CT Tools and Protocols Available Through AAPM

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AAPM Working Group on Standardization of CT Nomenclature and Protocols

Cynthia McCollough
Workgroup Co-Chair

Dianna Cody
Workgroup Co-Chair
Charge

• Develop consensus protocols for frequently performed CT examinations, summarizing the basic requirements of the exam and giving several model-specific examples of scan and reconstruction parameters.

• Develop a set of standardized terms for use on CT scanners
Membership

- AAPM
  - Mike McNitt-Gray, Bob Pizzutiello, Dustin Gress, Jim Kofler, Mark Supanich, Michael Heard
- ACR
  - Mark Armstrong, Penny Butler, Dina Hernandez
- ASRT
  - Virginia Lester
- FDA
  - Thalia Mills
Manufacturers

- GE
  - John Jaeckle
- Hitachi
  - Mark Silverman
- Neusoft
  - Keith Mildenberger
- Neurologica
  - Donald Fickett
- Philips
  - Amar Dhanantwari
- Siemens
  - Christianne Liedecker
- Toshiba
  - Kirsten Boedecker
- MITA
  - Richard Eaton
Additional Members

Pediatric protocol experts
- Marilyn Goske
- Sjirk Westra

DICOM
- Kevin O’Donnell
- David Clunie
Hello Dr. Cody...

AAPP Events that pertain to you...

Conference Call on 11/27/11 at 9:00 AM Eastern Time
- Topic: RSNA - Awards and Honors Committee Conf Call - Chicago Hilton, 720 S. Michigan Ave., Rm 4C / 4th Flr [8:00a-10:30a Chicago Time; 9:00a-11:30a Eastern Time]
- Participant(s): AH
- Download to Outlook/ICal [How to import to Outlook/ICal]
- Click here to send instructions to your email

Conference Call on 11/27/11 at 9:00 AM Eastern Time
- Topic: TG200 meeting at RSNA (Room 4M, Chicago Hilton). Audio conference for those members unable to attend mg.
- Participant(s): TG200
- Download to Outlook/ICal [How to import to Outlook/ICal]
- Click here to send instructions to your email

WebEx/Call on 12/1/11 at 11:00 AM Eastern Time
- Topic: WGCTNP Webex/Teleconference (8:00am Pacific, 10:00am Central, 11:00am Eastern, 5:00pm Germany)
- Participant(s): WGCTNP, neumann@hachimed.com
- Download to Outlook/ICal [How to import to Outlook/ICal]
- Click here to send instructions to your email

WebEx/Call on 12/15/11 at 11:00 AM Eastern Time
- Topic: WGCTNP Webex/Teleconference (8:00am Pacific, 10:00am Central, 11:00am Eastern, 5:00pm Germany)
- Participant(s): neumann@hachimed.com, WGCTNP
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What's New

Pay Your 2012 Dues Online [membership]

Latest AAPM Member Discussions
[see your discussion threads | all general discussions]:

Statement of Purpose

The American Association of Physicians in Medicine (AAPM) is a professional organization whose members include board-certified medical physicists who specialize in the safe and effective use of radiation in medicine. Medical physicists partner with radiologists, technologists, regulators, manufacturers, administrators and others to ensure that CT scans are performed using the minimum amount of radiation required to obtain the diagnostic information for which the CT scan was ordered.

The collection of settings and parameters that fully describe a CT examination is referred to as the exam protocol. These protocols specify how data collection and reconstruction, patient positioning and contrast administration are to be performed. The effect of these settings on the final exam quality or dose can be dramatic; a number of the settings are inter-related, where changing one parameter can require adapting several other parameters if image quality and/or dose are to be maintained at a specified level. Thus, the quality and dose of a CT exam are largely predetermined by the protocol used. In CT, there is however no single protocol that is "the correct protocol"; acceptable image quality and dose can be achieved using many different combinations of scan parameters.

In light of the increase in the number of CT exams performed in the US, concerns about variability in doses and/or image quality used by different practices or scanner models to accomplish similar diagnostic tasks, and several unfortunate cases of patient injury due to the use of improper scan protocols, the AAPM is committed to the publication of a set of reasonable scan protocols for frequently performed CT examinations, summarizing the basic requirements of the exam and giving several model-specific examples of scan and reconstruction parameters. This work is the charge of the Working Group on Standardization of CT Nomenclature and Protocols, whose membership includes academic and consulting medical physicists who specialize in CT imaging, representatives of each of the major CT scanner manufacturers, and liaisons to the American College of Radiology, American Society of Radiology Technologists, and the Food and Drug Administration.

The provided protocols are considered by the Working Group to be reasonable and appropriate to the specified diagnostic task. The settings provided are representative of typical clinical values and they may not always match default protocols.

The provided protocols represent a sampling of currently available scanner models. They are not intended to provide comprehensive information for all available scanner models.
CT Dose Check Feature

- New MITA Standard
- Intended to serve as safety feature on new scanners
- Two levels of dose checking:
  - Alert: 1 Gy (for entire exam)
  - Notification (for each pass over patient)
- Dose check levels are adjustable by site
- May include protocol parameter export feature
New Feature – CT Dose Check

!!! DOSE ALERT
A dose alert value will be exceeded!

Proceeding with this exam will exceed the dose alert level that has been set.

<table>
<thead>
<tr>
<th>Predicted Dose</th>
<th>Alert Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative CTD\text{vol}</td>
<td>120.37 mGy</td>
</tr>
<tr>
<td>Patient total DLP</td>
<td>6043.0 mGy.cm</td>
</tr>
</tbody>
</table>

Dose Alert

A Dose Alert Value will be exceeded.
Please input a password and click the “Confirm” button to scan.

Password:

Confirm | Cancel

Dose Alert - Alert value will be exceeded!

The scan has a CTD\text{vol} of 1255.6 mGy. This exceeds the Alert Value of 1000 mGy. This may result in an excessive level of radiation exposure.

Enter user name: 
Enter diagnostic reason: 
Enter password: 

Confirm and proceed | Go back and adjust scanning parameters

DoseAlert

The prescribed scan parameters result in a projected test dose exceeding the user configured Alert Value. Select Cancel to go back to ViewMode and adjust the scan parameters. An authorized user name and password must be entered to select Confirm. Selecting Confirm will proceed to scan and log user confirmation of scan parameters exceeding the Alert Value.

Logon Name: 
Password: 
Diagnostic Reason:

Confirm | Cancel
Link opens document with information about the CT Dose Check software (how it is intended to be used, etc.), and a table of suggested notification values to use as a starting point.
Workflow impact

- Overall goal is to alert the CT technologist before a relatively high-dose exam is performed.
- What is ‘relatively high’ may be site & exam specific.
- Initial suggested notification values will likely need adjustment at each site in order to be useful.
Workflow impact

- If dose notification value is set too low, it will occur too frequently, will be readily ignored, ceasing to be a safety measure...

- If dose notification value is set too high, it will never occur, and will not act as a safety measure...
### Table 1: Notification Values recommended by the AAPM Working Group on Standardization of CT Nomenclature and Protocols

<table>
<thead>
<tr>
<th>CT Scan Region</th>
<th>CTDIvol Notification Value (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Head</td>
<td>80</td>
</tr>
<tr>
<td>Adult Torso</td>
<td>50</td>
</tr>
<tr>
<td>Pediatric Head</td>
<td></td>
</tr>
<tr>
<td>&lt;2 years old</td>
<td>50</td>
</tr>
<tr>
<td>2 – 5 years old</td>
<td>60</td>
</tr>
<tr>
<td>Pediatric Torso</td>
<td></td>
</tr>
<tr>
<td>&lt;10 years old (16-cm phantom)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25</td>
</tr>
<tr>
<td>&lt;10 years old (32-cm phantom)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10</td>
</tr>
<tr>
<td>Brain Perfusion</td>
<td></td>
</tr>
<tr>
<td>(examination that repeatedly scans the same anatomic level to measure the flow of contrast media through the anatomy)</td>
<td>600</td>
</tr>
<tr>
<td>Cardiac</td>
<td></td>
</tr>
<tr>
<td>Retrospectively gated (spiral)</td>
<td>150</td>
</tr>
<tr>
<td>Prospectively gated (sequential)</td>
<td>50</td>
</tr>
</tbody>
</table>

MDA: 53mGy abd/pelv
CT Dose Check

- This feature was recommended by the FDA in response to over exposure incidents
- Will very likely require careful consideration and regular review
- Appearing on newer model CT scanners
- Have list feature for all instances of exams exceeding the NV and AV
- Requires access at scanner (not available remotely)
Texas regulations

- Require sites to establish “reference” value for each CT exam
- Require sites to monitor patients and identify those whose dose has exceeded the “reference” value
- Have determined max CTDIvol for our GE CT scanners for most exams
- Intend to use 110% of that value as our notification value for both GE & Siemens CT scanners
- Will use CT Dose Check feature to comply with regs
CT Scan Protocols

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Available Protocols

**Adult Protocols**

- **Routine Adult Chest CT** (added 11/20/2012) [Give Feedback]
- **Routine Adult Abdomen/Pelvis CT** (added 10/17/2012) [Give Feedback]
- **Routine Adult Head CT** (added 06/01/2012) [Give Feedback]
- **Routine Adult Brain Perfusion** (updated 05/22/2012) [Give Feedback]

Your feedback regarding the content of this website is welcome. Feedback regarding this website will not be monitored daily. **Users experiencing problems in performing an exam should contact their service provider.**
Scanner Protocols

- Peer review process
- Protocol reference for sites to confirm their approach is reasonable
- NOT intended to reflect “optimized” set of parameters
- NOT intended to reflect “recommended” set of parameters

Reasonable Reference!
Manufacturers Represented

- General Electric
- Hitachi
- Neurologica
- Neusoft
- Philips
- Siemens
- Toshiba

- Newest model scanners, plus several previous models
**ADULT BRAIN PERFUSION CT**

**Indications**
- Suspected acute infarction;
- Assessment of repulsion after treatment of acute stroke;
- Vasculitis;
- New neurological symptoms after subarachnoid hemorrhage suggesting vasospasm;
- Evaluation of the hemodynamic significance of a carotid stenosis;
- Transient ischemic attack;
- Evaluation of the cerebral vascular reserve using acetazolamide challenge;
- Evaluation of brain perfusion after significant head trauma;
- Brain tumor.

**Diagnostic Task**
- Detect brain ischemia in stroke, transient ischemic attack, vasculitis;
- Distinguish already-infarcted brain from brain at risk of infarction;
- Identify regions of brain made ischemic by vasospasm;
- Detect altered brain perfusion downstream a significant carotid stenosis;
- Assess altered cerebral vascular reserve in patients with ischemic symptoms;
- Assess altered cerebral perfusion after traumatic brain injury;
- Identify early brain tumor recurrence and higher-grade tumor components.

**Key Elements**
- Time-resolved scans are used to track the flow of iodinated contrast media through the brain;
- Multiple images (20-40) are acquired over the same section of anatomy;
- Patients must be able to remain still during the exam in order to avoid motion misregistration;
- The table may remain stationary during the entire exam, or move back and forth between a few table positions;
- Whole-brain perfusion CT can be accomplished using CT systems with wide detector arrays (8-16 cm); alternatively, scan modes that move the patient back and forth over the desired scan volumes can be used;
- Acquisitions are repeated at predetermined time intervals (e.g. every second to every 2-3 seconds) for a predetermined duration (e.g. 40-60 seconds);
- Relatively thick image widths are used to minimize image noise (5-10 mm is common);
- Image quality is inferior to a routine head CT. That is, images are noisier and trickier.
- Data are used to generate color maps of hemodynamic significance:
  - Blood volume (BV) and flow (BF), mean transit time (MTT), time to peak perfusion (TPP);
  - A non-contrast-enhanced head CT and/or a CT angiogram may be combined with a perfusion CT scan.

**Dose Management**
- 80 kV should be used to increase iodine signal brightness;
- Low dose per single scan (i.e. one tube rotation) is critical, since repeated scanning will result in a relatively high cumulative dose;
- Time interval between scans, and hence the total number of scans over the exam duration, should be set carefully, taking into account the analysis algorithm (some approaches require relatively dense data points);
- Dose (tube current) modulation should not be used, as it may interfere with the calculation of the BV and BF parameters.

**Additional Resources**
### Adult Head Protocol

<table>
<thead>
<tr>
<th>AXIAL SCANS</th>
<th>CHARACTERISTICS</th>
<th>HELICAL SCANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly longer</td>
<td>Acquisition Time</td>
<td>Slightly shorter</td>
</tr>
<tr>
<td>Less artifacts in some cases, especially for &lt; 16 detector row scanners</td>
<td>Artifacts</td>
<td>More artifacts for &lt; 16 detector row scanners; close to or equivalent to axial for ≥ 64 detector row scanners</td>
</tr>
<tr>
<td>Better in some cases, especially for &lt; 16 detector row scanners</td>
<td>Image Quality</td>
<td>Equivalent in many cases; close to or equivalent to axial for ≥ 64 detector row scanners</td>
</tr>
<tr>
<td>Depends more on protocol than on axial or helical</td>
<td>Radiation Dose</td>
<td>Depends more on protocol than on axial or helical</td>
</tr>
<tr>
<td>Present in both helical and axial scans</td>
<td>Over Beaming (x-ray beam extending beyond the edge of active detector rows)</td>
<td>Present in both helical and axial scans</td>
</tr>
<tr>
<td>None or very little over ranging (limited to that caused by over beaming)</td>
<td>Over Ranging (irradiation of tissue inferior and superior to desired scan range)</td>
<td>Helical scans all have over ranging(^2). Some scanners have features that minimize this</td>
</tr>
<tr>
<td>Detector configuration is often narrower than for body scans</td>
<td>Detector Configuration (N x T mm)</td>
<td>Detector configuration is often narrower than for body scans</td>
</tr>
<tr>
<td>Limited to thicknesses allowed by detector configuration</td>
<td>Image Thickness</td>
<td>Limited to thicknesses allowed by detector configuration</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Single Acquisition</td>
<td>Split Acquisition</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>X-ray tube load</td>
<td>May be too high for some patient/scanner combinations</td>
<td>Usually can accommodate larger patients more readily</td>
</tr>
<tr>
<td>AEC</td>
<td>Usually a single image quality parameter is required for the entire image span (future scanners may allow for different Image Quality settings in each region)</td>
<td>Image quality and radiation dose can be customized for each region (chest/abd/pelvis) of the exam</td>
</tr>
<tr>
<td>Anatomic discontinuities</td>
<td>Not an issue – a single acquisition guarantees smooth transitions between regions (chest/abd/pelvis) in axial, coronal, and sagittal views</td>
<td>May be some anatomic discontinuities at the boundaries of the different regions (chest/abd/pelvis) in axial and reformatted images, reformatted image sets might be split</td>
</tr>
<tr>
<td>IV contrast timing</td>
<td>May require a compromise of IV contrast for all regions (chest/abd/pelvis)</td>
<td>Can be adjusted for optimal IV contrast in each region (chest/abd/pelvis)</td>
</tr>
<tr>
<td>Scan (exposure) overlap</td>
<td>Not an issue</td>
<td>Overlap of scan regions results in an increase in overall radiation exposure</td>
</tr>
<tr>
<td>Exam splitting for interpretation by different radiologists.</td>
<td>May require manual intervention by the CT technologist</td>
<td>Likely to be a more efficient process</td>
</tr>
<tr>
<td>Breath hold</td>
<td>May be too difficult for patients to hold their breath during the entire acquisition interval, resulting in some motion artifact</td>
<td>Patients should more readily perform a breath hold for each separate acquisition event</td>
</tr>
</tbody>
</table>
**BRAIN PERFUSION CT (Selected SIEMENS Scanners)**

**GENERAL:** This protocol may include an optional, non-contrast-enhanced scan and/or an optional contrast-enhanced CT angiography. Center the table height, such that the external auditory meatus is located at the center of the gantry. The patient's chin should be tilted toward the chest (i.e., in a "ducked" position).

**CONTRAST:** Oral: None. IV: 150 mg/mL concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec. Preferred injection site: 18-20 gauge IV placed in an antecubital vein.

**SCANNING:** PA and Laterals, 512 mm coverage, 130 kV, 240 mAs.

**BRAIN PERFUSION CT (Selected GE Scanners)**

**GENERAL:** This protocol may include an optional, non-contrast-enhanced scan and/or an optional contrast-enhanced CT angiography. Center the table height, such that the external auditory meatus is located at the center of the gantry. The patient's chin should be tilted toward the chest (i.e., in a "ducked" position) to minimize the amount of fluid needed to reduce the risk of aspiration. The patient's head should be secured. Performance protocols are for adults; modifications must be done for pediatric patients.

**CONTRAST:** Oral: None. IV: 150 mg/mL concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec. Preferred injection site: 18-20 gauge IV placed in an antecubital vein.

**SCANNING:** PA and Laterals, 512 mm coverage, 130 kV, 240 mAs.

**BRAIN PERFUSION CT (Selected PHILIPS Scanners)**

**GENERAL:** These protocol parameters should not be used for pediatric patients.

**CONTRAST:** Oral: None. IV: 150 mg/mL concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec. Preferred injection site: 18-20 gauge IV placed in an antecubital vein.

**SCANNING:** PA and Laterals, 240 mm coverage, 120 kV, 30 mAs, coronary artery technique.

**BRAIN PERFUSION CT (Selected TOSHIBA Scanners)**

**GENERAL:** This protocol may include an optional, non-contrast-enhanced scan and/or an optional contrast-enhanced CT angiography. Center the table height, such that the external auditory meatus is located at the center of the gantry.

**CONTRAST:** Oral: None. IV: 150 mg/mL concentration contrast media at 4 mL/sec followed by 30 mL saline at 4 mL/sec. Preferred injection site: 18-20 gauge IV placed in an antecubital vein.

**SCANNING:** PA and Laterals, 240 mm coverage, 120 kV, 30 mAs, coronary artery technique.

Performance protocols are performed on an image-processing workstation after image completion.

The images below show the scan protocols for the Acquisition ONE. Each green bar represents a volume scan. The bar is increased for the central portion of the scan to provide improved image quality for the digitally reformatted angiogram (DRA) image.
Work in progress...

- More routine CT exams:
  - **Lung Screening CT**
  - Chest-Abdomen-Pelvis CT
  - Pediatric Head CT

- On the to-do list:
  - Pediatric Chest CT
  - Pediatric Abdomen-Pelvis
  - CT Coronary Calcium Scoring CT
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CT Nomenclature

- Many CT scan parameters are quite vendor specific
- Results in major challenges for operators (physicists & radiologists) facing deployment of a scanner from a vendor new to them
- Long term goal – to work with the CT vendors and develop a common generic vocabulary of parameters
- Short term goal – to develop an easily accessible translator (lexicon) for current CT terminology
<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan acquisition and user interface basics</td>
</tr>
<tr>
<td>Dose modulation and reduction tools</td>
</tr>
<tr>
<td>Multi-Slice Detector Geometry</td>
</tr>
<tr>
<td>Image Reconstruction and Display</td>
</tr>
<tr>
<td>Contrast Media Tools</td>
</tr>
<tr>
<td>Multi-planar formats and 3-D Processing</td>
</tr>
<tr>
<td>Service and Application Tools</td>
</tr>
<tr>
<td>Workflow</td>
</tr>
</tbody>
</table>
### 1. Scan acquisition and user interface basics

<table>
<thead>
<tr>
<th>Generic description</th>
<th>GE</th>
<th>PHILIPS</th>
<th>SIEMENS</th>
<th>TOSHIBA</th>
<th>HITACHI</th>
<th>NEUSOFT</th>
<th>NEUROLOGICA</th>
</tr>
</thead>
<tbody>
<tr>
<td>The portion of the user interface where scans are prescribed</td>
<td>Exam Rx</td>
<td>Scan Procedure</td>
<td>Examination</td>
<td>eXam Plan</td>
<td>Scan Protocol</td>
<td>Scan Procedure (Neuviz 16); Main Scan Interface (Neuviz DUAL)</td>
<td>Scan protocol</td>
</tr>
<tr>
<td>Other portions of the user interface, such as were reconstructed images are viewed</td>
<td>Desktop</td>
<td>Active viewer</td>
<td>Various “task cards”, such as “Viewing”</td>
<td>Active display</td>
<td>Image Viewer</td>
<td>Image Display Area (Neuviz 16); Viewer (Neuviz DUAL)</td>
<td>Desktop</td>
</tr>
<tr>
<td><strong>CT localizer radiograph</strong> (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)</td>
<td>Scout</td>
<td>Surview</td>
<td>Topogram</td>
<td>Scanogram</td>
<td>Scanogram</td>
<td>Surview</td>
<td>Scout</td>
</tr>
<tr>
<td><strong>Axial scan mode</strong>: 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.</td>
<td>Axial</td>
<td>Axial</td>
<td>Sequence</td>
<td>Scan &amp; View, Scan &amp; Scan, Volume, Wide Volume (Aquilion One)</td>
<td>Normal</td>
<td>Normal</td>
<td>Axial</td>
</tr>
<tr>
<td><strong>Helical or Spiral scan mode</strong>: Data acquisition while the patient table is continuously moving along the z axis.</td>
<td>Helical</td>
<td>Helical</td>
<td>Spiral</td>
<td>Helical</td>
<td>Volume</td>
<td>Helical</td>
<td>Helical</td>
</tr>
</tbody>
</table>
CT Lexicon is Publicly Available

- Useful when learning the ropes on a scanner new to the clinic (translating terms across vendors)
- Useful as teaching points for technologists
CT Scan Protocols

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The provided protocols are considered by the Working Group to be reasonable and appropriate to the specified diagnostic task. The settings provided are representative of typical clinical values and they may not always match default protocols.

The provided protocols represent a sampling of currently available scanner models. They are not intended to provide comprehensive information for all available scanner models.
Educational Materials

- Publicly available
- Specific to radiation dose in CT – generic version is now available for download
- Future (VERY SOON) - From each vendor
- How the acquisition parameters work
  - What can you expect when this parameter is increased or decreased?
  - What is the impact of each parameter to image quality and dose?
Computed Tomography Radiation Dose Education Slides

The Power Point slides that are accessible through the following link deal with factors that affect radiation dose in CT studies. They may be used as a resource for developing presentations on this topic.

AAPM Computed Tomography Radiation Dose Education Slides 09/06/2012

AAPM Working Group on Standardization of CT Nomenclature and Protocols

AAPM Computed Tomography Radiation Dose Education Slides

Many of the terms used in these slides can be found in the CT Terminology Lexicon

Topics covered in slide set

- What is dose?
  - CTDIvol vs patient dose
  - Patient size and dose
- CT scan acquisition parameter settings
- Tube current modulation
- CT Dose display
Purpose?

- Use these slides!
- Edit them at will! (Vendor version – more restricted)
- Save them!
- Re-use them!
- Supplement (or replace) your current presentation materials
FDA Award – June 10, 2013

- CDRH Director’s Special Citation Award
- “For developing CT imaging radiation safety instructional materials through a collaboration of end-users, CT manufacturers, and the Food and Drug Administration”

- “… outstanding example of what can be accomplished through collaboration of key stakeholders…”
Brian Abraham (MITA)  Cody (AAPM)  Don Fickett (Neurologica)  Thalia Mills (FDA)
2013
DIRECTOR'S SPECIAL CITATION AWARD
presented to the
Computed Tomography (CT) Nomenclature Working Group

FDA