The New ACR CT Quality Control Manual: Role of the Medical Physicist

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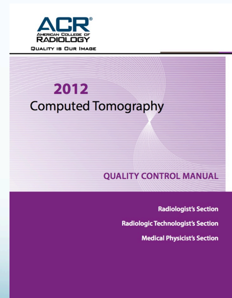
Finally!!

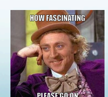


Learning Objectives

- Review the content of the new manual
- Understand the role of the medical physicist in the CT QC program
- Become familiar with errata (sorry, we're human...)

Similar To Other Programs

- "Effective one year from the publication of this manual (12/01/2012), all facilities applying for accreditation must maintain a documented QC program and must comply with the minimum frequencies of testing outlined in this manual."
- Some forms provided
- Most physics documentation is up to the physicist



Dissimilar To Other Programs

- Much is left up to the discretion of the Qualified Medical Physicist!
- NOT "trained monkeys"

Contents

- Follows the format of other manuals
  - Radiologist Section
  - Technologist Section
  - Physicist Section
- QA Committee is recommended
  - One or more radiologists
  - A qualified medical physicist
  - A supervisory CT technologist
  - Other radiology department personnel who care for patients undergoing CT, including a nurse, desk attendant, medical secretary, or others
  - Personnel outside the radiology department, which includes medical and paramedical staff, such as referring physicians

Scope

- Test procedures in this document are considered the minimum set of acceptable tests
- Additional tests may be required if the system is used routinely for advanced clinical CT procedures
- Description of advanced CT QC tests is beyond the scope of this manual. The qualified medical physicist is responsible for determining and setting up the methods and frequencies for these tests

Action Limits

- The qualified medical physicist should review action criteria annually
  - Ensure that they are adequately sensitive to detect CT equipment problems
  - May be tighter than what's in the manual
- Should be based on the performance of an individual scanner
- Should be reevaluated whenever there are hardware changes or major service activities

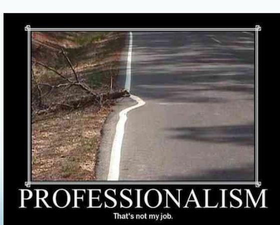
Radiologist Responsibilities

- Relative to the optimization of patient dose in CT:
  - Convene a team to design and review all new or modified CT protocol settings to ensure that both image quality and radiation dose are appropriate
  - Develop internal radiation dose thresholds
  - Implement steps to ensure patient safety and reduce future risk if an estimated dose value is above the applicable threshold for any routine clinical exam
  - Institute a review process, which occurs at least annually, for all protocols to ensure no unintended changes have been applied that may degrade image quality or unreasonably increase dose (similar to TJC SEA 47)
  - Establish a policy stating that the CT dose estimate interface option is not to be disabled and that the dose information is displayed during the exam prescription phase

Radiologist Responsibilities

- Should develop appropriate elements of good practice in CT QC
  - Provide technologists access to adequate training and continuing education in CT that includes a focus on patient safety
  - Provide an orientation program for technologists based on a carefully established procedures manual
  - Arrange staffing and scheduling so that adequate time is available to carry out the QC tests and record and interpret the results
  - Follow the facility procedures for corrective action when asked to interpret images of poor quality (all rads)

The staff's commitment to high quality will often mirror that of the radiologist-in-charge



Radiologist and RT

- With respect to the technologist, the radiologist has three important QC roles:
  - Reviews, with the technologist, image quality problems identified during interpretation of clinical images
  - Decides whether patient studies can continue or must be postponed pending corrective action when image quality or radiation dose issues arise
  - Participates in the initial assessment of image quality at implementation of the QC program and regularly monitors QC results in the intervals between the annual QC data reviews

MP and RT

- With respect to the technologist, the qualified medical physicist has three important QC functions:
  - Responsible for ensuring the correct implementation and execution of the technologist's QC procedures
  - Should help design the QC scan protocol technique to be used on each CT scanner
  - Resource to answer questions concerning image quality and patient dose to help identify and correct image quality problems or radiation dose issues

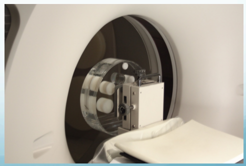
Technologist Section

Table 1. Technologist's QC Tests: Minimum Frequencies

PROCEDURE	MINIMUM FREQUENCY	APPROXIMATE TIME IN MINUTES
Water CT Number and Standard Deviation	Daily	5
Artifact Evaluation	Daily	5 (or less)
Wet Laser Printer Quality Control	Weekly (if film is used for primary interpretation)	10
Visual Checklist	Monthly	5
Dry Laser Printer Quality Control	Monthly (if film is used for primary interpretation)	10
Display Monitor Quality Control	Monthly	5

What Phantom?

- A water-filled, cylindrical phantom, which is typically provided by the scanner manufacturer at installation, should be used for the QC program
- The ACR CT phantom may be used as an alternative to the water phantom



Alternative Protocols

- It is acceptable to use proprietary scanner QC procedures in lieu of some tests
  - "Automatic QC procedures may be used in place of these tests if the QMP has critically reviewed them and approved this substitution (in writing)."
- If you use the manufacturer's test for water CT number and standard deviation, you must do a visual artifact evaluation.

Recommended QC

- Water CT number and standard deviation
- Artifact analysis
- Visual checklist
- (Printer QC)
- May be necessary to add tests for a specific scanner if indicated clinically

Personnel

- Best to identify a single individual
  - Greater consistency
  - Improved sensitivity to problems
- QC must be completed, regardless of individual
- Appropriate training must be provided

QC Notebook

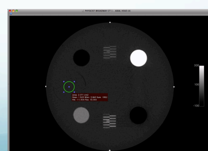
- QC policies and procedures
- Data forms for each test
- Area for comments and communications
- Service engineer should also utilize the notebook
- Data reviewed at least annually by physicist
- Supervising physician should also review

CT Number Accuracy & Noise

- Warm up scanner per manufacturer recommendations
- Perform air calibrations per manufacturer recommendations
- Position phantom
- If manufacturer's (MFG), use manufacturer's holder
- If ACR, place on table or use optional stand
- Use alignment lights

CT Number Accuracy & Noise

- Scan phantom
  - MFG: Use manufacturer protocol
  - ACR: Adult head technique
  - Recommend both helical and axial
  - Consider alternating modes each day
- Place ROI on image
  - 400 mm2
  - Same location each time
  - Same slice if multi-slice

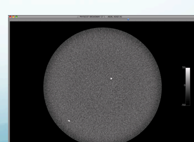


CT Number Accuracy & Noise

- Action limits
  - MFG
    - Use manufacturer limits
  - ACR
    - Water value: 0 ± 5 HU (± 7 max)
    - Noise: Limits must be established by the medical physicist based on the scan protocol used
  - Water
    - Water value: 0 ± 3 HU (± 5 max)
- Schedule service if either value exceeds action limits 3 days in a row or 3 times in one week

Artifact Analysis

- Position phantom
- Scan parameters (assume approx. 16 cm water)
  - Axial
    - 120 kV
    - 350 mAs
    - Maximum number of slices possible
    - Want to check every data channel
    - 320 slices?
  - Helical
    - 120 kV
    - 350 mAs
    - About 2.5 mm images

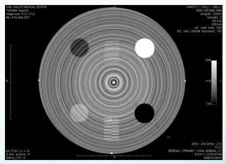


Artifact Analysis

- Visual analysis
- Window width ≈ 100
- Window level ≈ 0
- Rings, streaks, lines
- Record all findings
- Very effective to rapidly scan through the images, as the eye is sensitive to change

Artifact Analysis

- Corrective action
  - While still sub-clinical
  - Re-run air calibrations
    - Often cover just a sub-set of scan conditions
    - May need to run several times
  - If still present
    - Determine if scanner can be used
    - Radiologist, medical physicist
    - Limited use?
  - Schedule service



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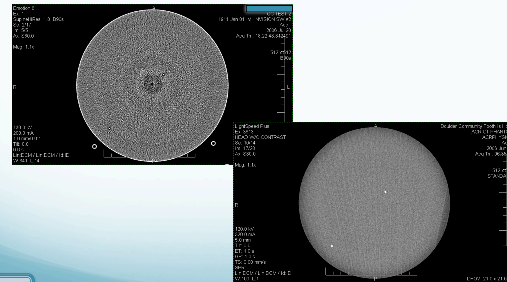
Artifacts



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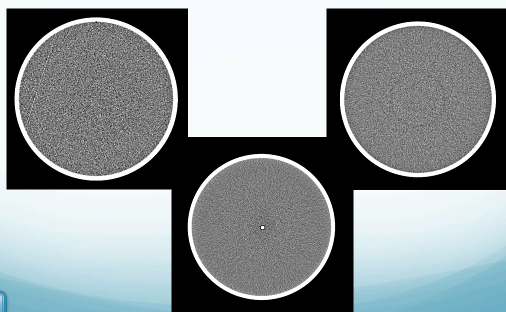
Artifacts



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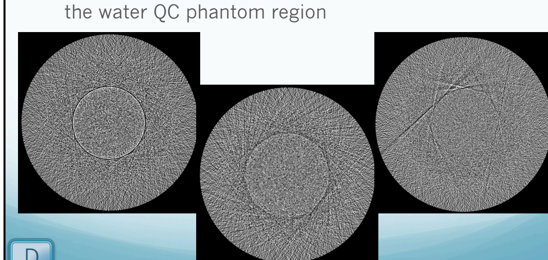
Artifacts

- It is recommended to use larger uniform phantom on a regular basis to identify artifacts outside of the water QC phantom region



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A. DATA FORM FOR DAILY CT EQUIPMENT QUALITY CONTROL

CT Facility Name:__________________

CT Scanner Identifier: ____________________

Date		Water HU	Limit	Water SD	Limit	Axial Artifacts	Notes
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	
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	Axial		Y/N		Y/N	Y/N	
	Helical		Y/N		Y/N	Y/N	

Reviewed by: ____________________ ____________________

Qualified Medical Physicist Date of Review

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Laser Printer QC

- Very few wet lasers left in the field
- Dry lasers generally have self-calibration feature
- Is QC necessary?

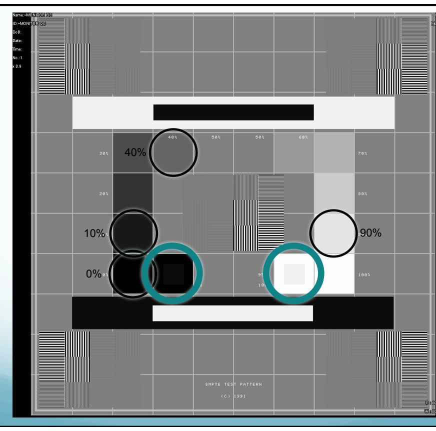
YES!

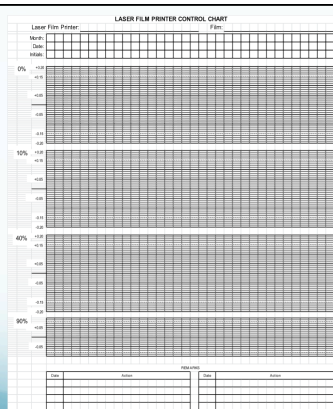
Laser Printer QC

- Case study
  - Kodak 8700 laser printer
  - Self-calibration performed on schedule
  - QC not performed
  - Got complaints regarding image quality
  - Sensitometric curve significantly different from same model
  - Internal densitometer had drifted and needed replacement
- Require monthly QC if used for primary interpretation

Laser Printer QC

- Visual analysis
  - 5%, 95% patches visible
- Quantitative analysis
  - Measure 0%, 10%, 40%, 90% squares
- Plot values
  - Action limits of ± 0.15 from operating level





Acquisition Display Monitors

- Applies ONLY to the acquisition station (the scanner)
  - Interpretation workstations will – hopefully – be covered by a separate manual
- Display SMPTE or equivalent pattern
- Examine the pattern to confirm that the gray level display on the imaging console is subjectively correct
  - The 5% patch can be distinguished in the 0/5% patch
  - The 95% patch can be distinguished in the 95/100% patch
  - All the gray level steps around the ring of gray levels are distinct from adjacent steps
  - Do not adjust the display window width/level in an effort to correct the problem

Visual Checklist

- Table height indicator functioning
- Table position indicator functioning
- Angulation indicator functioning
- Laser localization light functioning
- High-voltage cable/other cables safely attached (and not frayed)
- Acceptable smoothness of table motion
- X-ray on indicator functioning
- Exposure switch functioning
- Display window width/level
- Panel switches/lights/meters working
- Door interlocks functioning
- Warning labels present
- Intercom system functioning
- Postings present
- Service records present

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CT QUALITY CONTROL VISUAL CHECKLIST

Facility: ____________ Room # ____________ Unit: ____________

GANTRY	Table height indicator													
	Table position indicator													
	Angulation indicator													
	Laser localization light													
	High voltage cable/other cables													
	Smoothness of table motion													
	X-ray on indicator													
CONTROL CONSOLE	Exposure switch													
	Display Window Width/Level													
	Panel switches/lights/meters													
	X-ray on indicator													
	Door interlocks													
	Warning labels													
	Intercom system													
OTHER	Postings													
	Service records													
	____________													
	____________													
	____________													
	____________													
PASS =	P Month:													
FAIL =	F Date:													
DOES NOT APPLY =	NA Initials:													

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Follow-Up

- Quality control must be active, not passive
- Data must be analyzed immediately
- All results must be logged or plotted
- Corrective action must be taken promptly

Medical Physicist Oversight

- The QMP must review the QC data at least annually (quarterly preferred, if possible)
  - Be visible
  - Be accessible
- Data should be presented to the service engineer
- Radiologists must be involved
  - Reporting artifacts

Medical Physicist Section

A*

So Many Phantoms, So Little Time

- Manufacturer
  - Designed specifically for unit
  - Automated testing
  - May not allow all “physics” measurements
- ACR CT Accreditation
  - Good general, all purpose phantom
  - Direct comparison to ACR standards
- Phantom Lab
  - “Gold standard”
  - Many advanced measurement capabilities

Alternative Approaches

- Manufacturers may provide phantoms and software to automate performance of many of the tests
- Use of such programs is acceptable during the annual performance evaluations
- At acceptance of the scanner, tests listed below should be performed independently of the software
- If it is to be used for the annual performance evaluation, the software must also be run at acceptance testing so that the results and conclusions can be verified.
- If the automated software was not tested by the QMP at acceptance testing, then it must be tested during the next annual QMP survey.

Control Limits

- Suggested acceptable limit criteria provided for some tests
- Guidelines in case no other acceptable limit criteria exist
- QMP may elect to use manufacturer-provided testing conditions and criteria

Tests & Evaluations

- Review of Clinical Protocols
- Scout Prescription and Alignment Light Accuracy
- Image Thickness – Axial Mode
- Table Travel Accuracy
- Radiation Beam Width
- Low-Contrast Performance
- Spatial Resolution
- CT Number Accuracy
- Artifact Evaluation
- CT Number Uniformity
- Dosimetry
- Gray Level Performance of CT Acquisition Display Monitors

Protocol Review

- Review at least 6 clinical protocols, including:
  - Pediatric head (1 year old)
  - Pediatric abdomen (5 years old; 40-50 lb or approx. 20 kg)
  - Adult head
  - Adult abdomen (70 kg)
  - High-Resolution chest
  - Brain perfusion (if performed at the facility)
- Pay special attention to
  - kV
  - mA (or mAs or effective mAs)
  - Rotation time
  - Pitch
  - Detector configuration (beam collimation)
  - Reconstructed image thickness and interval
  - Reconstruction algorithm or kernels
  - Dose reduction methods

Protocol Review

- Firm rules for clinical imaging are difficult to establish. The ACR has set several practice standards:
  - Reconstructed scan width for standard Adult Head and standard Adult Abdomen should ≤5 mm.
  - Pitch for Pediatric Abdomen should not be less than 1.
    - Sometimes a pitch slightly lower than 1 is more does efficient.

Protocol Review

- Several other rules of thumb should be kept in mind:
  - On a multi-slice scanner, the largest number of images for the chosen reconstructed scan width should be used, as this improves dose efficiency. For example, 5 mm x 4 slices is up to 30% more dose efficient than 5 mm x 2 slices in axial mode with no image quality penalty.
    - The facility may wish to be able to reconstruct to thinner in addition to the standard scan. N×T should allow for this.
- Lower kV settings should be used for pediatric scans and scans in which contrast media is used.

Protocol Review

- High Resolution Chest (HRC) protocol should incorporate a very sharp reconstruction algorithm (GE recommends the BONE algorithm).
- HRC are typically thin slices separated by 10-20 mm. If HRC images are extracted from a helical chest scan, it must be verified that the chest scan is used appropriately for diagnosis.

Protocol Review

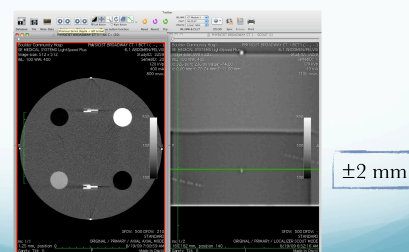
- Doses should be as low as diagnostically appropriate (ALADA). For the Adult Head protocols and the Adult and Pediatric Abdomen protocols, the CTDIvol must not exceed ACR Pass/Fail levels and should not exceed ACR reference levels.
- The ACR standards must be met when available.
- Protocols should be designed to optimize dose and image quality

Scout Prescription Accuracy

- Required Test Equipment
  - Phantom incorporating radiopaque fiducial markers or an image center indication (ACR CTAP Phantom Module 1)
- Test Procedure Steps
  - Scan the entire phantom in scout mode.
  - Magnify the image, if possible, and position a single cut at the location of the radiopaque fiducial markers.
  - Perform an axial scan using a reconstructed scan width less than 2 mm, or as thin as the scanner can produce in axial mode.

Scout Prescription Accuracy

- Data Evaluation



Alignment Light Accuracy

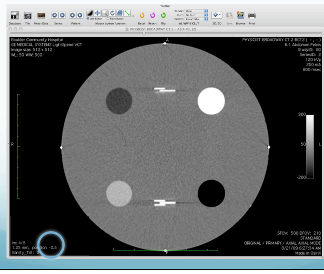
- Most important when biopsies are performed
- Required Test Equipment
  - Phantom incorporating externally visible radiopaque fiducial markers or an image center indication (ACR CTAP Phantom Module 1)

Alignment Light Accuracy

- Test Procedure Steps
  - Using the alignment lights, carefully position the phantom to the radiopaque markers in all three orthogonal planes.
  - Zero the table location indication.
  - Scan the phantom in axial mode, using a reconstructed scan width less than 2 mm at the zero position. Use technique to allow accurate visualization of the fiducial markers; for most phantoms, the Adult Abdomen technique works well.
  - Useful to scan also at ±0.5, ±1.0

Alignment Light Accuracy

- Data Evaluation



±1 mm if biopsies
±2 mm otherwise

Image Thickness

- Detected / Reconstructed image thickness
  - Rarely an issue
- Required Test Equipment
  - Phantom with internal targets allowing determination of reconstructed image thickness (Module 1 of the ACR CTAP Accreditation Phantom)

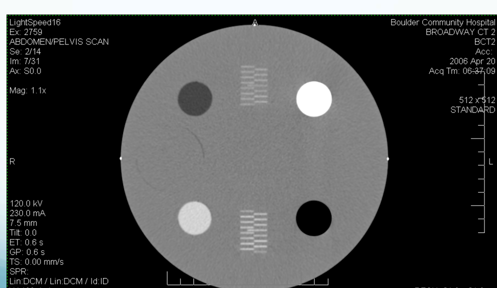
Image Thickness

- Test Procedure Steps
  - Align the phantom to the reconstructed image thickness determination targets in the phantom.
  - Using zero table increment and techniques adequate to allow unambiguous visualization of the targets (for most phantoms, 120 kV, 200 mAs is adequate), scan the phantom in axial mode using each reconstructed image thickness used clinically
  - Use as many different data channel (detector) configurations as possible.

Image Thickness

- Data Interpretation and Analysis
  - View the axial images collected above
  - Determine the reconstructed image thickness of each nominal thickness tested
  - For the ACR CTAP Phantom, each line represents ½ mm thickness
    - Count each line that is at least 50% of the brightness of the brightest line

Reconstructed Scan Width



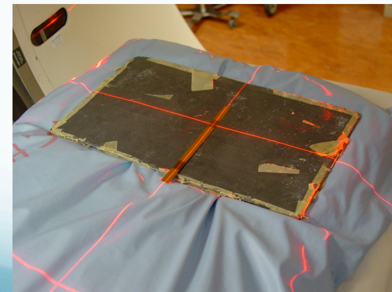
Radiation Beam Width

- Width of collimated beam
  - Often an issue
- "Required" Test Equipment
  - External radiation detector (CR plate, self-developing film)
  - Flat radiation attenuator (1/16" lead)[recommended]; OR
  - Electronic test tool (vendors working on this)

Radiation Beam Width

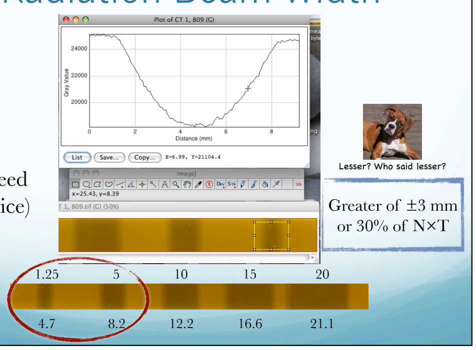
- Test Procedure Steps
  - Place the radiation attenuator on the table, unless contra-indicated by the test device being used.
  - Place the external radiation detector on the flat attenuator.
  - Adjust the table height so that the external radiation detector is at the isocenter.
  - Scan using each unique N×T product available, adjusting table position as appropriate for the beam width being used.

Radiation Beam Width



Radiation Beam Width

GE LightSpeed Plus (4 slice)



Radiation Beam Width

- Data Interpretation and Analysis
  - Using a method appropriate for the external radiation detector used, determine the actual radiation beam width for each unique N×T product. For film and CR-based measurements, determination should be made at the full width at half maximum (FWHM).

Radiation Beam Width

- Precautions and Caveats
  - Many manufacturers have standards that are in excess of the criteria stated below.
    - It has been the experience of the ACR CTAP Physics Subcommittee that most scanners can be calibrated to meet these tighter standards.
  - The above notwithstanding, scanners may exhibit over-beaming that can impact these tolerances.

Radiation Beam Width

- Scanner-specific caveats
  - Toshiba
    - Thin beams (4 x 0.5) may be 2x wider than nominal. 1 x 1 mm is ok on Aquilion 64.
  - GE
    - 5 mm beam width often measures ~8.3 mm
    - 1.25 mm beam width often ~4-5 mm, but often is corrected when air cal selects it.

Table Travel Accuracy

- Required Test Equipment
  - Phantom with two sets of external fiducial markers of known separation (ACR CTAP Phantom Modules 1 and 4)
  - If possible, additional weight on the table to simulate the weight of a typical patient.

Table Travel Accuracy

- Test Procedure Steps
  - Using the alignment light, carefully position the phantom to the first set fiducial markers in the axial plane
  - Zero the table position indication
  - Move the table to the second set of external fiducial markers
  - Record the table position
  - Translate the table to full extension and return to the first set of fiducial markers
  - Record the table position

Table Travel Accuracy

- Data Interpretation and Analysis
  - Using the number recorded in Step 4, Compare the distance between the fiducial markers as determined by the table travel to the known distance.
  - Compare the number recorded above to the zero position.
- Precautions and Caveats
  - Some scanners have specific limitations on the extent of table travel under which the performance specifications are valid. Scanner-specific limitations must be noted.

Low Contrast Detection

- Required Test Equipment
  - Phantom incorporating low contrast targets of known contrast (Module 2 of the ACR CTAP phantom)

Low Contrast Detection

- Test Procedure Steps
  - Align the phantom
  - Perform clinical scans covering the low contrast section
  - Any Auto mA feature must be disabled
  - Use an mAs value appropriate for an average sized patient
- The scans performed should include at least
  - Adult Head (average)
  - Adult Abdomen (average)
  - Pediatric Head (1 year old)
  - Pediatric Abdomen (50 lb, 20 kg; 5 y.o.)

Low Contrast Detection

- Data Interpretation and Analysis
  - Visual Analysis
    - View each series and determine the slice providing the visually best low contrast performance
    - Adjust the window width and window level to optimize visibility of the low contrast targets. On the ACR CTAP phantom, this is about WW=100, WL=100
    - Record the size and contrast of the smallest visualized target

Low Contrast Detection

- Data Interpretation and Analysis
  - Numeric Analysis
    - Select the slice most central to the module containing the low contrast targets.
    - Place a Region of Interest (ROI) over the largest representative target and record the mean HU value.
    - Place an ROI adjacent to the target and record both the mean HU and the HU standard deviation.
    - Calculate the Contrast-Noise Ratio as

CNR = target mean HU - background mean HU

Low Contrast Detection

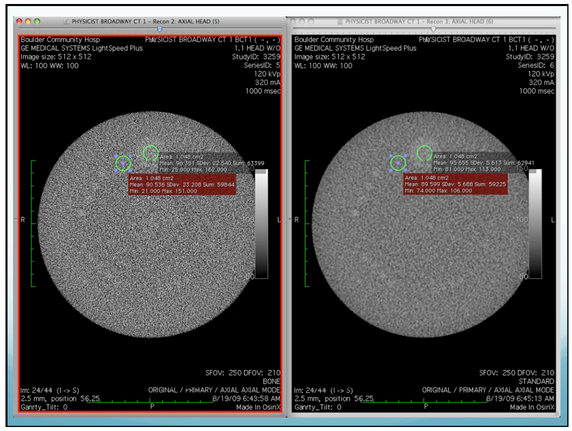
- Noise limited
- Specific realization of the noise may hide a target
- For ACR
  - OK to select any slice in Module 2 for low contrast performance evaluation
  - If all 4 lower rods visible, count larger
  - Use best slice

CNR Measurements

- Extremely sensitive to reconstruction algorithm
- The specific algorithm used must be recorded for each clinical protocol
- Auto mA features must be disabled
  - Failure to do this leads to a low mA value
  - Poorer performance than should be
- Note that iterative reconstruction might make CNR undefined!

The Use of a Simple Contrast to Noise Ratio (CNR) Metric to Predict Low Contrast Resolution Performance in CT

Med. Phys. Volume 36, Issue 6, pp. 2451-2451 (June 2009)



Low Contrast Detection

- Assuming typical reconstruction algorithms, CNR should meet the following criteria:

Protocol	Minimum CNR
Adult Head	1.0
Adult Abdomen	1.0
Pediatric Head	1.0
Pediatric Abdomen	0.5

Note that these values are under review based on experience of the CTAP

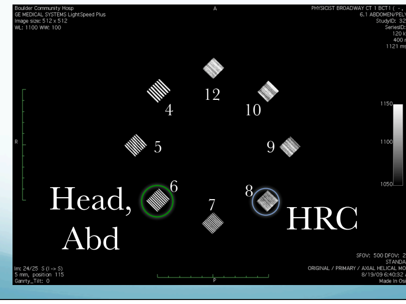
High Contrast Resolution

- Line pair pattern
- MTF
  - Point response
  - Via line pair standard deviation per Droege and Morin. A practical method to measure the MTF of CT scanners. Med. Phys. (1982) vol. 9 (5) pp. 758-60
- Required Test Equipment
  - Phantom incorporating high contrast targets of known resolution (Module 4 of the ACR CTAP phantom)

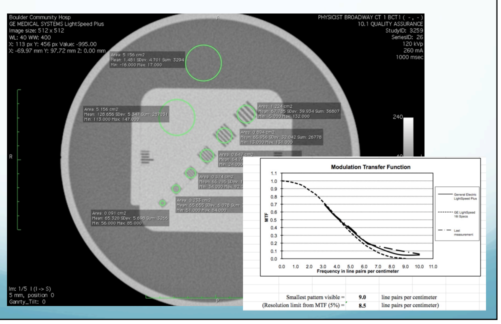
High Contrast Resolution

- Test Procedure Steps
  - Align the phantom
  - Perform clinical scans
    - Auto mA feature must be disabled
    - Use an mAs for average sized patient
    - The scans performed should include scans appropriate to the facilities clinical scanning. These may include
      - Adult Head (average)
      - Adult Abdomen (average)
      - Pediatric Head (1 y.o.)
      - Pediatric Abdomen (50 lb, 20 kg; 5 y.o.)
      - High Resolution Chest

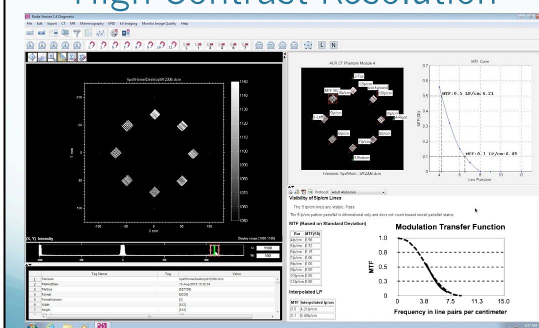
High Contrast Resolution



High Contrast Resolution



High Contrast Resolution



CT Number Accuracy

- Why is this important?
  - Diagnosis
  - Treatment planning
- Required Test Equipment
  - Phantom incorporating targets providing at least three different, known CT number values including water (or water equivalent material) and air. (ACR CTAP Phantom Module 1)

CT Number Accuracy

- Test Procedure Steps
  - Align the phantom
  - Perform clinical scans covering the CT number accuracy section
    - Disable any Auto mA features
    - Use an mAs value appropriate for an average sized patient

CT Number Accuracy

- The scans performed should include at least
  - Adult Head (average)
  - Adult Abdomen (average)
  - Pediatric Head (1 y.o.)
  - Pediatric Abdomen (50 lb, 20 kg; 5 y.o.)
- Perform scans of the CT number accuracy section of the phantom with each kV setting available on the scanner (Adult abd technique works usually)

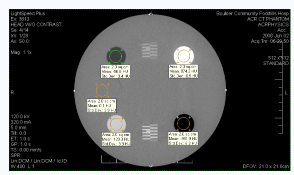
CT Number Accuracy

- Data Interpretation and Analysis
  - Select the image most central to the module containing the CT number accuracy targets
  - Adjust the window width and window level to optimize visibility of the targets
    - On the ACR CTAP phantom, this is about WW=400, WL=0
  - In the image from the 120 kV scan, place a circular ROI, approximately 80% of the size of the target, in each target
  - Record the measured CT number mean for each target
  - For the images from each kV scan, place the ROI in the water target only
  - Record the measured water CT number mean in each image

CT Number Accuracy

- All available kV stations must be calibrated and tested
- The CT number accuracy targets in most phantoms are calibrated only for 120 (or 130) kV
- CT numbers other than water will vary with kV
  - May be useful information for scanners used for RT
- For ACR Phantom, use 200 mm2 ROI

CT Number Accuracy



Material	CT # Range
Water	-5 to +5 HU
Air	-970 to -1005 HU
Teflon (bone)	850 to 970 HU
Polyethylene	-107 to -84 HU
Acrylic	110 to 135 HU

CT Number Uniformity

- Required Test Equipment
  - Phantom incorporating a uniform region, preferably water or water-equivalent

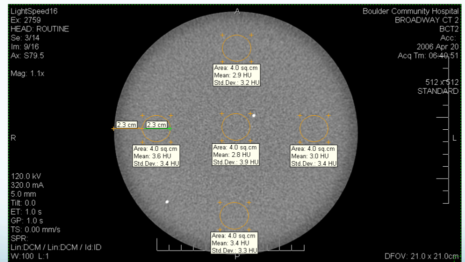
CT Number Uniformity

- Test Procedure Steps
  - Align the phantom
  - Perform clinical scans covering the CT number uniformity section
    - Disable any Auto mA features
    - Use an mAs value appropriate for an average sized patient
  - The scans performed should include at least
    - Adult Head (average)
    - Adult Abdomen (average)
    - Pediatric Head (1 y.o.)
    - Pediatric Abdomen (50 lb, 20 kg; 5 y.o.)
  - Perform scans of the CT number uniformity section of the phantom with each kV setting available on the scanner (Adult abd tech works usually)

CT Number Uniformity

- Data Interpretation and Analysis
  - Select the image most central to the CT number uniformity module.
  - In each image, place a circular ROI, approximately 400 mm2 (ACR phantom), at the center of the phantom.
  - Place similar ROIs at 12:00, 3:00, 6:00 and 9:00, one ROI diameter in from the periphery.
  - Record the measured CT number mean and standard deviation.

CT Number Uniformity



$$|ROI_{center} - ROI_n| \le 5$$

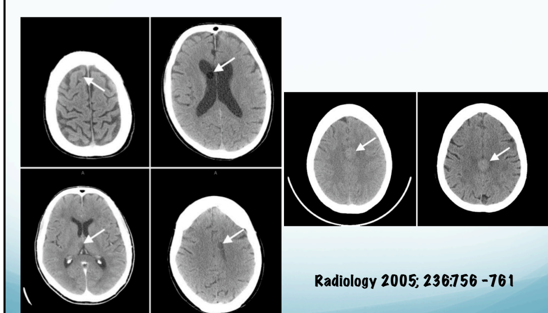
Artifact Evaluation

- Required Test Equipment
  - Phantom incorporating uniform section of adequate length for all data channels to be simultaneously used. (ACR CTAP Phantom Module 3)
  - Optional larger uniform phantom

Artifact Evaluation

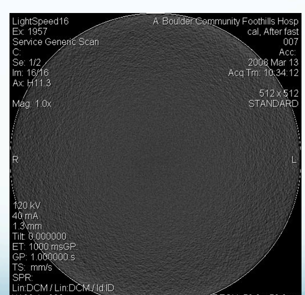
- Test Procedure Steps
  - Align the phantom
  - Perform scan covering the uniformity section
    - Disable any auto mA features
    - Use an mAs value appropriate for an average-sized patient
    - The protocol defined for the RT Artifact Analysis Test may be used
    - It is recommended to use larger uniform phantom on a weekly or monthly basis to identify artifacts outside of the water QC phantom region
    - [Personal experience indicates that also scanning with all kV stations may be appropriate]

Artifact Evaluation



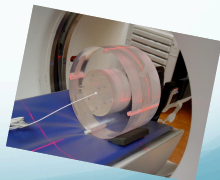
Radiology 2005; 236:756 -761

Artifact Evaluation



Dosimetry

- Not just for patient dose estimates
- Generator calibration
- Tube condition
- Dose characterization



Dosimetry

- CTDIvol for at least four clinical protocols
- Compare to reference levels — Less than ref. level
- Verify scanner CTDIvol — ±20%
- For large values of N×T, approaching or greater than the length of the ionization chamber, significant portions of the scatter tails may not be measured. Therefore, it may be necessary to mathematically correct for them to more closely estimate actual CTDIvol.

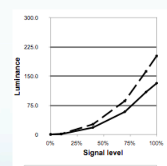
Geleijns et al. Computed tomography dose assessment for a 160-mm wide, 320 detector row, cone beam CT scanner. *Physics in Medicine and Biology.* 2009;54(10):3141-59.

CT Scanner Display Calibration

- Required Test Equipment
  - SMPTE Test Pattern (see Figure 1 in Radiologic Technologist's Section, Section II K) or equivalent
  - Calibrated photometer with adequate precision, accuracy, and calibration to effectively measure to 0.1 cd/m2 significance

CT Scanner Display Calibration

- Test Procedure Steps (continued)
  - Use the photometer to measure the maximum and minimum monitor brightness (0% and 100% steps)
  - Measure additional steps within the pattern to establish a response curve (10%, 40%, 70%, 90%)
  - Measure the brightness near the center of the monitor and near all four corners (or all four sides, depending on the test pattern used)

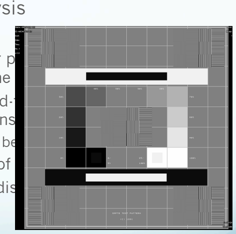


CT Scanner Display Calibration

- Data Interpretation and Analysis
  - Visual Analysis
    - Examine the pattern to confirm that the gray level display on the imaging console is subjectively correct
    - The 5% patch can be distinguished in the 0/5% patch
    - The 95% patch can be distinguished in the 95/100% patch
    - All the gray level steps around the ring of gray levels are distinct from adjacent steps
    - Do not adjust the display window width/level in an effort to correct the problem
  - Ensure that the finest line pair pattern can be visualized in the center and at each of the four corners

CT Scanner Display Calibration

- Data Interpretation and Analysis
  - Visual Analysis (continued)
    - Ensure that the finest line pair p in the center and at each of the
    - There must not be visible bleed- direction of all black-white trans
      - All high-contrast borders must be
    - There must not be scalloping of
    - There must not be geometric dis



CT Scanner Display Calibration

- Data Interpretation and Analysis
  - Photometric Analysis (same as MR QC Manual)
    - The minimum brightness must be ≤1.2 cd/m2
    - The maximum brightness must be ≥90 cd/m2
    - The measured response curve should be compared visually to the prior year's result, verifying no significant change to the curve
    - Calculate the nonuniformity of the display brightness using the equation
      - CRT: Nonuniformity ≤ 30%
      - LCD: Nonuniformity ≤ 15%

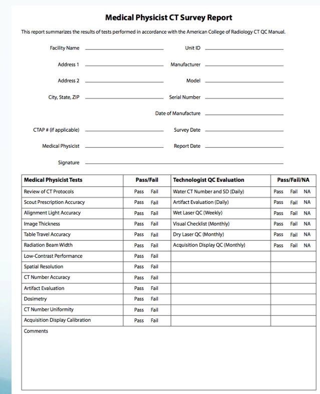
$$\% \text{ difference} = 200 \times (L_{max} - L_{min}) / (L_{max} + L_{min})$$

CT Scanner Display Calibration

- Corrective Action
  - Most often the problem is caused by incorrect adjustment of the monitor's brightness and contrast
    - Excessive ambient lighting can aggravate this problem
  - Perform the manufacturer's recommended procedure for monitor contrast and brightness adjustment
  - LCD brightness fades over time
    - Eventually, monitors need to be replaced

Reporting

- Must use ACR summary form
- Report contents are at the discretion of the physicist
  - Include relevant data
  - Include comments
  - May include more than is required by this manual



Medical Physicist CT Survey Report

This report summarizes the results of tests performed in accordance with the American College of Radiology CT QC Manual.

Facility Name ____________ Unit ID ____________

Address 1 ____________ Manufacturer ____________

Address 2 ____________ Model ____________

City, State, ZIP ____________ Serial Number ____________

Date of Manufacture ____________

CTAP # (if applicable) ____________ Survey Date ____________

Medical Physicist ____________ Report Date ____________

Signature ____________

Medical Physicist Tests	Pass/Fail	Technologist QC Evaluation	Pass/Fail/NA
Review of CT Protocols	Pass Fail	Water CT Number and SD (Daily)	Pass Fail NA
Scout Prescription Accuracy	Pass Fail	Artifact Evaluation (Daily)	Pass Fail NA
Alignment Light Accuracy	Pass Fail	Wet Laser QC (Weekly)	Pass Fail NA
Image Thickness	Pass Fail	Visual Checklist (Monthly)	Pass Fail NA
Table Travel Accuracy	Pass Fail	Dry Laser QC (Monthly)	Pass Fail NA
Radiation Beam Width	Pass Fail	Acquisition Display QC (Monthly)	Pass Fail NA
Low-Contrast Performance	Pass Fail		
Spatial Resolution	Pass Fail		
CT Number Accuracy	Pass Fail		
Artifact Evaluation	Pass Fail		
Dosimetry	Pass Fail		
CT Number Uniformity	Pass Fail		
Acquisition Display Calibration	Pass Fail		

Comments

Annual Test Requirements

- Test SHOULD be dated within year of previous report
- Test MUST be dated within 14 months of previous report

Summary

- The new ACR CT QC Manual has been described
- Tests presented capture failure modes or areas in which the scanner should be characterized
- Not intended to be comprehensive
  - Acceptance testing
  - Problem scanner
  - Troubleshooting
- State and local regulations must be followed

The ACR CT QC Manual was officially published on 12/1/2012. It must be implemented by facilities by

20%	1.	12/2/2012
20%	2.	1/1/2013
20%	3.	6/1/2013
20%	4.	12/1/2013
20%	5.	12/1/2014

10

The ACR CT QC Manual was officially published on 12/1/2012. It must be implemented by facilities by

- 12/2/2012
- 1/1/2013
- 6/1/2013
- **12/1/2013**
- 12/1/2014

ACR 2012 Computed Tomography Quality Control Manual, p. 4

The QC technologist must perform artifact analysis at least

20%	1.	Daily
20%	2.	Weekly
20%	3.	Monthly
20%	4.	Quarterly
20%	5.	Semi-annually

10

The QC technologist must perform artifact analysis at least

- **Daily**
- Weekly
- Monthly
- Quarterly
- Semi-annually

ACR 2012 Computed Tomography Quality Control Manual, p. 26

The maximum brightness of the scanner display monitor must be at least

20%	1.	70 cd/m^2
20%	2.	90 cd/m^2
20%	3.	125 cd/m^2
20%	4.	250 cd/m^2
20%	5.	600 cd/m^2

10

The maximum brightness of the scanner display monitor must be at least

- 70 cd/m2
- **90 cd/m2**
- 110 cd/m2
- 150 cd/m2
- 500 cd/m2

ACR 2012 Computed Tomography Quality Control Manual, p. 78

Ring artifacts are typically caused by

20%	1. Tube arcing
20%	2. Detector miscalibration
20%	3. Contrast media on the mylar window
20%	4. Bowtie filter not matched to phantom
20%	5. Reconstruction algorithm error

10

Ring artifacts are typically caused by

- Tube arcing
- **Detector calibration**
- Contrast media on the mylar window
- Bowtie filter not matched to phantom
- Reconstruction algorithm error

ACR 2012 Computed Tomography Quality Control Manual, p. 71

Radiation beam width should be measured

20%	1. For all unique values of N x T
20%	2. For all permutations of N x T
20%	3. Only for the maximum beam width
20%	4. Only for the minimum beam width
20%	5. Only for the one closest to 5 mm

10

Radiation beam width should be measured

- **For all unique values of N x T**
- For all permutations of N x T
- Only for the maximum beam width
- Only for the minimum beam width
- Only for the one closest to 5 mm