Useful strategies for protocol development
Conflict of Interest

TPS supplies CT protocols to GE Healthcare under a licensing agreement, is a consultant to GE Healthcare, receives research support from GE Healthcare, is on the MAB of iMALOGIX LLC, is the founder of Protocolshare.org, is co-owner of LiteRay Medical LLC.

This presentation includes materials posted on Protocolshare.org
TALK FOCUS

- Essential elements of a CT protocol
- Example data mining you can do to help your clinical partners
USEFUL STRATEGIES FOR PROTOCOL DEVELOPMENT/ AGENDA

Essential elements of a CT protocol
01 | compliance/regulatory details
02 | clinical details
03 | workflow details
04 | technical details

Data mining/analysis: physicist contributing to CT protocol optimization team
05 | clinical background: contrast dynamics
06 | clinical background: breath hold
07 | using dose data to get scan time/length
08 | optimized protocols across your fleet
Scanner specific instructions

- Info you get from your apps person
- Info you read out of the scanner’s user manual

Indication specific instructions

- # phases for various indications
- Timing delays

Examples:
- Hospital guideline on Foley catheter
- Injector loading instructions

Information we can assume our technologists know

Overlap/Integration of these three circles is what needs to make it into technologist protocol documentation, all information needs to get documented somewhere
ESSENTIAL ELEMENTS OF A PROTOCOL: RESOURCES

• AAPM lexicon
  – “Rosetta stone” Of CT scanners
  – Best resource for sites using multiple vendors
  – Great resource for sites desiring to come up with their own standard layout for CT protocol information
  – May point your team to consider facets of your protocols you currently do not document

http://www.quarkquark.com/electronman/
ESSENTIAL ELEMENTS OF A PROTOCOL: RESOURCES

Search for “CT protocol wiki” on youtube for a video demonstration of this.
ESSENTIAL ELEMENTS OF A PROTOCOL: RESOURCES

Other examples of nice CT protocols:

• AAPM CT protocols

• Device company CT protocols (Heartflow/Sapien have great publicly available CT protocols)

• Ctisus.com
## COMPLIANCE/REGULATORY DETAILS

<table>
<thead>
<tr>
<th>Contributors</th>
<th>Who wrote the protocol and what qualifications do they have?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Philosophy</td>
<td>Why are the timing delays/dose levels/slice thicknesses/etc. set at the values they are?</td>
</tr>
<tr>
<td>Clinical Indication/s</td>
<td>Most protocol can be used for many indications, what are they?</td>
</tr>
<tr>
<td>Dose Data</td>
<td>Document expected dose index ranges (ideally size/age based)</td>
</tr>
</tbody>
</table>

---

See TJC Provision of Care, Treatment, and Services PC.01.03.01 A26

See TJC Provision of Care, Treatment, and Services PC.01.03.01 A26

See TJC Provision of Care, Treatment, and Services PC.01.03.01 A25

See TJC Performance Improvement PC.02.01.01 A6
Easily a source of confusion, so you need to document well and develop a systematic approach for this. Be aware different roles think of protocol names in unique ways.

Tech “6.23 ABD-LIVER BIPHASIC MEDIUM ADULT”
Radiologist “Biphasic liver”
Billing department “CT Abdomen Angio”
Dose Repository “RPID5”

What programs/studies/trial does the protocol comply with?
- e.g. ACR LCS, ACR CTC, Research trial, Device manufacturer (robotic surgery), OPTN/UNOS, etc.
COMPLIANCE/REGULATORY DETAILS

Billing Code
Mistakes made by techs here will cause downstream issues. Each protocol should explicitly state what billing code (usually techs just choose text description, billing department will assign code) to use and any modifications due to scan time changes to the protocol.

RSNA reporting template
Whether your site uses RSNA or in house templates, what template to use should be documented somewhere linked to the protocol used to realize that study.
Patient Preparation
- Jewelry removal, practice breathing, IV access, etc.

Oral Contrast Instructions
- How to mix, how much to give, when to give, frequency of drinking.
- Volume, rate, chaser volume, timing, IV access details, etc.

IVC Contrast Instructions
- Breath hold, Valsalva maneuver, etc.

Patient Coaching Instructions
- See TJC Provision of Care, Treatment, and Services PC.01.03.01 A25
**Patient Preparation**

**IVC Contrast Instructions**

**Oral Contrast Instructions**

**Patient Coaching Instructions**

---

**Pre-Scan Instructions**

Clamp Foley catheter prior to scanning. Make sure to place Foley below the level of the bladder.

**Oral Contrast**

Give a total 400 mL of water prior to scan (A 200mL dose every 15 minutes over 30 minutes). Give an additional 200mL dose of water on the CT scan table.

**IV Contrast Parameters**

Madrid™ PTT PA protocol

To set up P37 choose P37, Thorax, PA then click on ok. Confirm contrast and load fluids. Enter scan duration and click ok.

Iopamidol (Isovue 370) 76% injection

For sites without the Madrid™ PTT or P37 PA option, refer to the weight based contrast tables we provide in the protocol booklet. Click here to access these tables.

**Pre-Scan Instructions**

Practice the 3 breaths for scouts, smart prep, and the actual helical scan. We do not want to induce a transient interruption of contrast (TIC) which would mimic a PE and or produce an indeterminate exam. Please give the patient these instructions: When you take your last breath before the exam, please do not breathe down, take a deep breath, tense up or strenuously hold your breath. This exam will be over in about 4 seconds from when we tell you hold your breath to when you may breath again.

We would like to visualize contrast in the pulmonary arteries and aorta because this is a double rule out protocol. If you see the contrast in the pulmonary arteries at a much lower intensity than the SVC and aorta, the patient likely had a TIC which kept the PA from enhancing correctly. This is not a scan timing issue, but an issue with un-opacified blood entering the heart faster from the IVC than opacified blood from the SVC caused by a pressure imbalance between the thorax and abdomen. This is why the breathing instructions we provide above are critical for this exam.
Documentation of what physicians should be looking for to guide the diagnostic exam. For example in coronary CTA, if after the non con a patient’s coronaries are full of Calcium, the CCTA may be skipped.

Most important for MSK where joint angles are important. Details (ideally with pictures) should be given to guide patient set-up.
High level description of what the tech will be doing for each part of the exam.

What planes and what source data to use to make them.

What to send where. Not trivial since you may send to PACS, 3D lab, perfusion processing, etc. which will likely differ at different sites.
WORKFLOW DETAILS

Exam Logistics by series

Scan Description
- Series 1 - PA and Lateral Scout
- Coverage: Lower Neck to Below lung Base
- Series 2 - Non - Contrast – Calcium Score
  - Coverage: Carina to below heart
- Series 3 – Timing Bolus = on the ascending aorta (use your without series to find the level)
  - Use 10 ml of ioxilan and 50 ml of saline
  - Take 16 + Bolus time = Prep delay
  - If the timing for the prep delay is less than 20 seconds, please change the prep group to 20 seconds. We do not want to use anything less than 20 seconds for a delay.
- Series 4 – CTA
  - Use Timing Bolus
  - Coverage: Same as non – contrast scan
  - Number 13 breathing instructions on the scanner (10 s breath in and out + 4 s pause)

Reformat Instructions
Use DMPR on THIN ST.

Reformats

<table>
<thead>
<tr>
<th>Name</th>
<th>Source Recon</th>
<th>DMPR or Manual</th>
<th>Type (MF, Average, etc.)</th>
<th>WW/WL</th>
<th>Slice Thickness (mm)</th>
<th>Interval (mm)</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA BODY</td>
<td>THIN ST</td>
<td>DMPR</td>
<td>Average</td>
<td>45/50</td>
<td>5</td>
<td>2.5</td>
<td>sagittal</td>
</tr>
<tr>
<td>CO BODY</td>
<td>THIN ST</td>
<td>DMPR</td>
<td>Average</td>
<td>45/50</td>
<td>5</td>
<td>2.5</td>
<td>coronal</td>
</tr>
</tbody>
</table>
In the interest of time, I am not going to go into the details of technical acquisition parameters. This should be the wheel house of the physicist. For good references, see the parameters listed within the AAPM CT protocols.

This is not trivial, you should worry about all the recons the techs/docs need, not “just recon 1” or the acquisition parameters.
TECHNICAL DETAILS: RESOURCES

This is online as well. https://www.radiology.wisc.edu/ug-ge-ct-protocol-project/resources/

We made this because we were sick of “making these names up” which lead to complete non uniformity across our thousands of CT protocols. Hopefully you can find value in it as well! 😊
USEFUL STRATEGIES FOR PROTOCOL DEVELOPMENT/ AGENDA

Essential elements of a CT protocol
01 | compliance/regulatory details
02 | clinical details
03 | workflow details
04 | technical details

Data mining/analysis: physicist contributing to CT protocol optimization team
05 | clinical background: contrast dynamics
06 | clinical background: breath hold
07 | using dose data to get scan time/length
08 | optimized protocols across your fleet
CLINICAL BACKGROUND: CONTRAST DYNAMICS

Non contrast localizer phase

Arterial Phase

Late Arterial Phase

Parenchymal Phase

HCC (hepatocellular carcinoma) Liver protocol

~20 seconds

~20 seconds

~30 seconds

~2 minutes

3 Minute Delays
CLINICAL BACKGROUND: CONTRAST DYNAMICS


# CLINICAL BACKGROUND: CONTRAST DYNAMICS

<table>
<thead>
<tr>
<th>Series</th>
<th>Type</th>
<th>Scan Range (mm)</th>
<th>CTDIvol (mGy)</th>
<th>DLP (mGy-cm)</th>
<th>Phantom cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scout</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Helical</td>
<td>78.750–1179.250</td>
<td>5.91</td>
<td>176.97</td>
<td>Body 32</td>
</tr>
<tr>
<td>3</td>
<td>Axial</td>
<td>150.250–150.250</td>
<td>60.71</td>
<td>30.35</td>
<td>Body 32</td>
</tr>
<tr>
<td>4</td>
<td>Helical</td>
<td>78.750–1179.250</td>
<td>16.00</td>
<td>478.60</td>
<td>Body 32</td>
</tr>
<tr>
<td>4</td>
<td>Helical</td>
<td>1179.250–578.750</td>
<td>6.29</td>
<td>188.40</td>
<td>Body 32</td>
</tr>
<tr>
<td>4</td>
<td>Helical</td>
<td>578.750–1431.250</td>
<td>6.91</td>
<td>381.26</td>
<td>Body 32</td>
</tr>
<tr>
<td>6</td>
<td>Helical</td>
<td>78.750–1179.250</td>
<td>9.10</td>
<td>272.37</td>
<td>Body 32</td>
</tr>
</tbody>
</table>

Total Exam DLP: 1527.95

- Just liver coverage: 258 mm
- Diaphragm to pubic synthesis: 258 mm, 510 mm, 258 mm
CLINICAL BACKGROUND: CONTRAST DYNAMICS

258 mm imaged @ 0.516 pitch @ 40 mm collimation @ 0.4 sec rotation time → 5 sec
258 mm imaged @ 0.516 pitch @ 40 mm collimation @ 0.6 sec rotation time → 7.5 sec
510 mm imaged @ 0.516 pitch @ 40 mm collimation @ 0.4 sec rotation time → 9.9 sec
258 mm imaged @ 1 pitch @ 10 mm collimation @ 1 sec rotation time → 26 sec
510 mm imaged @ 1 pitch @ 10 mm collimation @ 1 sec rotation time → 51 sec

Scan time is given in DICOM (tag 0018,1150) which may or may not be in your image volume or dose sheet.
Scan time can be calculated as \( \frac{\text{scan length} \times \text{rotation time}}{\text{collimation} \times \text{pitch}} \).

These two methods will likely give slightly different results as DICOM will include helical over scanning time.
CLINICAL BACKGROUND: BREATH HOLD

Some patients who simply cannot hold their breaths at all, others can only do so for ~18 seconds→ this study was not on patients with cancer...

Preliminary Report

Breath-Holding Capability of Adults

Implications for Spiral Computed Tomography, Fast-Acquisition Magnetic Resonance Imaging, and Angiography

SPENCER B. GAY, MD,* CHRIS L. SISTROM, MD;† CHAD A. HOLDER, MD,* AND PAUL M. SURATT, MD‡
CLINICAL BACKGROUND: BREATH HOLD

<table>
<thead>
<tr>
<th>ADULT LUNG CANCER Screening Technical Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Chest for Lung Cancer Screening</td>
</tr>
<tr>
<td>Technique Parameters (Items in bold are designation requirements. Failure to meet these requirements will result in deferral of Designation)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scan Parameter</th>
<th>Parameter Specification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanner type</td>
<td>multidetector helical (spiral) detector rows ≥ 4</td>
<td>non helical and single detector scanners are not appropriate for lung cancer screening CT.</td>
</tr>
<tr>
<td>Required Series</td>
<td></td>
<td>No IV or oral contrast should be used.</td>
</tr>
<tr>
<td>kV</td>
<td>100 to 140 acceptable for standard sized patient</td>
<td>Should be set in combination with mAs to meet CTD/ivol specifications.</td>
</tr>
<tr>
<td>mAs</td>
<td>Should be set in combination with kVp to meet CTD/ivol specifications.</td>
<td>The mAs selected should result in diagnostic-quality images of the lungs.</td>
</tr>
<tr>
<td>Max. Tube Rotation Time</td>
<td>≤ 0.5 seconds</td>
<td>0.75 second is acceptable if a single breath hold ≤15 seconds can be achieved for scanners that cannot perform 0.5 second rotation time.</td>
</tr>
<tr>
<td>Pitch (IEC Definition)</td>
<td>Between 0.7 and 1.5</td>
<td>Should be set with other technical parameters to achieve single breath hold scan and CTD/ivol specifications.</td>
</tr>
<tr>
<td>Respiration</td>
<td>single breath hold full inspiration</td>
<td>To acquire the scan though entire lungs within a single breath.</td>
</tr>
<tr>
<td>Scan duration/ Acquisition time</td>
<td>≤ 15 seconds</td>
<td></td>
</tr>
<tr>
<td>Reconstructed image width (nominal width of reconstructed image along z-axis)</td>
<td>≤ 2.5 mm</td>
<td>≤ 1 mm preferred.</td>
</tr>
<tr>
<td>Reconstructed image spacing (Distance between two reconstructed images)</td>
<td>≤ slice width</td>
<td>Overlapping reconstructions are not necessary but are acceptable.</td>
</tr>
</tbody>
</table>
CLINICAL BACKGROUND: BREATH HOLD

2 YO M, 15 cm coverage

51 YO F, 23 cm coverage

55 YO M, 34 cm coverage
CLINICAL BACKGROUND: BREATH HOLD

15 cm imaged @ 1.5 pitch @ 40 mm collimation @ 0.4 sec rotation time → 1 sec
23 cm imaged @ 1.5 pitch @ 40 mm collimation @ 0.4 sec rotation time → 1.5 sec
34 cm imaged @ 1.5 pitch @ 40 mm collimation @ 0.4 sec rotation time → 2.3 sec

15 cm imaged @ 1 pitch @ 10 mm collimation @ 1 sec rotation time → 15 sec
23 cm imaged @ 1 pitch @ 10 mm collimation @ 1 sec rotation time → 23 sec
34 cm imaged @ 1 pitch @ 10 mm collimation @ 1 sec rotation time → 34 sec

Scan time is given in DICOM (tag 0018,1150) which may or may not be in your image volume or dose sheet.
Scan time can be calculated as \( \frac{\text{scan length} \times \text{rotation time}}{\text{collimation} \times \text{pitch}} \)

These two methods will likely give slightly different results as DICOM will include helical over scanning time.
USING DOSE DATA TO GET SCAN TIME/LENGTH

Almost all dose monitoring vendors allow a "data dump"

Fields in the data dump will likely include fields usable to either directly yield scan length/times or provide the values needed to calculate them

Your Dose monitoring system will either directly give you
Scan range, scan time
Or you can can get scan range and time
Scan range $\sim$ DLP/CTDIvol
Scan time $= \frac{scan \ length \times rotation \ time}{collimation \times pitch}$

Your dose monitoring vendor should output these values for each irradiation event which can be filtered by patient age, protocol name, location, etc.
USING DOSE DATA TO GET SCAN TIME/LENGTH

Data export in csv format

Trivial spreadsheet filtering and math

<table>
<thead>
<tr>
<th>Protocol Name</th>
<th>Patient Age</th>
<th>Scan Length</th>
<th>Scan Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine abd/pel</td>
<td>41</td>
<td>52</td>
<td>10.3</td>
</tr>
<tr>
<td>Routine head</td>
<td>16</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Chest PE</td>
<td>67</td>
<td>40</td>
<td>3</td>
</tr>
</tbody>
</table>
OPTIMIZED PROTOCOLS ACROSS YOUR FLEET

Using the method shown on the last slide, you can monitor scan times for any protocol on any scanner in your fleet.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Mean</th>
<th>Median</th>
<th>25th</th>
<th>75th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen/Pelvis</td>
<td>9.6479</td>
<td>10.0514</td>
<td>9.4179</td>
<td>10.5806</td>
</tr>
<tr>
<td>Routine Chest</td>
<td>3.0938</td>
<td>2.8288</td>
<td>2.6533</td>
<td>3.1447</td>
</tr>
<tr>
<td>Lung Screening</td>
<td>2.6999</td>
<td>2.7856</td>
<td>2.6751</td>
<td>2.9052</td>
</tr>
<tr>
<td>Upper Extremity</td>
<td>8.4346</td>
<td>8.1231</td>
<td>6.6434</td>
<td>9.9302</td>
</tr>
</tbody>
</table>
OPTIMIZED PROTOCOLS ACROSS YOUR FLEET

Using the data from the last slide, you can sit at the table with your clinical colleagues armed with real data on how long scans will take. You can make informed decisions on scan delay lengths for complicated multiphasic protocols. Or scan delay adjustments as a function of patient size and scanner capabilities.

- Taller patients will need longer scan ranges for the same body region.
- Bigger (i.e. water equivalent diameter) patients will need higher tube outputs for the same body region relative to smaller patients.

Scan time = \( \frac{\text{scan length} \times \text{rotation time}}{\text{collimation} \times \text{pitch}} \)

Scan time = \( \frac{\text{scan length} \times \uparrow \text{rotation time}}{\text{collimation} \times \downarrow \text{pitch}} \)
### Radiology Group

#### Sub specialty section experts

<table>
<thead>
<tr>
<th>Scanners</th>
<th>Neuro</th>
<th>Thoracic</th>
<th>Cardio-Vascular</th>
<th>Abdomen Pelvis</th>
<th>MSK</th>
<th>Pediatric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vendor 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 1</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 3</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vendor 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 1</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 2</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vendor 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Model 1</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Uniformity in Workflow**

**Uniformity in Protocols**

---

Adapted from a slide given by Professor Mika Koresniemi at the Prague 2018 CT workshop hosted by EFOMP.
THANK YOU.

Feel free to contact me at tszeczykutowicz@uwhealth.org