate and check values); Calibrate (part of Check-up, can be performed separately)	Warm up	Warm up	tube warm up	Warmup
Daily calibrations	Fast Cals (done in daily prep)	Not necessary to do daily calibrations	Quality Daily	Selectable air calibrations can be scheduled after warm-up	Air cals built into Warm up	not required daily, recommend air calibration weekly	Daily Calibration
Application information	Learning Solutions or User Manual	On-line Help	On-line Help; CT Life (task card)	E-Learning Center	Sentinel (Remote Service)	On-line Help	On-line help
Application support assistance	Insite or Iliq	Customer Care Solutions Center	Uptime	In Touch Center	CT Applications Helpline	Applications Specialist or Field Service Engineer	Service center

8. Workflow							
Generic description	**GE**	**PHILIPS**	**SIEMENS**	**TOSHIBA**	**HITACHI**	**NEUSOFT**	**NEUROLOGICA**
Scheduled (but not yet scanned) patient list is called	Patient Schedule	Scheduled (HIS-RIS) and Catalog-(manual list)	Patient Browser – Scheduler	Modality Worklist Manager	MWM-modality worklist management	Schedule	Modality Worklist Manager
Already scanned patient list is called	List/Select	Archive Manager	Patient Browser – Local Database	Directory	Patient List	Archive Manager (Neuviz 16); Archive Management Interface (Neuviz DUAL)	Patient Browser – Local Database
User comments or text added to an image is called	User annotation	Label (series) and Annotate (image)	Comment	Annotation	Comment	N/A	Annotation
Filming tools are called	Auto/manual film composer	Filming	Film Sheet on Filming task card	Filming	Filming	Filming	Printer
Data page summarizing scan parameters, CTDIvol and DLP	Exam Text Page or Series Text Page	Image Parameters	Patient Protocol (series number 501)	Summary and Exposure Record	Text Page	Information Display Bar on the right hand side of the Main Scan Interface & Dose Info series in Image Information List and Dose report at last series	Image Parameters
Sorting patient list	Sort	Click on sort field (name, date, etc.)	In Patient Browser: select "Sort" or "Filter" functions in menu bar	Click on sort field (name, date, etc.)	Click on sort field (name, date, etc.)	Select field to sort by (name, patient ID, etc.) and left click with mouse to sort.	Sort

Reference Materials for CT scanners/protocols

- Scanner to scanner verbiage
- What is a protocol

Reference Materials for CT scanners/protocols

- What constitutes a CT protocol (AAPM Practice guidelines 1.a definition)
  - CT Protocol – the collection of settings and parameters that fully describe a CT examination. Protocol may be relatively simple for some body part specific systems or highly complex for full-featured, general-purpose CT systems.

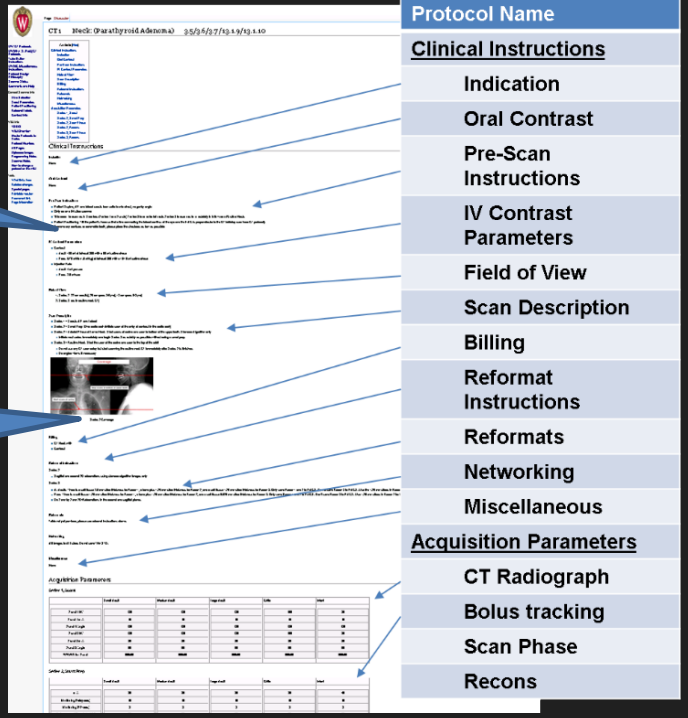
My philosophy is that anything that happens to a patient before/during/after their scan can affect diagnostic utility and should be standardized.

RSNA Reporting templates http://radreport.org/
DICOM 121 defining technical protocol parameters http://dicom.nema.org/Dicom/News/June2016/docs/sups/sup121.pdf
Radlex playbook http://playbook.radlex.org/playbook/SearchRadlexAction
IHE profile on protocol management http://wiki.ihe.net/index.php/Enterprise_Scanner_Protocol_Management_-_Proposal
AAPM CT lexicon http://www.aapm.org/pubs/CTProtocols/default.asp?tab=5

Reference Materials for CT scanners/protocols

Need balance between too verbose for frequent users

…and not low level enough for novice users



- Protocol Name
- Clinical Instructions
  - Indication
  - Oral Contrast
  - Pre-Scan Instructions
  - IV Contrast Parameters
  - Field of View
  - Scan Description
  - Billing
  - Reformat Instructions
  - Reformats
  - Networking
  - Miscellaneous
- Acquisition Parameters
  - CT Radiograph
  - Bolus tracking
  - Scan Phase
  - Recons

Go to youtube and search for “CT protocol wiki”. My techs love our wiki, I would be glad to assist you in setting one up for yourself.

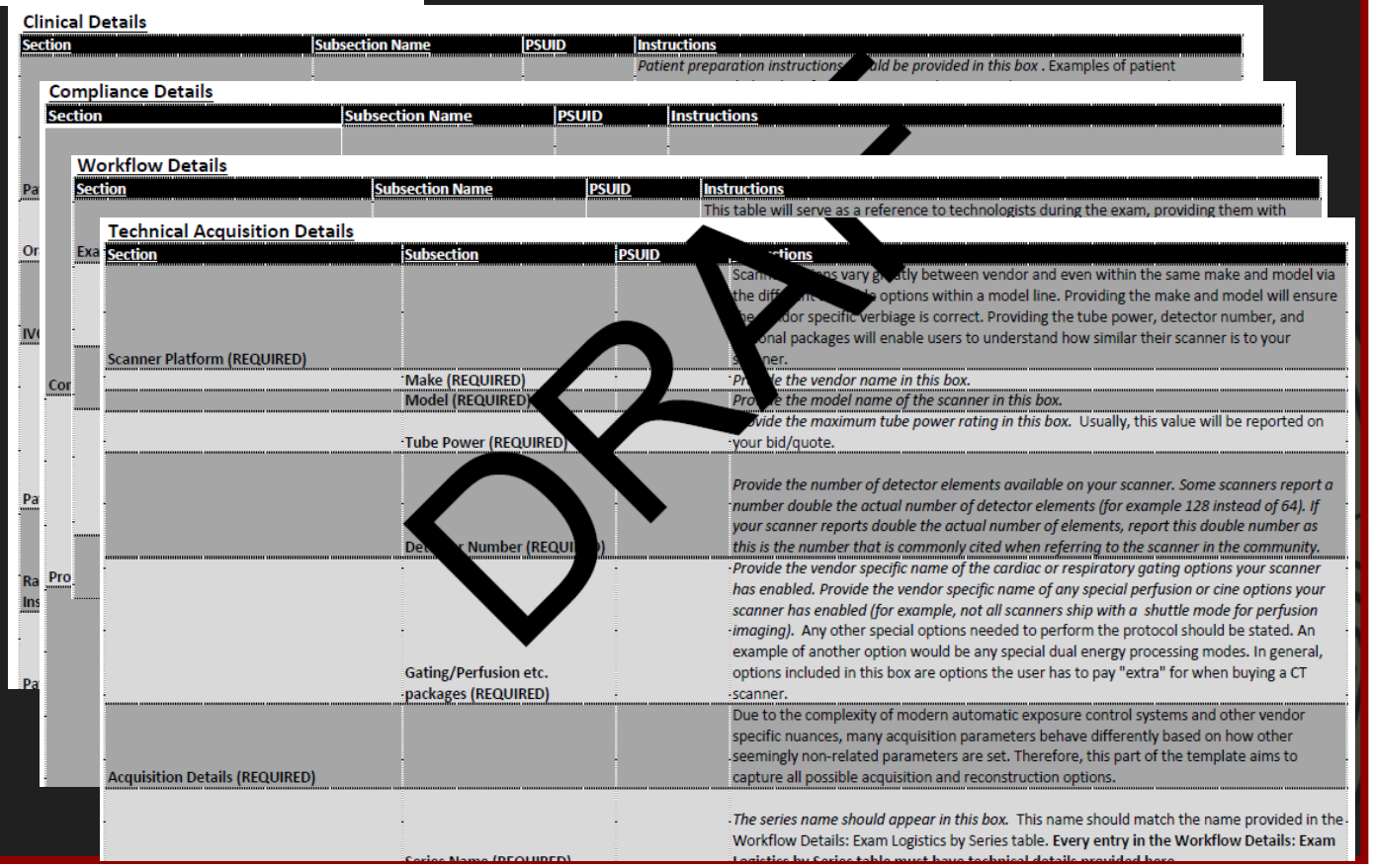
TP Szczykutowicz, N Rubert, D Belden, A Ciano, A Duplissis, A Hermanns, S Monette, E JanssenSaldivar. A wiki based solution to managing your nstitutions imaging protocols. Journal of the American College of Radiology 2016

TP Szczykutowicz, N Rubert, D Belden, A Ciano, A Duplissis, A Hermanns, S Monette, E JanssenSaldivar. A Wiki Based CT Protocol Management System. Radiology Management Nov/Dec Issue 2015

Reference Materials for CT scanners/protocols

www.protocolshare.org template

My effort at helping people think about what to put into a protocol. The template provides an overview of all the elements of a protocol and examples of documenting those elements.



Clinical Details

Section	Subsection Name	PSUID	Instructions
			Patient preparation instructions ...ld be provided in this box . Examples of patient

Compliance Details

Section	Subsection Name	PSUID	Instructions

Workflow Details

Section	Subsection Name	PSUID	Instructions
			This table will serve as a reference to technologists during the exam, providing them with

Technical Acquisition Details

Section	Subsection	PSUID	...tions
Scanner Platform (REQUIRED)			Scan...ns vary g...tly between vendor and even within the same make and model via the dif...t ...s options within a model line. Providing the make and model will ensure ...dor specific verbiage is correct. Providing the tube power, detector number, and ...nal packages will enable users to understand how similar their scanner is to your ...ner.
	Make (REQUIRED)		*Pr...e the vendor name in this box.*
	Model (REQUIRED)		*Pro...e the model name of the scanner in this box.*
	Tube Power (REQUIRED)		*...vide the maximum tube power rating in this box.* Usually, this value will be reported on your bid/quote.
	De...r Number (REQU...)		*Provide the number of detector elements available on your scanner. Some scanners report a number double the actual number of detector elements (for example 128 instead of 64). If your scanner reports double the actual number of elements, report this double number as this is the number that is commonly cited when referring to the scanner in the community.*
	Gating/Perfusion etc. packages (REQUIRED)		*Provide the vendor specific name of the cardiac or respiratory gating options your scanner has enabled. Provide the vendor specific name of any special perfusion or cine options your scanner has enabled (for example, not all scanners ship with a shuttle mode for perfusion imaging).* Any other special options needed to perform the protocol should be stated. An example of another option would be any special dual energy processing modes. In general, options included in this box are options the user has to pay "extra" for when buying a CT scanner.
Acquisition Details (REQUIRED)			Due to the complexity of modern automatic exposure control systems and other vendor specific nuances, many acquisition parameters behave differently based on how other seemingly non-related parameters are set. Therefore, this part of the template aims to capture all possible acquisition and reconstruction options.
	Series Name (REQUIRED)		*The series name should appear in this box.* This name should match the name provided in the Workflow Details: Exam Logistics by Series table. **Every entry in the Workflow Details: Exam**

DRAFT

Reference Materials for CT scanners/protocols

List of things to consider documenting as part of a protocol

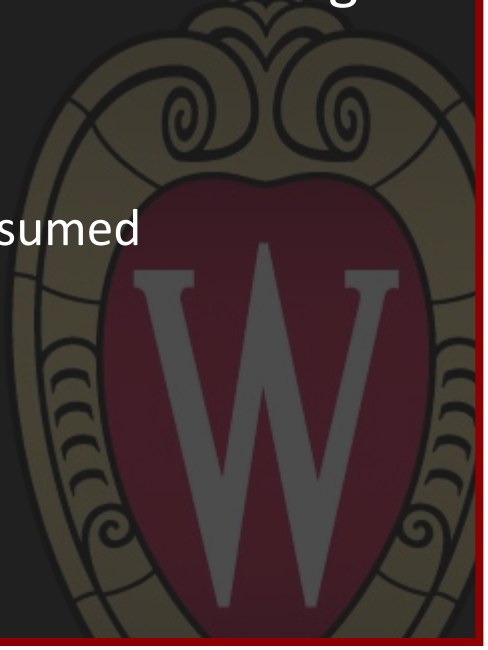
Protocol name (Radlex RPID, ACR common ID), clinical indication, design philosophy, billing codes, RSNA reporting template #, dose information, compliance with screening standards, compliance with organ transplant criteria, trial/study compatibility, patient prep, oral contrast details, IVC contrast details, patient coaching, monitoring instructions for nurse/physician, patient positioning, exam logistical details (scan description), reformat instructions (including examples), networking details, scanner model, tube power, detector configuration, gating/perfusion package options, series name, scan type, kV, pitch, rotation time, mAs/effective mAs, collimation, AEC/TCM settings, slice thickness, interval, recon name, recon kernel, recon RFOV, recon slice thickness, recon interval, recon iterative options, recon ww/wl

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

CT Dose Calculation

- Conversions from DLP to effective dose
  - There are many published tables of such conversions using a variety of different weighting factors.
  - Tips
    - Know what weighting factor your k factor table assumed
      - ICRP 26 (1977), ICRP 60 (1991), and ICRP 103 (2007)
    - Know what age your k factor table assumed
      - “adult”, 0 y.o., 1 y.o., 5 y.o., and 10 y.o. common
    - Know what the scan ranges were for your table
      - Will not be the same between different reports/papers



CT Dose Calculation

Organ	ICRP 26 (1977)	ICRP 60 (1991)	ICRP 103 (2007)
Brain			0.01
Salivary Glands			0.01
Thyroid	0.03	0.05	0.04
Esophagus		0.05	0.04
Breast	0.15	0.05	0.12
Lung	0.12	0.12	0.12
Stomach		0.12	0.12
Liver		0.05	0.04
Colon		0.12	0.12
Bladder		0.05	0.04
Gonads	0.25	0.2	0.08
Bone Surfaces	0.03	0.01	0.01
Bone Marrow	0.12	0.12	0.12
Skin		0.01	0.01
Remainder	0.3	0.05	0.12

- International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection. Oxford: ICRP; Publication 26; 1977.
- International Commission on Radiological Protection. 1990 recommendations of the International Commission on Radiological Protection. Oxford: ICRP; Publication 60; 1991.
- International Commission on Radiological Protection. The 2007 recommendations of the International Commission on Radiological Protection. Oxford: ICRP; Publication 103; 2007.

CT Dose Calculation

Scan Region	Age	Phantom Diam-eter (cm)	Huda 2011	Jessen 1999	EUR NRPB	UK 2003	EUR 2004	Deak 2010	EUR1999
Head	Adult	16	0.0024	0.0021	0.0021	0.0021	0.0023	0.0019	0.0023
Head and Neck	Adult	16	0.0045	0.0031		0.0031			
Neck	Adult	32	0.0053	0.0048	0.0059	0.0059		0.0051	0.0054
Chest	Adult	32	0.0204	0.0014	0.014	0.014	0.0018	0.0145	0.0017
Abdomen	Adult	32	0.0163	0.012	0.015	0.015	0.0017	0.0153	0.0015
Pelvis	Adult	32	0.0171	0.019	0.015	0.015	0.0017	0.0129	0.00191
CAP (Trunk)	Adult	32	0.0186	0.015		0.015			
Legs	Adult	32					0.0008		

A couple review papers:

Obed, et al. "Comparison of the ICRP 60 and ICRP 103 Recommendations on the Determination of the Effective Dose from Abdominopelvic Computed Tomography." *International Journal of Medical Physics, Clinical Engineering and Radiation Oncology* 4.02 (2015): 172.

Christner et al. "Estimating effective dose for CT using dose–length product compared with using organ doses: consequences of adopting International Commission on Radiological Protection Publication 103 or dual-energy scanning." *American Journal of Roentgenology* 194.4 (2010): 881-889.

Scan Region	Age	Phantom Diameter (cm)	EUR 2004	Deak 2010
Head	0 y.o.	16	0.011	0.0087
Head	1 y.o.	16	0.0067	0.0054
Head	5 y.o.	16	0.004	0.0035
Head	10 y.o.	16	0.0032	0.0027
Head and Neck	0 y.o.	16	0.013	
Head and Neck	1 y.o.	16	0.0085	
Head and Neck	5 y.o.	16	0.0057	
Head and Neck	10 y.o.	16	0.0042	
Neck	0 y.o.	16	0.017	0.021
Neck	1 y.o.	16	0.012	0.0168
Neck	5 y.o.	16	0.011	0.0121
Neck	10 y.o.	16	0.079	0.0094
Chest	0 y.o.	16	0.039	0.0739
Chest	1 y.o.	16	0.026	0.0482
Chest	5 y.o.	16	0.018	0.0323
Chest	10 y.o.	16	0.013	0.0237
Abdomen and Pelvis	0 y.o.	16	0.049	
Abdomen and Pelvis	1 y.o.	16	0.03	
Abdomen and Pelvis	5 y.o.	16	0.02	
Abdomen and Pelvis	10 y.o.	16	0.015	
Trunk	0 y.o.	16	0.044	
Trunk	1 y.o.	16	0.028	
Trunk	5 y.o.	16	0.019	
Trunk	10 y.o.	16	0.014	
Abdomen	0 y.o.	16		0.0841
Abdomen	1 y.o.	16		0.0530
Abdomen	5 y.o.	16		0.0357
Abdomen	10 y.o.	16		0.0249
Pelvis	0 y.o.	16		0.0701
Pelvis	1 y.o.	16		0.0446
Pelvis	5 y.o.	16		0.03
Pelvis	10 y.o.	16		0.0219

- Huda, W., Magill, D., & He, W. (2011). CT effective dose per dose length product using ICRP 103 weighting factors. *Medical physics*, *38*(3), 1261-1265.
- Jessen, K. A., Shrimpton, P. C., Geleijns, J., Panzer, W., & Tosi, G. (1999). Dosimetry for optimisation of patient protection in computed tomography. *Applied Radiation and isotopes*, *50*(1), 165-172.
- Jones, D. G., Shrimpton, P. C., & Britain, G. (1991). *Survey of CT practice in the UK. Part 3: Normalised organ doses calculated using Monte Carlo techniques*. Chilton, UK: National Radiological Protection Board.
- Shrimpton, P. C., Hillier, M. C., Lewis, M. A., & Dunn, M. (2006). National survey of doses from CT in the UK: 2003. *The British journal of radiology*, *79*(948), 968-980.
- MSCT: European guidelines for multislice computed tomography. Technical Report Appendix A, European Commission, 2004
- Deak, P. D., Smal, Y., & Kalender, W. A. (2010). Multisection CT protocols: sex-and age-specific conversion factors used to determine effective dose from dose-length product. *Radiology*, *257*(1), 158-166.
- European guidelines on quality criteria for computed tomography. Technical report, European Commission's Radiation Protection Actions, 1999.

CT Dose Calculation

- Need effective dose fast?
  - There is an app for that! (there are actually many apps for that)
  - These apps simply take published data of k factors as a function of body region and patient age and present it in a nice calculator type format
  - Age ranges and anatomical regions will differ between the apps and choices within the apps

CT Dose Calculation

Scan Region	Age	Phantom Diam-eter (cm)	Huda 2011	Jessen 1999	EUR NRPB	UK 2003	EUR 2004	Deak 2010	EUR1999
Head	Adult	16	0.0024	0.0021	0.0021	0.0021	0.0023	0.0019	0.0023
Head and Neck	Adult	16	0.0045	0.0031		0.0031			
Neck	Adult	32	0.0053	0.0048	0.0059	0.0059		0.0051	0.0054
Chest	Adult	32	0.0204	0.0014	0.014	0.014	0.0018	0.0145	0.0017
Abdomen	Adult	32	0.0163	0.012	0.015	0.015	0.0017	0.0153	0.0015
Pelvis	Adult	32	0.0171	0.019	0.015	0.015	0.0017	0.0129	0.00191
CAP (Trunk)	Adult	32	0.0186	0.015		0.015			
Legs	Adult	32					0.0008		

Scan Region	Age	Phantom Diameter (cm)	EUR 2004	Deak 2010
Head	0 y.o.	16	0.011	0.0087
Head	1 y.o.	16	0.0067	0.0054
Head	5 y.o.	16	0.004	0.0035
Head	10 y.o.	16	0.0032	0.0027
Head and Neck	0 y.o.	16	0.013	
Head and Neck	1 y.o.	16	0.0085	
Head and Neck	5 y.o.	16	0.0057	
Head and Neck	10 y.o.	16	0.0042	
Neck	0 y.o.	16	0.017	0.021
Neck	1 y.o.	16	0.012	0.0168
Neck	5 y.o.	16	0.011	0.0121
Neck	10 y.o.	16	0.079	0.0094
Chest	0 y.o.	16	0.039	0.0739
Chest	1 y.o.	16	0.026	0.0482
Chest	5 y.o.	16	0.018	0.0323
Chest	10 y.o.	16	0.013	0.0237
Abdomen and Pelvis	0 y.o.	16	0.049	
Abdomen and Pelvis	1 y.o.	16	0.03	
Abdomen and Pelvis	5 y.o.	16	0.02	
Abdomen and Pelvis	10 y.o.	16	0.015	
Trunk	0 y.o.	16	0.044	
Trunk	1 y.o.	16	0.028	
Trunk	5 y.o.	16	0.019	
Trunk	10 y.o.	16	0.014	
Abdomen	0 y.o.	16		0.0841
Abdomen	1 y.o.	16		0.0530
Abdomen	5 y.o.	16		0.0357
Abdomen	10 y.o.	16		0.0249
Pelvis	0 y.o.	16		0.0701
Pelvis	1 y.o.	16		0.0446
Pelvis	5 y.o.	16		0.03
Pelvis	10 y.o.	16		0.0219

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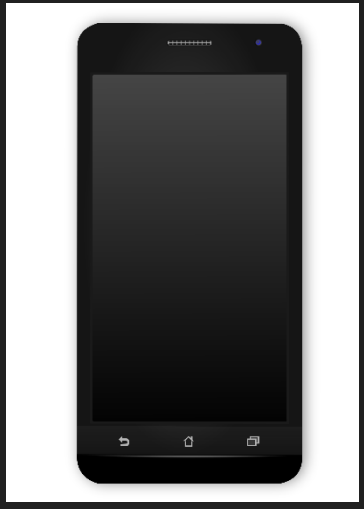

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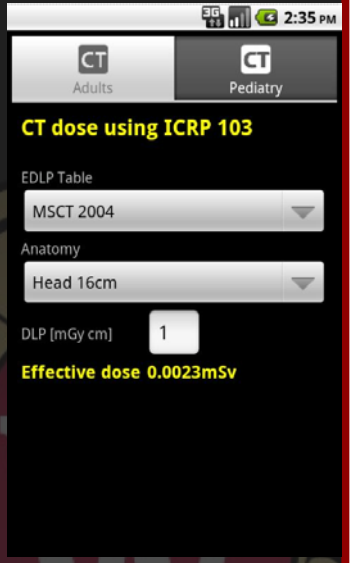


CT Dose Calculation

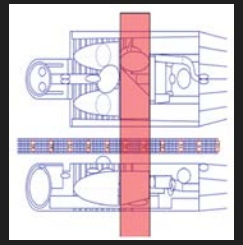
- When CT dose calculation meets the real world
  - What to do for custom scan ranges…?
  - What to do when we know the dose is modulated between regions…?
  - For example, a head scan of just the temporal bone anatomy, a abdomen scan of just the liver, an extremity scan…
    - For these, you really need a custom Monte Carlo or measurement based method. Not something your average physicists is going to be able to do.
  - For example, a CAP we know will have ½ the dose over the chest. You can combine different k factors in weighting schemes, but it would be nice to be free of published scan range/k factor combinations.

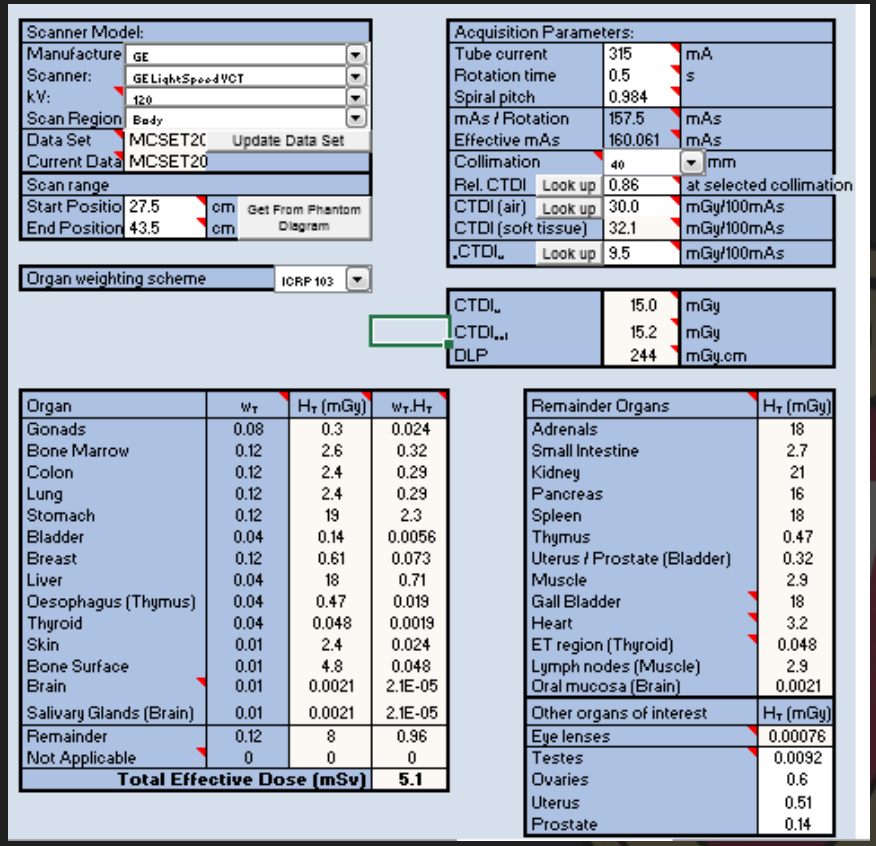
CT Dose Calculation

- ImPACT CTdosimetry calculator (free) retrieved from www.impactscan.org/ctdosimetry.htm

(I would download this ASAP, this group is no longer funded so I am not sure how much longer it will be online)

Another option is CT-Expo http://www.sascrad.com/page9.php (free demo version is online, paid full version available)





Scanner Model:			
Manufacture	GE		
Scanner:	GELightSpeedVCT		
kV:	120		
Scan Region	Body		
Data Set	MCSET20	Update Data Set	
Current Data	MCSET20		
Scan range			
Start Positio	27.5	cm	Get From Phantom Diagram
End Position	43.5	cm	

Acquisition Parameters:			
Tube current	315	mA	
Rotation time	0.5	s	
Spiral pitch	0.984		
mAs / Rotation	157.5	mAs	
Effective mAs	160.061	mAs	
Collimation	40	mm	
Rel. CTDI	Look up	0.86	at selected collimation
CTDI (air)	Look up	30.0	mGy/100mAs
CTDI (soft tissue)	Look up	32.1	mGy/100mAs
CTDI$_{vol}$	Look up	9.5	mGy/100mAs

Organ weighting scheme	ICRP 103

CTDI$_{vol}$	15.0	mGy
CTDI$_{w}$	15.2	mGy
DLP	244	mGy.cm

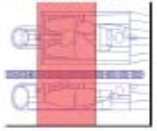
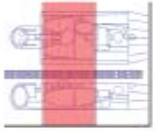
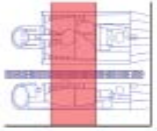
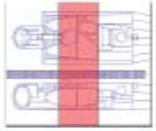
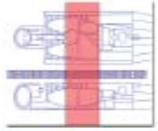
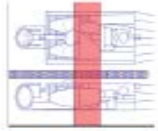
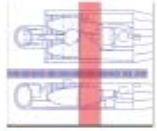
Organ	w_T	H_T (mGy)	$w_T.H_T$
Gonads	0.08	0.3	0.024
Bone Marrow	0.12	2.6	0.32
Colon	0.12	2.4	0.29
Lung	0.12	2.4	0.29
Stomach	0.12	19	2.3
Bladder	0.04	0.14	0.0056
Breast	0.12	0.61	0.073
Liver	0.04	18	0.71
Oesophagus (Thymus)	0.04	0.47	0.019
Thyroid	0.04	0.048	0.0019
Skin	0.01	2.4	0.024
Bone Surface	0.01	4.8	0.048
Brain	0.01	0.0021	2.1E-05
Salivary Glands (Brain)	0.01	0.0021	2.1E-05
Remainder	0.12	8	0.96
Not Applicable	0	0	0
Total Effective Dose (mSv)			**5.1**

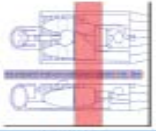
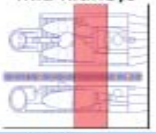
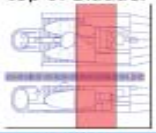
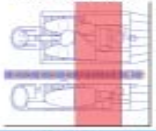
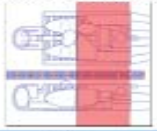
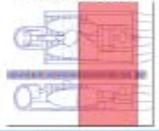
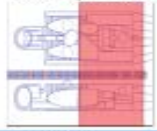
Remainder Organs	H_T (mGy)
Adrenals	18
Small Intestine	2.7
Kidney	21
Pancreas	16
Spleen	18
Thymus	0.47
Uterus / Prostate (Bladder)	0.32
Muscle	2.9
Gall Bladder	18
Heart	3.2
ET region (Thyroid)	0.048
Lymph nodes (Muscle)	2.9
Oral mucosa (Brain)	0.0021

Other organs of interest	H_T (mGy)
Eye lenses	0.00076
Testes	0.0092
Ovaries	0.6
Uterus	0.51
Prostate	0.14

CT Dose Calculation

With this program, you can set any ranges you desire

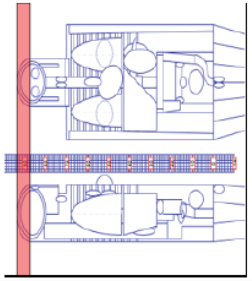
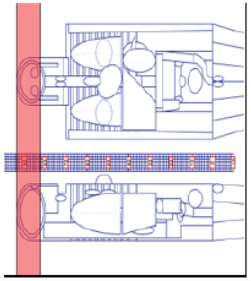
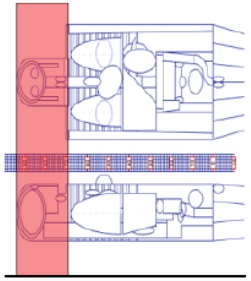
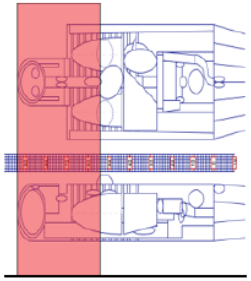
	Above Lung Apices to Bottom of liver	Lung Apices to Bottom of liver	Lung Apices to Bottom of liver	Mid Thorax to Bottom of liver	Top of Heart to Bottom of liver	Mid Heart to Bottom of liver	Extent of Liver
							
k factor	0.020	0.021	0.022	0.023	0.023	0.020	0.021
$CTDI_{vol}$ (mGy)	15	15	15	15	15	15	15
DLP (mGy)	700	624	548	472	396	320	244
Effective Dose (mSv)	14	13	12	11	9	6.5	5.1

	Top of Liver to Extent of Small Intestine	Top of Liver to mid Kidneys	Top of Liver to top of Bladder	Top of :Liver to mid Bladder	Top of Liver to Extent of Bladder	Top of Liver to mid Testes	Top of Liver to Pubic Synthesis
							
k factor	0.020	0.018	0.018	0.18	0.16	0.016	0.015
$CTDI_{vol}$ (mGy)	15	15	15	15	15	15	15
DLP (mGy)	320	396	472	548	624	700	776
Effective Dose (mSv)	6.3	7.3	8.6	9.6	10	11	12

For lower extremities (not covered fully in the example shown on this or the next page), see “Saltybaeva, Natalia, et al. "Estimates of effective dose for CT scans of the lower extremities." *Radiology* 273.1 (2014): 153-159.”

With this program, you can set any ranges you desire

CT Dose Calculation

	Top of Head to top of Eyes	Extent of Skull	Extent of Head and Neck	Top of Head to Aorta
				
k factor	0.002	0.003	0.004	0.006
$CTDI_{vol}$ (mGy)	50	50	50	50
DLP (mGy)	612	1083	2307	3719
Effective Dose (mSv)	1.4	3	9.5	21
Eye Lenses (mGy)	2.4	79	88	89

CT Dose Calculation

- Practical advice on using the ImPACT dose calculator
  - If you cant find exactly the scanner model you need on the ImPACT list…don't sweat it
  - I prescribed a 15 mGy abd/pelvis scan on 4 different vendor models over the same scan length, all the effective doses were within 1 mSv
    - GE LightSpeed 64 slice VCT, Siemens Definition AS, Philips Brilliance 64, Toshiba Aquillion 16 returned effective doses of 13/12/12/13 mSv respectively and DLPs of 771/774/774/770 mGy*cm respectively

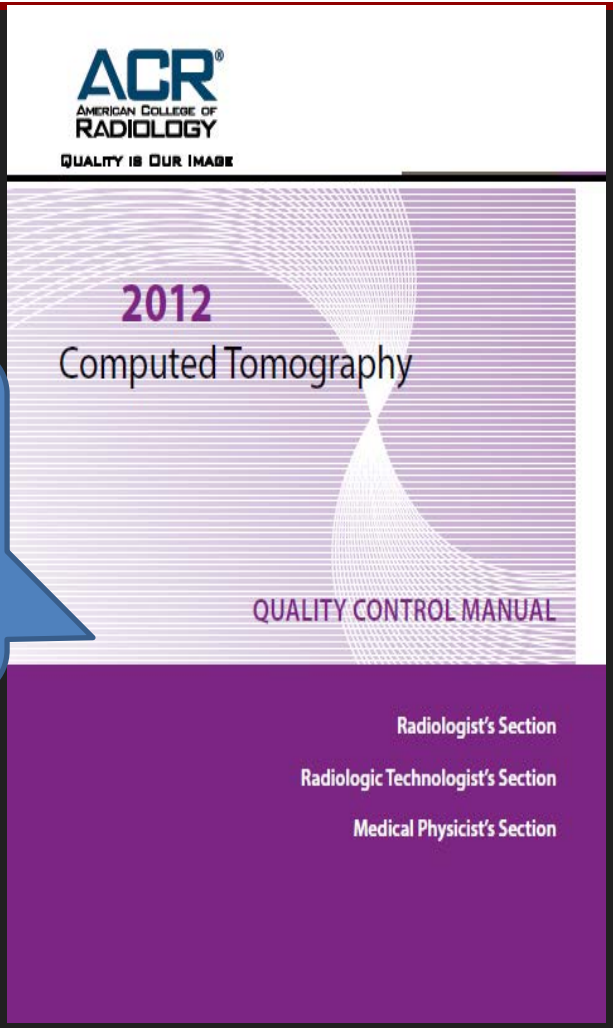
CT Dose Calculation

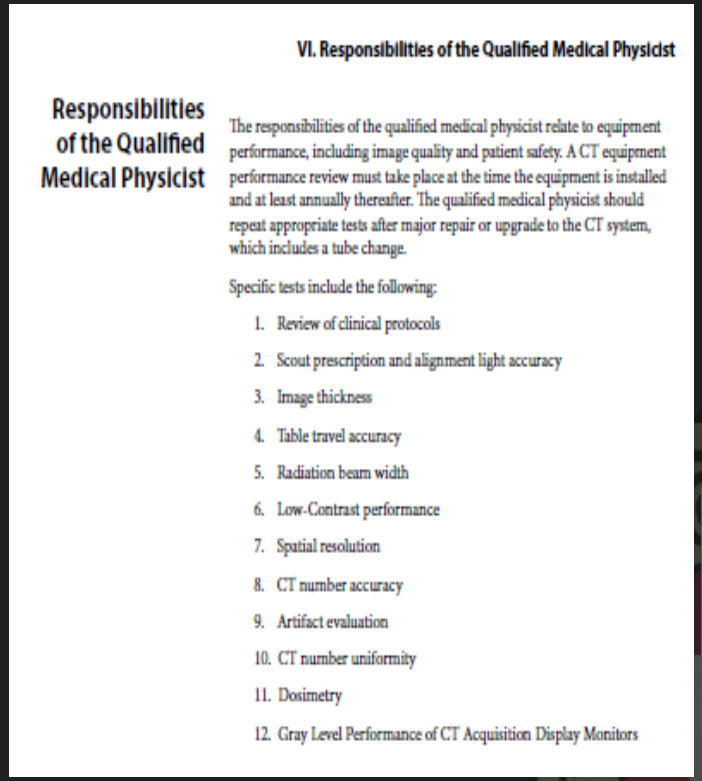
- Fetal dose calculations
  - You can use ImPACT dose calculator tool and report the uterus dose as the fetal dose
  - Measure the fetus depth and mother's circumference and use a look up table "Angel et al. Radiation dose to the fetus for pregnant patients undergoing multidetector CT imaging: Monte Carlo simulations estimating fetal dose for a range of gestational age and patient size. *Radiology*, *249*(1), 220-227."
  - Use the normalized reference dose method (need to know fetus depth and technique used for scan) "Felmlee et al. Estimated Fetal Radiation Dose from Multislice CT Studies *American Journal of Roentgenology* **154** 1990"

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

You have to pay for this from the ACR Currently $40





VI. Responsibilities of the Qualified Medical Physicist

Responsibilities of the Qualified Medical Physicist

The responsibilities of the qualified medical physicist relate to equipment performance, including image quality and patient safety. A CT equipment performance review must take place at the time the equipment is installed and at least annually thereafter. The qualified medical physicist should repeat appropriate tests after major repair or upgrade to the CT system, which includes a tube change.

Specific tests include the following:

1. Review of clinical protocols
2. Scout prescription and alignment light accuracy
3. Image thickness
4. Table travel accuracy
5. Radiation beam width
6. Low-Contrast performance
7. Spatial resolution
8. CT number accuracy
9. Artifact evaluation
10. CT number uniformity
11. Dosimetry
12. Gray Level Performance of CT Acquisition Display Monitors

Must read supplement to the ACR manual

McCollough, Cynthia H., et al. "The phantom portion of the American College of Radiology (ACR) computed tomography (CT) accreditation program: practical tips, artifact examples, and pitfalls to avoid." *Medical physics* 31.9 (2004): 2423-2442.

The Joint Commission

Prepublication Requirements

• Issued January 9, 2015 •

The Joint Commission has approved the following revisions for prepublication. While revised req
in the semiannual updates to the print manuals (as well as in the online E-dition®), a
and paid subscribers can also view them in the monthly periodical *The Joint Commission F*
your subscription, call 877-223-6866 or visit http://www.jcrinc.com.

Joint Commission

Requirement

Revised Requirements for Diagnostic Imaging Services

A 19. Ⓓ **For diagnostic computed tomography (CT) services:** At least annually, a diagnostic medical physicist conducts a performance evaluation of all CT imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluation includes the use of phantoms to assess the following imaging metrics: A

- Image uniformity
- Slice thickness accuracy
- Slice position accuracy (when prescribed from a scout image)
- Alignment light accuracy
- Table travel accuracy
- Radiation beam width
- High-contrast resolution
- Low-contrast resolution
- Geometric or distance accuracy
- CT number accuracy and uniformity
- Artifact evaluation

Note 1: *This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the*

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The Joint Commission has approved the following re published in the semiannual updates to the print manuals anizations and paid subscribers can also view them in the m To begi your subscription, call 877-223-6866 or visit http://ww

Joint Commission

Revised Requir

A 17. ⓓ ~~For [critical access] hospitals in California that provide computed tomography (CT) services: A qualified medical physicist measures the actual radiation dose * produced by each diagnostic CT imaging system at least annually and verifies that the radiation dose displayed on the system for standard adult brain, adult abdomen, and pediatric brain protocols is within 20 percent of the actual amount of radiation dose delivered. The dates of these verifications are documented.~~ Ⓜ

Note: ~~*This element of performance is applicable only for systems capable of calculating and displaying radiation doses.*~~

~~* For the definition of "radiation dose" refer to section 115111(f) of the California Health and Safety Code.~~

For diagnostic computed tomography (CT) services: At least annually, a diagnostic medical physicist does the following: Ⓐ

- Measures the radiation dose (in the form of volume computed tomography dose index [CTDIvol]) produced by each diagnostic CT imaging system for the following four CT protocols: adult brain, adult abdomen, pediatric brain, and pediatric abdomen. If one or more of these protocols is not used by the [critical access] hospital, other commonly used CT protocols may be substituted.
- Verifies that the radiation dose (in the form of CTDIvol) produced and measured for each protocol tested is within 20 percent of the CTDIvol displayed on the CT console. The dates, results, and verifications of these measurements are documented.

Note 1: *This element of performance is only applicable for systems capable of calculating and displaying radiation doses.*

Note 2: *This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.*

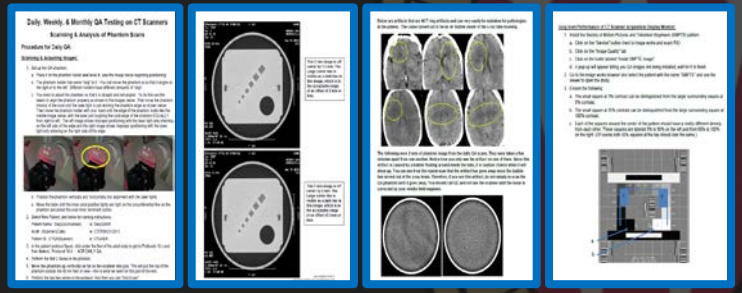
Note 3: *Medical physicists are accountable for these activities. They may be assisted with the testing and evaluation of equipment performance by individuals who have the required training and skills, as determined by the physicist. (See also HR.01.02.01, EP 1; HR.01.02.05, EP 20; HR.01.02.07, EPs 1 and 2; HR.01.06.01, EP 1; and LD.03.06.01, EP 4)*

Note: A scanner with the dose check feature dose not ensure anything related to benchmarking, reviewing, or indexing dose since it is up to the user to turn dose check on an populate the notification values with meaningful values.

CT QA/QC and shielding

- In addition to requirements, we do have several guidance documents in our field
- 1993 AAPM Report 39 "*SPECIFICATION AND ACCEPTANCE TESTING OF COMPUTED TOMOGRAPHY SCANNERS*"
  - **Solid review of fundamentals, not much at all has changed since this report in the basics of CT (exceptions being multi-slice CT, more advance cardiac modes and dual energy to name a few big ones)**
- 2010 AAPM Report 111 **"***Comprehensive Methodology for the Evaluation of Radiation Dose in X-Ray Computed Tomography*"
- 2003 AAPM Report 86 (Task Group 66) "*Quality assurance for computed-tomography simulators and the computed-tomography-simulation process: Report of the AAPM Radiation Therapy Committee Task Group No. 66*"
- All CT scanner come with an OEM list of testing procedures
  - They have these to get them out of trouble if the scanner doesn't work as you want…if it works as they say it should using their tests then they are off the hook unless you contractually ask for other performance metrics

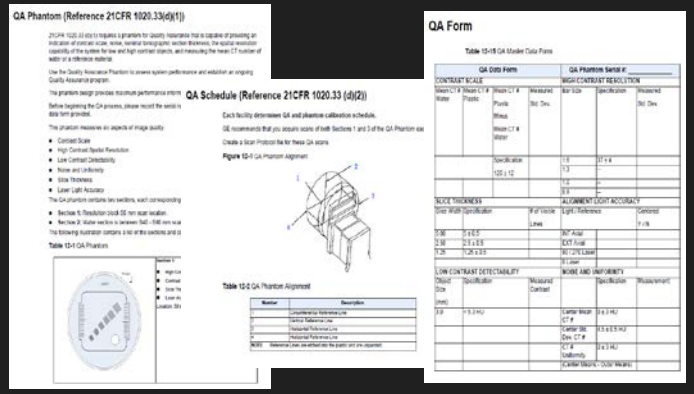
Example UW daily/weekly/monthly QA instructions and data forms can be found here
https://www.radiology.wisc.edu/protocols/CT/resources.php



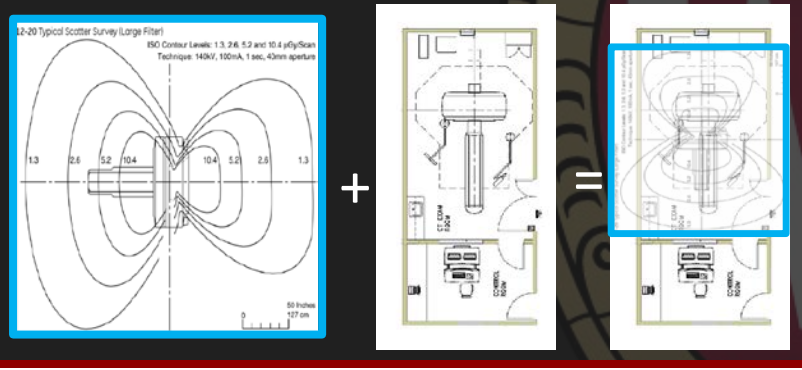
CT QA/QC and shielding

- Shielding
  - 2006 AAPM Report 108 “AAPM Task Group 108: PET and PET/CT Shielding Requirements”
    - Kind of light on content compared to the NCRP report
  - 2004 NCRP Report 147 “Structural Shielding Design for Medical X-Ray Imaging Facilities”
    - Covers all modalities of x-ray, it is THE reference for shielding

The vendors usually supply pretty robust daily/weekly QA programs (phantom, instructions, and limits)



The vendors usually supply iso-dose maps making shielding calculations easier



CT QA/QC and shielding

Steps to understanding CT QA/QC

1. Get your hands on the ACR QC Manual
2. Get your hands on as many physicists reports as you can to see how others do it
3. Get your hands on as many tech daily/weekly/monthly quality instructions/training materials as you can
4. Read the vendor supplied acceptance testing and routine QA/QC test instructions and KNOW the vendor supplied limits for those tests!
   - When we received our mobile CT unit, Neurologica sent a 24 page manual detail what phantom, what protocol, how to set-up, and how to evaluate the scanner for acceptance testing. The listed the values for our specific unit they measured in their factor , the ACR action limits (when applicable) and their own limits. All of the vendors do similar, ask for the “technical/user/dose/reference protocol” manuals (names and types of manuals differ by vendor) before you go to work on a scanner.

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

CT Dose Check

- This section will cover dose notifications and alerts which are defined in NEMA XR-25.
  - NEMA XR-25 is one of 4 requirements listed in NEMA XR-29
  - NEMA XR-29 is required for diagnostic CT payment from CMS
  - NEMA XR-25 (dose check) compliance can be met by vendor technology or 3rd party scanner add-ons

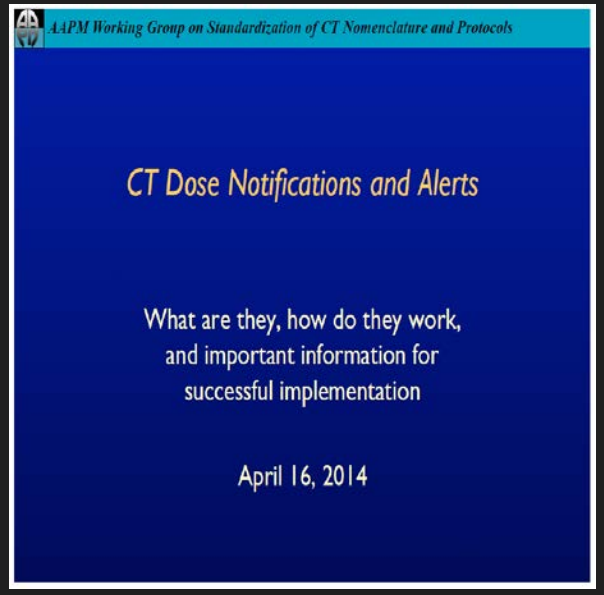
Good introduction paper to Dose Check

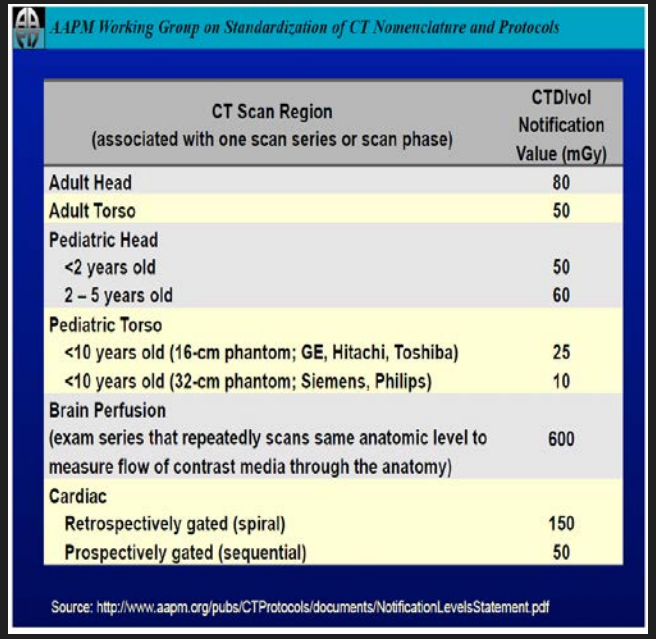
What Is the CT Dose Check Standard, and Why Do CT Scanners Need to Be in Compliance? By Mahadevappa Mahesh JACR 2015

Good paper on Dose Check and CT intervention/fluoro

McCollough, Cynthia H., and Christopher P. Favazza. "Potential Clinical Ramifications of Dose Alert on CT-Guided Interventional Procedures." *Journal of the American College of Radiology* 13.5 (2016): 542-544.

CT Dose Check





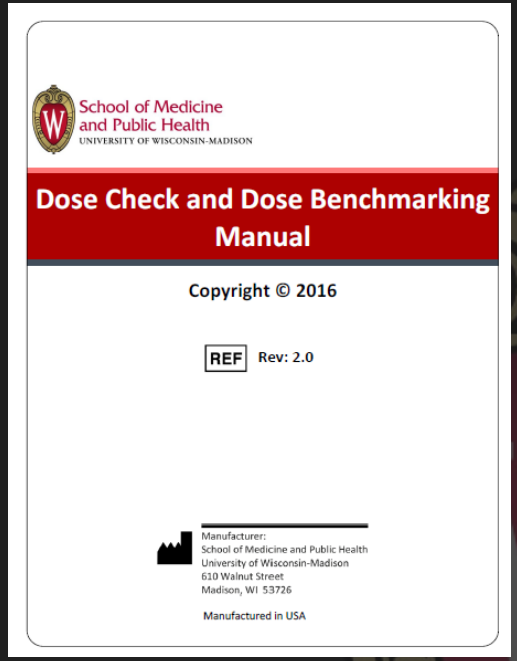
CT Scan Region (associated with one scan series or scan phase)	CTDIvol Notification Value (mGy)
Adult Head	80
Adult Torso	50
Pediatric Head	
<2 years old	50
2 – 5 years old	60
Pediatric Torso	
<10 years old (16-cm phantom; GE, Hitachi, Toshiba)	25
<10 years old (32-cm phantom; Siemens, Philips)	10
Brain Perfusion (exam series that repeatedly scans same anatomic level to measure flow of contrast media through the anatomy)	600
Cardiac	
Retrospectively gated (spiral)	150
Prospectively gated (sequential)	50

http://www.aapm.org/pubs/CTProtocols/default.asp

CT Dose Check

How we took the AAPM values and augmented for our own clinic

- Our manual lists NV and Alert levels for
  - Each of our ~300 protocols (x3)
  - Each series within each protocol
- While we customized to our scanners and protocols, our values should serve as a good reference for all vendors since **image quality needs vary as a function of indication/protocol**, not vendor
- This manual also has UW-Madison dose data (CTDIvol, DLP, SSDE 25/50/mean/75 percentile for all of our protocols/series/phases)



https://www.radiology.wisc.edu/protocols/CT/resources.php

CT Dose Check

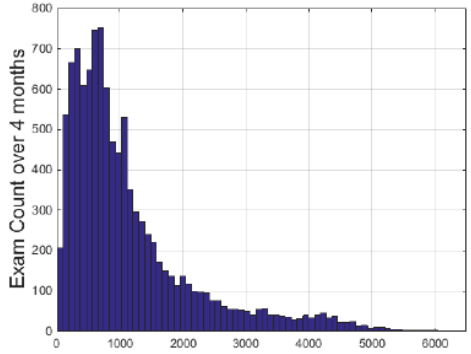
Setting the AV

To set the AV, you must be a user who is a member of the Dose Check Administrator group. Please contact your site Dose Check Administrator. If your site does not have a Dose Check Administrator, consult your GE documentation manuals or contact your applications specialist to you in setting up appropriate permissions.

Instructions for setting the AV:

1. From the scan monitor, click the **Protocol Management icon** located on the left bottom of the screen.
2. Click on the box labelled **Dose Check Management**.
3. In the AV checking section, de-select the box labelled **$CTDI_{vol}$** and select the box labelled **DLP**.
4. Enter a value of 5000 mGy-cm into the box below the **DLP** box.
5. Click save. You have now set the AV.

An AV value of 5000 mGy-cm was chosen using data from our institution as shown below. Below is a histogram of DLP data taken over a 4 month period. Only 4% of our exams exceeded 5000 mGy-cm. These exams consisted mainly of stroke codes (multiphasic exams which include a perfusion series), trauma exams (require high dose to visualize small spinal fractures), and multiphasic routine heads (non-contrast, with contrast, and axial scans acquired with a gantry tilt).



Setting the NV

To set the NV, you must be a user who is a member of the Standard User Group if protocol change control (PCC) is turned on. Please consult your site's Dose Check Administrator to assist you with obtaining this level of permissions if you are not a Standard User already.

Instructions for setting the NV:

1. From the scan monitor, click the **Protocol Management icon** located on the left bottom of the screen.
2. Click on the box labelled **Dose Check Management**.
3. In the NV Checking section, de-select the box labelled **DLP** and select the box labelled **$CTDI_{vol}$**.
4. Click save. You have now set the NV to use $CTDI_{vol}$ instead of DLP.

Now you must enter the proper $CTDI_{vol}$ NV for every protocol. Depending on the version of UW protocols you have, this may have already been done for you when you load the UW protocols onto your scanner.

To edit the NV for a single protocol:

1. From the scan monitor, click the **Protocol Management icon** located on the left bottom of the screen.
2. Click on the box labelled **Protocol Management**.
3. Navigate to the protocol you wish to add a NV to and click edit.
4. Navigate to the specific series to which you wish to add a NV.
5. In the upper right hand corner of the screen, dose information will be displayed. Click on the box labelled **set up**.
6. Enter the proper $CTDI_{vol}$ values as listed in this document in the section titled "UW Table of NV".

UW Dose Check philosophy: We set NV based on max dose of unaltered protocol and AV at 1 Gy (we also give guidance on setting bolus tracking limits and using DLP for AV)

CT Dose Check

- By protocol (neuro, thoracic, abdomen, MSK, peds, CV)
- By series
- By patient size

Protocol Name	Acquisition	Patient Size	NV (mGy)
Abd/Pelvis	S2	Small	20
		Medium	35
		Large	60
Abd/Pelvis - Flank Pain	S2	Small	20
		Medium	35
		Large	60
	S3	Small	10
		Medium	20
		Large	30
Abd/Pelvis - Peritoneogram	S2	Small	20
		Medium	35
		Large	60
Abd/Pelvis - Colonography	S2	Small	15
		Medium	10
		Large	10
	S4	Small	15
		Medium	10
		Large	10
	S6	Small	15
		Medium	10
		Large	10
		Infant	30
Adult Brain: (Axial Mode)	S2	Adult	85
	S3	Adult	70
Adult Brain: Helical Scan with Angled Axial Reformations	S2	Adult	85
	S3	Adult	70
Adult Brain: Routine (Helical Mode)	S2	Adult	85
	S3	Adult	70

Outline

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CT Dose Tracking

- ACR DIR https://nrdr.acr.org/Portal/DIR/Main/page.aspx
- Pediatric leap frog effort http://www.leapfroggroup.org/survey-materials/survey-and-cpoe-materials
- Radiance (the only free and open source tool I am aware of for CT doses) http://radiancedose.com/
- There are a plethora of commercial dose tracking solutions available
- "home brew solutions" At the end of the day dose tracking is really about two things (a) getting dose data from your scanner (we have a DICOM standard for that) and (b) Making sense of the data
  - With a commercial solution, you can outsource worrying about how to connect and get data from your devices to satisfy (a) and the vendor will make pretty plots and trend comparisons to satisfy (b)

AAPM Practice guideline on this

AAPM medical physics practice guideline 6.a.: Performance characteristics of radiation dose index monitoring systems.

CT Dose Tracking

Dose tracking is not trivial

- Handling add-ons
  - Separate series versus extensions of scan ranges
  - Order of add-on with respect to original exam when sent to ACR DIR (ACR DIR can only map to 1 RPID)
- Handling “optional” delayed series/phases
- How to treat bolus tracking phases/series doses (these can be hundreds of mGy…)
- The need for having both orderable and protocol name available in mapping to RPID
- How to handle variable dose protocols (UW adjusts dose in some special cases depending on patient age/indication/prior pathology presentation/acuity of illness)
  - Ex: palliative care cancer follow up
- Handling mapping of single phase protocol to multiphasic protocol
  - Ex: Post-endostent at UW is single phase depending on result, other sites commonly do this as a multiphasic exam. Do we map ours to a multiphasic endo stent, or to a single phase (non contrast angio RPID).
- My scan range doesn’t match any RPID scan range … what to do? …
  - At UW, we rarely do just a routine abdomen or a routine pelvis, we usually combine them. Differences in scan range can sometimes we flushed out by comparing CTDIvol and DLP together.

Outline

- Reference CT protocols
- Reference Materials for CT scanners/protocols
- CT dose calculation
- CT QA/QC and shielding
- CT dose check
- CT dose tracking
- CT acquisition parameter setting

CT Acquisition Parameter Setting

- Pediatric scanning www.imagegently.org
  - Dose lowering tables provided by Strauss et al

Abdomen/	Abdomen/	Abdomen/	kVp	mA	Time (sec)	Pitch During Measured CTDIvol	Pitch During Clinical Exam	Adult SSDE					
Pelvis:	Pelvis:	Pelvis:	120	200	1	1.0	1.0	23					
AP Thickness (cm)	LAT Thickness (cm)	Effective Diameter (cm)	Mass (kg)	Age	*Limited* mAs Reduction Factor	*Moderate* mAs Reduction Factor	*Aggressive* mAs Reduction Factor	*Limited* mAs SSDE (mGy)	*Moderate* mAs SSDE (mGy)	*Aggres-sive* mAs SSDE (mGy)	*Limited* NB = Adult SSDE Estimated mAs	*Moderate* NB = 0.75 * Adult SSDE Estimated mAs	*Aggressive* NB = 0.5 * Adult SSDE Estimated mAs
10	14	11.8	4	newborn	0.52	0.39	0.25	23	17	11	104	77	50
11	16	13.3	10	1 yr	0.55	0.42	0.29	23	18	12	110	84	59
14	20	16.7	18	5 yr	0.62	0.50	0.39	23	19	15	123	100	78
16	25	20.0	33	10 yr	0.70	0.62	0.53	23	20	18	140	123	106
19	29	23.5	54	15 yr	0.80	0.74	0.68	23	21	20	160	148	137
22	32	26.5	65	20 yr	0.89	0.86	0.83	23	22	22	179	172	165
25	35	29.6	75	md adult	1.00	1.00	1.00	23	23	23	200	200	200
31	41	35.7	110	lg adult	1.21	1.28	1.35	23	25	27	242	256	270

For different body regions, dose lowering tables allow a mapping from adult to ped protocol

These tables plus many good references can be found here http://www.imagegently.org/Procedures/Interventional-Radiology/Protocols

CT Acquisition Parameter Setting

- An issue with our field…not a lot of good places to figure out how to propagate protocols vendor to vendor and even within vendor

Slice thickness, noise, spatial resolution, Dose

Favazza, Christopher P., et al. "A cross-platform survey of CT image quality and dose from routine abdomen protocols and a method to systematically standardize image quality." *Physics in medicine and biology* 60.21 (2015): 8381.

Vendor to vendor and inter vendor AEC

- Keat, N. "Report 05016 CT scanner automatic exposure control systems. London, England: ImPACT, 2005." (2008): 651.
- Szczykutowicz, Timothy P., et al. "CT protocol management: simplifying the process by using a master protocol concept." *Journal of Applied Clinical Medical Physics* 16.4 (2015).
- McKenney, Sarah E., et al. "Methods for CT automatic exposure control protocol translation between scanner platforms." *Journal of the American College of Radiology* 11.3 (2014): 285-291.

CT Acquisition Parameter Setting

- How to change dose level, change kV, account for iterative denoising, etc.?

$$mA_{new\ master} = mA_{original} \frac{T_{original} P_{new\ master}}{T_{new\ master} P_{original}} \left(\frac{NI^*_{original}}{NI^*_{new\ master}} \right)^2 F_{kV} F_D$$

Rotation time

pitch

Noise level

How does changing the kV change the required mA?

How do denoising algorithms change the required mA?

This equation lets us easily create various dose protocols at different beam energy levels

Szczykutowicz, Timothy P., et al. "CT protocol management: simplifying the process by using a master protocol concept." *Journal of Applied Clinical Medical Physics* 16.4 (2015).

CT Acquisition Parameter Setting

- Reference AAPM protocols may not employ a scientific method to ensure equal dose and or image quality **across** vendor or scanner model. They are a collection of vendor provided and committee approved protocols.
  - This is not a bad thing, but needs to be stated. They can be used to map acquisition/recon parameters vendor to vendor model to model but this should be evaluated by your CT Protocol Optimization Team.
  - I am not saying no scientific approach went into making them for any specific scanner.
  - Don’t expect to use them as a Rosetta stone to ensure equal IQ across your fleet but they are the best place to begin such an effort in my opinion.

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Thanks for your attention!

When in need of something try starting your search at the AAPM CT Alliance for Quality website and/or the DXIMGMEDPHYS http://aapm.org/links/medphys/#lists list serv.

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