Practical Procedures for Achieving and Maintaining ACR CT Accreditation

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Outline

- Requirements for physics testing
- Practical aspects of ACR testing CT systems
- Performance of pre-application testing and annual surveillance testing
- Establishment of routine quality assurance protocols and record keeping

Image Requirements

Physics Testing
- SMPTE
- Phantom Alignment
- CT Number Calibration and slice thickness
- Low contrast resolution
- Uniformity
- High contrast resolution
- CTDI Images of head, body, pediatric phantom

Clinical Testing
- Specific images from representative studies done using protocols at the testing location
- Images from studies performed with the system being tested
- Specific instruction for head/neck, chest, abdomen for adult and pediatric examinations

Film Output for Submission Of Phantom Images

If the facility has a film printer, the submitted physics images must be on film in 3 x 4 format, up to 21 images.

Facilities with no film printers can submit physics images on CD (call ACR)

Video Test Pattern for First Box of Film Sheet

SMPTE test pattern or similar required in first box of each of two submitted sheets

No aliasing of bar patterns or other artifacts
95% square must be visible (white)
5% square must be visible (black)
Equipment Requirements

- Standard phantom
- Calibrated meter and CT probes
- CTDI phantom sets
- Miscellaneous equipment

100 mm ionization chambers

Equipment Requirements

- Inclinometer
- ACR CT Accreditation Phantom
- Level and Lead Ruler

Phantom Scanning Form

- Read the Instructions
- Be sure you understand what the site uses for standard acquisitions
- Be sure you know what patient types are done
- Be sure you understand the characteristics of the system and how used for each study
  - Detector configuration
  - Number of data channels (N) used
  - Maximum number of data channels (Nmax)
  - Z-axis collimation (T)
  - Table increment (I) – axial or for each tube rotation in helical
- Fill out Table 1 of the ACR Phantom Scanning Forms
- FOV appropriate for the size of the ACR phantom is permitted. Not so with the dose phantoms: must use FOV for the protocol being tested

ACR Phantom

- Four sections or modules
  - Module 1: Alignment, CT #, and slice width
  - Module 2: Low contrast resolution
  - Module 3: Uniformity and noise, distance accuracy, and slice sensitivity profile (SSP)
  - Module 4: High contrast resolution
- 20 cm diameter, 4 cm spacing between modules, total length 16 cm
- Alignment beads located in center of module 1 and 4 (1 mm steel)
- Markings at center of each section plus marking for head, foot, top
- Phantom holder to aid in positioning

ACR Table 1 For a 16 Slice System Used for Adults

<table>
<thead>
<tr>
<th>Detector Configuration</th>
<th>Detector Channels</th>
<th>Detector Channels</th>
<th>Detector Channels</th>
<th>Detector Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 1.5</td>
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</tbody>
</table>

24 mm asymmetrical detector
(4 x 1.5 x 1.5 x 0.75, 4 x 1.5)
Allows various combinations
32 detectors, 16 data channels

Pitch = Table speed / T

1. Must be filled out correctly
2. Will use this to do scans
3. Will do either axial or helical scans depending on your protocols
4. Important to use axial scans for module 1
5. Modules 2-4 done either axial or helical according to your protocol
6. Dose phantoms must be done axial
Nylon standoffs can cause artifacts; Position carefully

**Module 1: Alignment, Slice Thickness, HU Values**

- **Phantom alignment**
  - This must be correct
  - Beads (1 mm) must be seen uniformly or phantom will fail
  - Longer bar must be located in center of slice measurement section on 2 mm slice. This is more sensitive to alignment than beads
- **Water value must be less than or equal to +/- 7 HU (+/- 5)**
  - Using abdominal protocol and ROI of ~200 mm²
  - Water value must be less than or equal to /- 7 HU (+/- 5)
  - Using abdominal protocol and ROI of ~200 mm²
  - Images required for water values at all kVps system uses
  - Polyethylene (-107 to -87 HU), acrylic (110 to 130 HU), bone (850 to 970 HU), air (-1005 to 970 HU)
  - Slice thickness determined to nearest 0.5 mm by counting visible bars over approximate 3.5 and 7 mm slice thicknesses. Use next larger value system will do

**Notes on Phantom Alignment**

- Centering of slices depends on how system specifies start
  - Our 16 slice system specifies at center of array
  - Our 64 slice system specifies at beginning of array
- External lasers can be out of alignment a significant amount (one of ours ~1 cm)
- Inner laser usually properly aligned
- For axials from a helical protocol, be sure that the image of interest will fall in the center of the array to avoid cone beam artifacts (40 mm arrays and wider)

**Positioning of ACR Phantom**

- Alignment without cradle is often very difficult
  - Window width = 1000, Window level = 0
  - High resolution chest protocol
Module 1 Alignment Problem

Alignment incorrect:
1. BBs not shown at all four locations
2. Long bar on slice thickness ramp not properly visible on top of image

Adult abdomen protocol

Module 2: Low Contrast Detestability

- Low contrast performance
  - Large rod 25 mm
  - 100 mm² ROI over 25 mm rod and next to it
  - Series of rods of 6 mm, 5 mm, 4 mm, 3 mm and 2 mm
  - For adult head and adult abdomen protocols, must see clearly all 4 rods 6 mm diameter at window width of 100 and window level of 100
- This section interacts with dose measurements
  - Must be able to see rods
  - Must keep dose below ACR recommendations
  - Must keep dose as low as possible
  - Measurements made without system dose reduction turned on
- For systems with established protocols, may be more efficient during testing to use specified protocol that is known to be below the ACR dose requirements to make sure the rods are visible.

Pediatric Abdomen Protocol

Low Contrast Section of ACR Phantom

How you view the image can make a difference:
Viewing distance, size on monitor, room lighting

Module 3: Uniformity

- Uniform section of water-equivalent material
- Two small bbs spaced at 100 mm
  - Distance measurements
  - SSP
- Use for uniformity testing
  - Edge and section HU differences of > 5 HU
  - ROIs must be placed properly and be of proper size for this
  - Center number using adult abdomen protocol must be -7 to 7 HU or better (+/- 5 HU better)
  - Image must not show artifacts with WW = 100 and WL = 0.
- Adult abdomen protocol

Module 3 Uniformity and Noise Measurements

Each ROI about 400 mm²
WW " 100, WL = 0
Edge to edge variation no more than 5 HU
Center should be 0 +/- 5 HU
Module 4: High Contrast Resolution

- Use with two protocols
  - Adult abdomen
  - High resolution chest
- For abdomen, must see 5 lp/cm bars
- For HRC, must see 6 lp/cm bars
- Window width = 100, window level ~ 1100; there is some flexibility with setting the level
- Note that the four beads must be visible for proper alignment

High resolution Chest Protocol, Module 4

- Highest resolution for system
  - 7-8 lp/cm visible here
  - 2 mm slice thickness
  - Alignment correct
- ACR requires 5 lp/cm for adult abdomen, 6 lp/cm for adult HRC
- Acquired as axial or helical, depending on your site protocol

ACR Phantom Notes

- Machine should be calibrated before you get there; doesn’t always happen
- If you get low contrast, wide, ring artifacts, an air cal may help
- If there are calibration or artifact issues, check for contrast or other material on x-ray transparent window of system

ACR CT Dose Requirements

- Adult head CTDIvol
  - Pass/fail – 80 mGy
  - Reference level – 75 mGy
- Adult abdomen CTDIvol
  - Pass/fail – 30 mGy
  - Reference level – 25 mGy
- Pediatric abdomen CTDIvol
  - Pass/fail – 25 mGy
  - Reference level – 20 mGy
Dose Measurements (CTDI)

- All require axial scans of dose phantoms
- All require use of adult head, adult abdomen, pediatric abdomen protocols (if performed)
- Head dose phantom in head holder
- Body dose phantom on bare table top
- Pediatric abdomen – use head phantom on table top
- For helical protocols, must use axial scan with the detector configuration of the helical protocol (kVp, mA, time, N, T)
- Use spreadsheet provided by ACR to report CTDIvol (exposure or air kerma, depending on meter)

Adult Body Configuration for Dose Measurements

- Axial Slice at center of phantom
- Three measurements with 100 mm probe at both 12:00 and 3:00

Make Sure the Dose Phantom has all pins in place

ACR Dose Phantom Measurements

- If your dose measurements vary when doing the three averages, check to see if the system is doing a 420 degree over scan rather than a 360 degree scan
- Be sure FOV is set properly for the dose scan and phantom centered properly
- May be a good idea to check dose first so that you know your protocol does not exceed ACR dose limits

Annual Testing System Tests

- Alignment light accuracy
- Alignment of table to gantry
- Table/gantry tilt
- Table increment accuracy
- Slice thickness
- Image quality
  - High contrast resolution
  - Low contrast resolution
  - Image uniformity
  - Noise
  - Artifact evaluation
- CT number accuracy and linearity
Annual Testing
Other Tests

- Display devices
  - Monitors
  - Film-printers
- Dosimetry
  - CTDI measurements
  - Patient radiation doses for representative exams
  - Many newer systems estimate CTDIvol and DLP for exams
- Visual safety inspection
- State and local inspection and testing as required
- ACR phantom or other suitable phantom can be used

Laser Light – Bed Positioning Test
Ruler with lead scale
Can check bed index
Can check scout position

Verification of Tilt Readout Position and Repeatability
This device gives a check, but is not very accurate

Recommended Quality Control
- Established by medical physicist
- Performed by technologist on regular basis
- Frequency based on facility and usage
- Image quality
  - High and low contrast resolution
  - Image uniformity
  - Noise
  - Artifact evaluation
- Alignment light accuracy
- Slice thickness
- CT number accuracy
- Display and output devices

Manufacturer-Provided Water Phantom
16 slice scanner, lung screening protocol (120 kVp, 25 mAs, 2 mm)

Technologist Quality Assurance Form
Requires scanning water phantom daily at standard acquisition
Summary

- Qualified medical physicist must be present for annual survey and ACR testing when dose measurements are made.
- Read the materials from ACR including FAQ.
- Use the ACR Phantom Site Scanning Data Form.
- Understand the operating modes and detector configuration of the scanner.
- Be sure Table 1 properly reflects the standard protocols for the site.
- Remember that clinical images with the site protocols will also be submitted.
- For dosimetry, be sure to use the appropriate spreadsheet for the dose measurements.
- Be sure the system is calibrated and the periodic QC program is ongoing.
- Be prepared to perform annual surveillance; does not need to be submitted to ACR but needs to be available for inspection.