Computed Tomography Imaging: CT Protocol Management

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Caveat

- Coordination amongst QMP, Radiology section heads, and lead technologist(s) is key to CT Protocol Management
- Use vendor applications specialist when available for further assistance in management and optimization

Outline

- Protocol – What’s in a Name?
- Role of Protocols in CT Imaging
- Quality Assurance of Protocols
- Matching Protocols Across Scanners
- Generating/Reviewing Protocols on New Scanners
- Using External Benchmarks and Reference Levels
Protocol – what’s in a name?

- A radiologist *protocols* a scan
- An institution has a master *protocol*
- The scanner comes with built in *protocols*
- The patient was scanned with this *protocol*

We Need Definitions and Categorizations to Communicate Effectively

DICOM Supplement 121: CT Protocol Storage
- Published in 2016
- Defines two SOP classes for protocol storage that include
  - Patient preparation & positioning
  - Equipment characteristics
  - Acquisition technique
  - Reconstruction technique
  - Image handling (post processing)
  - Data storage

Defined Procedure Protocol: Is independent of a specific patient; may describe acquisition parameters common to multiple device models; and may include information such as the clinical purpose, indications, appropriate device models, etc.
Example Defined Procedure Protocol

- Perform Procedure Protocol
  - Associated with a specific patient and encodes the parameters values used in an acquisition

Example Performed Procedure Protocol

- What's in a name?
Protocol – what’s in a name

• Implementation of protocol SOP classes is key for quantitative imaging and clinical trials to compare results from serial scans
• QiBA profiles require scan protocols to meet certain benchmarks
  • Protocol SOP classes may be used to assess conformance to profiles

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Role of Protocols in CT Imaging

• Protocols define how imaging acquisition proceeds
  • Patient Preparation
  • Acquisition(s)
  • Reconstruction(s)
  • Post Processing
  • Transmission to PACS

Role of Protocols in CT Imaging

• Initial order from clinician sets in process the steps to image the patient
  • Patient scheduled and instructions given (NPO, medications, etc)
  • Patient arrives and prepped (oral contrast, remove necklaces, belt, etc)
  • Tech positions patient for scan
  • Tech selects protocol on scanner corresponding to defined procedure protocols

Role of Protocols in CT Imaging

• The Joint Commission Standard PC.01.02.15 Element of Performance 10 requires that prior to a diagnostic study the institution verifies:
  • Correct patient
  • Correct imaging site
  • Correct patient positioning
  • Correct CT imaging protocol
  • Correct CT scanner parameters
Role of Protocols in CT Imaging

- TJC requires traceable documentation from order to protocol on the system used to scan patient
- In absence or in association with Radiologist
- Protocling a Defined Procedure Protocol can be used to document the correct protocol is used
  - Can include associated procedure codes
  - Can include scanner protocol names

Example Defined Procedure Protocol

Role of Protocols in CT Imaging

- Master Protocols (containing Defined Procedure Protocols) are roadmap for technologist
  - Start at patient preparation
  - End at images sent to PACS
- Master Protocols may include
  - Pictures
  - Reference CTDI ranges
  - Radlex Playbook IDs
Role of Protocols in CT Imaging

• Protocol may call for patient preparation
  • NPO
  • Oral Contrast
  • Removal of belt/bra/necklaces...
  • IV location and gauge
  • Positioning orientation and location of arms
Role of Protocols in CT Imaging

- Protocols define acquisitions and timing
  - Extent of scan
  - Target image quality
  - Number of acquisitions
  - Timing of acquisitions and contrast

Role of Protocols in CT Imaging

- Protocols define reconstruction, post processing and image transmission
  - Reconstruction kernel
  - Iterative reconstruction
  - Window Level/Width
  - Reformats, MPRs, MIPs
  - DE or 3D post processing
  - Series to send to PACS

Example Defined Procedure Protocol

<table>
<thead>
<tr>
<th>SOMATOM Definition Flash [融入]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
</tr>
<tr>
<td>KV 120.0 160.0</td>
</tr>
</tbody>
</table>

[Protocol details table]
Role of Protocols in CT Imaging

• Control and understanding of CT Protocols ensures
  • Regulatory compliance
  • Consistent application of patient preparation
  • Consistent image quality

  You CANNOT just ‘Set it and Forget it’

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Quality Assurance of Protocols

• Good clinical practice to review protocols
  • Ensure producing required results
  • Examine inter-scanner variations

• ACR requires annual review/QA of protocols
  • 2012 CT QC Manual calls for review of:
    • CT protocols to be used, including pertinent information on
      radiation dose, positioning, and contrast agent administration
      that includes dose
Quality Assurance of Protocols

The Joint Commission Standard PC.01.03.01 requires:

- EOP 3: The institution establishes or adopts diagnostic computed tomography (CT) imaging protocols based on current standards of practice, which address key criteria including clinical indication, contrast administration, age (to indicate whether the patient is pediatric or an adult), patient size and body habitus, and the expected radiation dose index range.

AAPM 2017 Computed Tomography Imaging: CT Protocol Management

How do we meet these requirements?

AAPM practice guideline 1.a CT Protocol Management and Review

Portions of practice guideline incorporated into ACR QC Manual

Revision of practice guideline (published in 2013) due in 2018

Feedback on usefulness of guideline is welcome (direct comments to Dianna Cody [dcody@mdanderson.org])
Quality Assurance of Protocols

• Practice guideline calls for:
  • Protocol review team of QMP, Lead Tech and Radiologist
  • Protocol review must comply with federal and state/local regulations
  • Frequency must comply with requirements of regulatory and accrediting bodies
  • Protocols that must be reviewed annually
    • Peds head
    • Peds abdomen
    • Adult head
    • Adult abdomen
    • High Res Chest
    • Brain Perfusion

Quality Assurance of Protocols

• Practice guideline calls for:
  • Evaluating current protocols and considering new techniques
  • Taking into account capabilities of each scanner protocol
  • Review of current literature to ensure state of the art protocols are employed

Quality Assurance of Protocols

• Practice guideline recommends
  • Review of acquisition parameters
  • Permissions to modify protocols on scanners
  • Expected CTDIvol ranges and DRLs for protocol
  • Documentation of review and changes to protocols
  • Use of consistent nomenclature
Quality Assurance of Protocols

- AAPM practice guideline recommends consistent naming of protocols across scanners
  - If possible, consistent naming of each reconstruction series is key
  - Allows easy implementation of hanging protocols for radiologists on PACS

How should we name our protocols?

Quality Assurance of Protocols

- CT Protocol Nomenclature
  - You can't do QA if you don't know the names of your protocols!
  - Use of Radlex Playbook ID (RPIDs) is recommended
    - Used by ACR Dose Index Registry
    - Unique Identifier codes for names
  - RPIDs allow apples to apples comparisons of dose indices of protocols across scanners or institutions
Quality Assurance of Protocols

- Submission of radiation dose information (in the future image quality data) to registries
  - Review dose distributions at institution
  - Identify protocols with dose distributions higher than averages
  - Identify scanners with different dose distributions

Quality Assurance of Protocols

- Use of Radiation Dose Index Monitoring software
  - You can't do QA if you don't have the data!
  - AAPM Practice Guideline 6.a: Performance characteristics of radiation dose index monitoring systems

Use of RDIMs discussed later this session
Quality Assurance of Protocols

- Review current literature/best practices
- Use RDIM/Registry data to review dose distribution
- Examine Outliers
- Review acquisition parameters
- Implement changes
- COMMUNICATE CHANGES

Key Parameters to review

- Acquisition time
- Detector configuration
- Reconstruction thickness
- Image quality reference parameter (or manual setting)
- Tube potential(s)
- Beam shaping filter
- Iterative reconstruction

References on QA of protocols

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Matching Protocols Across Scanners
• Ideal world
  • All the scanners at institution are latest and greatest and the protocols are all the same

• Real world
  • Different scanners
  • Different capabilities
  • Matching protocols on same model can be challenging

Matching Protocols Across Scanners
How do we ensure protocols are consistent across same/similar model scanners?
Matching Protocols Across Scanners

- IHE profile on Management of Acquisition Protocols
  - Establishes framework for development of protocol management tools
  - Allows for use of DICOM Protocol SOP classes to be pushed/pulled from scanners to/from Protocol Manager
Matching Protocols Across Scanners

How do we match protocols across different models/brands?

• Target same image quality across scanners
• Radiation dose distribution may be different due to scanner capabilities
• Some scans may not be able to be done on some scanners
• Routing of certain cases (Multi Energy, Cardiac) to particular scanners may be required
Matching Protocols Across Scanners

• 3 Key Image Quality Metrics to match
  • For quantitative imaging and consistent image quality
    • SSP
    • MTF
    • NPS

Matching Protocols Across Scanners

• Tomographic Section Thickness (Slice Sensitivity Profile)
  • Basic metric is Reconstructed Tomographic Section Thickness
  • Advanced metric is Slice Sensitivity Profile
  • Measure using thin high contrast object
  • Affects partial volume artifacts and volumetry

Favazza et al, Phys Med Biol 2015
Matching Protocols Across Scanners

- In Plane Spatial Resolution (Modulation Transfer Function)
- Basic metric of spatial resolution (line pairs/mm)
- Advanced metric of MTF
  - Measure using edge or wire and use Fourier analysis
- Affects ability to resolve small objects or sharp edges

Matching Protocols Across Scanners

- Standard Deviation of Noise (Noise Power Spectrum)
- Basic metric of Noise Standard Deviation (ROI measurement)
- Advanced Metric of NPS
  - Measure using scans of uniform object
  - Fourier analysis of noise only image
  - Must consider scanned object size as different AEC approaches are attenuation dependent
  - May need to have size specific protocol settings
Matching Protocols Across Scanners

- Additional considerations
  - Impact of iterative reconstruction
    - Noise (and spatial distribution)
    - Spatial resolution
    - Low contrast resolution
    - Required radiation dose
  - Scan time
    - Older scanners may have slow rotation time
    - Possibility of tube current limitation at fast rotation times
Matching Protocols Across Scanners

• AAPM Alliance for Quality in CT
• Medical Physicists
• ASRT
• ACR
• Vendors
• Publish reasonable protocols for wide variety of scanners for common exams

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Generating/Reviewing Protocols on a New Scanner

• New scanners must come with reference adult and pediatric protocols (per NEMA XR-29)
• Reference protocols may not match radiologist preferences or standard practices at site
• Most common adjustments
  • Image quality reference parameters
  • Reconstruction kernels
  • Reconstructed series
Generating/Reviewing Protocols on a New Scanner

- Introduction of Iterative Reconstruction to protocols requires GREAT CARE
  - Start at standard dose with iterative turned on and gradually decrease dose until image quality is just acceptable
  - Iterative reconstruction may result in loss of low contrast resolution

Generating/Reviewing Protocols on a New Scanner

- New scanners typically come with many hours of applications specialist training
  - Make full use of training time
  - Consider breaking up applications specialist time
  - Ensure automated patient instructions are accurate (and available in required languages)

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External Benchmarks and Reference Levels

- TJC Elements of Performance for Diagnostic Imaging requires institutions performing CT to:
  - Review of scans exceeding dose notification levels
  - Compare scans exceeding those levels to external benchmarks
  - Include expected dose distribution in CT Scan Protocol

- Review of scans exceeding notification levels
  - Most easily documented by use of Radiation Dose Index Monitoring software
  - Categorization of reason for exceeding notification level useful for analysis
    - Large patient
    - Patient positioning
    - Metal implant
    - Tech error
    - ...
External Benchmarks and Reference Levels

- **External Benchmarks**
  - Comparison of scans to ACR DIR data/reference levels
  - Comparison of scans to AAPM dose notification levels

- **External Dose Reference Levels/Benchmarks are NOT SIZE DEPENDENT**

Should they be size dependent? Should we review scans BELOW typical radiation dose levels?

CTDI vs WED with Fixed DRL

Exams above and below the 95th and 5th percentile are highlighted.

Are these the scans we should review?

CTDI vs WED with Size Specific DRL

Size specific DRLs in WED bins established.

Scans outside Size specific DRLs may be most useful outliers to examine.
Figure 2c: Graphs show chest AD achievable dose and DRL diagnostic reference level for chest without contrast material—CTDIvol volume CT dose index and SSDE size specific dose estimate. (a) AD achievable dose and DRL diagnostic reference level for chest without contrast material—CTDIvol volume CT dose index and SSDE size specific dose estimate. (b) AD achievable dose and DRL diagnostic reference level for chest without contrast material—DLP dose-length product. (c) AD achievable dose and DRL diagnostic reference level for chest with contrast material—CTDIvol volume CT dose index and SSDE size specific dose estimate. (d) AD achievable dose and DRL diagnostic reference level for chest with contrast material—DLP dose-length product. (e) AD achievable dose and DRL diagnostic reference level for chest pulmonary arteries with contrast material—CTDIvol volume CT dose index and SSDE size specific dose estimate. (f) AD achievable dose and DRL diagnostic reference level for chest pulmonary arteries with contrast material—DLP dose-length product.

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