CT Lung Cancer Screening and the Medical Physicist: Moving Forward

D Aberle, W Hsu, M McNitt-Gray,
David Geffen School of Medicine at UCLA
Los Angeles, CA

WE-D-207-0 (Wednesday, July 15, 2015)
11:00 AM - 12:15 PM Room: 207

Disclosures

- UCLA Department of Radiology has an Institutional research agreement with Siemens Healthcare;
- Dr. McNitt-Gray has been a recipient of Research Support from Siemens Healthcare in the past.
- Dr. Aberle has been a Member of Advisory Boards for the LUNGevity Foundation (2011-present) and Siemens Medical Solutions. (2013).

CT Lung Cancer Screening Protocols

- The primary goal of lung cancer screening CT is to detect abnormalities that may represent lung cancer and may require further diagnostic evaluation
- Therefore, the primary task is to detect nodules or masses, and characterize their size, shape and relationships to organs

CT Lung Cancer Screening Protocols

- Common Elements:
  - Low Dose (how low?)
  - Thin Slice (how thin?)
  - Single Breathhold

CT Lung Cancer Screening Protocols

References:

- AAPM CT Protocols for Lung Cancer Screening
- http://www.aapm.org/pubs/CTProtocols/documents/LungCancerScreeningCT.pdf
- **ACR–STR Practice Parameter for the Performance and Reporting of Lung Cancer Screening Thoracic Computed Tomography (CT).** Available at:
- http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/LungScreening.pdf
- **United States Preventive Services Task Force (USPSTF) Recommendations on Lung Cancer Screening using Low Dose CT**. Available at: http://www.uspreventiveservicestaskforce.org/Page/Document/RecommendationStatementFinal/lung-cancer-screening
- **CMS (Medicare) Decision Memo for Screening for Lung Cancer with Low Dose Computed Tomography (LDCT) (CAG-00439N)**
- http://www.cms.gov/medicare-coverage-database/details/nca-decision-memo.aspx?NCAId=274

Scanner Type

- ACR-STR Practice Parameter:
  - Gantry rotation times: ≤0.5 seconds
  - Slice thickness: ≤ 2.5 mm (≤1.0mm is preferred)
  - Detector rows: ≥16 detector rows are preferred

- ACR Designated Lung Screeening Center
  - REQUIRES multidetector helical (spiral) detector rows ≥ 4
    - non helical and single detector scanners are not appropriate for lung cancer screening CT
  - Max.Tube Rotation Time ≤ 0.5 seconds; 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

- http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/LungScreening.pdf
- http://www.acr.org/~/media/ACR/Documents/PDF/QualitySafety/Lung%20Screening/Lung%20Cancer%20Screening%20Technical%20Specifications.pdf

Low Dose

- CTDIvol ≤ 3 mGy for a standard sized patient
  - Standard Sized (not average size): 5'7" and 155 pounds
- Reduce CTDIvol for smaller patients
- Increase CTDIvol for larger patients
- Goal is to produce a study which can be interpreted for presence of lung nodules (4mm or greater), so focus should be on maintaining that level of image quality

- References:
- **ACR–STR Practice Parameter for the Performance and Reporting of Lung Cancer Screening Thoracic Computed Tomography (CT).** Available at:
- http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/LungScreening.pdf
- **CMS (Medicare) Decision Memo for Screening for Lung Cancer with Low Dose Computed Tomography (LDCT) (CAG-00439N)**
- http://www.cms.gov/medicare-coverage-database/details/nca-decision-memo.aspx?NCAId=274

Low Dose

Can be accomplished in one of two ways:

1. Automatic Exposure Control Systems, e.g. Tube Current Modulation (TCM)
    - Automatically adjust for patient size
2. Manual Technique Charts
    - For example, use of a manual technique chart that prescribes different tube current and/or kV values as a function of patient size

- Examples of manual adjustment may include (but are not limited to):
    - Reducing the mAs for small patients by 50%
    - Increasing the mAs for large patients by 50-100%
    - (See AAPM Protocols for guidance)

Thin Slice (Reconstructed Image Thickness)

- ≤ 2.5 mm (1 mm preferred)

- This was what was used in vast majority of NLST scans
- Desire was to make the requirements for images even thinner, but NLST demonstrated mortality reduction with these techniques, so with 2.5 mm thickness we can provide a benefit
  - and expect to provide **at least** that level of benefit with thinner slices
- Reference
- **ACR–STR Practice Parameter for the Performance and Reporting of Lung Cancer Screening Thoracic Computed Tomography (CT).** Available at:
- http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/LungScreening.pdf

Single Breathhold

- With Modern CT scanners, scanning through the entire lungs (apices to bases) in a single breathhold is commonplace.
- However, scanning through the lungs in a single breathhold and producing thin slices may be a challenge.

- How long is a single breathhold?
  - ACR Designated Lung Screening Program defined it to be ≤ 15 seconds
  - Most patients can hold it that long, but for some that will be a challenge so even shorter is preferred.

Single Breathhold

- Typical Scan Length is 30-35 cm
  - In Cagnon et al, we reported the time for a 40 cm long chest, but that was meant to be a worst case scenario to determine if all patients could be scanned in a single breathhold
- So, for a 4 slice scanner using 4x2.5mm collimation and a 0.8 second rotation time with a pitch of 1.5:
  - Table feed is NT*P = 15 mm/rotation
  - Table Speed is NT*P/rot. Time = 18.75 mm/sec
  - Time to cover 30 cm (300 mm) is 16 seconds, which is pushing it.
- If that 4 slice scanner can perform 0.5 second rotation time with pitch 1.5, then:
  - Table feed is NT*P = 15 mm/rotation
  - Table Speed is NT*P/rot. Time = 30 mm/sec
  - Time to cover 30 cm (300 mm) is 10 seconds, which is fine

Single Breathhold

- However for a 4 slice scanner using 4x1.25mm collimation and a 0.5 second rotation time with a pitch of 1.5:
  - Table feed is NT*P = 7.5 mm/rotation
  - Table Speed is NT*P/rot. Time = 15 mm/sec
  - Time to cover 30 cm (300 mm) is 20 seconds, which is too long.
  - So, getting both thin slices and single breathhold coverage of entire lungs can be an issue (though this would still meet ACR Designated Lung Screening Center technical specs).
- For a 16 slice scanner using even 16x0.75mm collimation with 0.5 second rotation time and pitch 1, then:
  - Table feed is NT*P = 12 mm/rotation
  - Table Speed is NT*P/rot. Time = 24 mm/sec
  - Time to cover 30 cm (300 mm) is 12.5 seconds, which is fine

AAPM Protocols – Lung Screening CT

"The Lung Cancer Screening Protocols described in this document are a set of reasonable protocols developed by the AAPM's Working Group on Standardization of CT Nomenclature and Protocols that are to be used in the specific context of Lung Cancer Screening. These protocols were based in part on manufacturers' Low Dose Chest protocols, but were adapted based on the Working Group's experience with the National Lung Screening Trial and other screening studies"

AAPM Protocols – Lung Screening CT

- Describes
- The purpose of the exam
- Diagnostic Tasks(s)
- Key Elements
- Patient Positioning
- Anatomic Coverage
- Radiation Dose Management
- Several References

AAPM Protocols – Lung Screening CT

- Covers 6 Manufacturers:
  - GE, Hitachi, Neusoft, Philips, Siemens, Toshiba
- 27 different scanner models
  - From 16 to 320 detector rows
- For some, fixed mA (with patient size adjustments) are described
- For others, AEC settings are described (which adjusts for patient size)
- Describes both acquisition and reconstruction parameters
- ALL Described techniques meet the Dose, Slice thickness and Breathhold requirements

LUNG CANCER SCREENING CT (Selected GE scanners)

(Back to INDEX)

SCOUT: AP S60-I400; scan from top of shoulder through mid-liver, if automatic exposure control is used.
PA scout if manual mA is used.

GE	LightSpeed 16 BrightSpeed 16	Optima 660	LightSpeed VCT	Discovery CT750 HD
Scan Type	Helical	Helical	Helical	Helical
Rotation Time (s)	0.5	0.6	0.5	0.5
Beam Collimation (mm)	10/20	40	40	40
Detector Configuration	16x0.625/ 16x1.25	64x0.625	64x0.625	64x0.625
Pitch	1.375	1.375	0.984	0.984
Speed (mm/rot)	13.75/ 27.50	55.0	39.37	39.37
kV*	120	120	120	120
mA*	60	50	50	50
SFOV	Large Body	Large Body	Large Body	Large Body
CTDIvol*	2.3/ 2.0 mGy	1.8 mGy	1.9 mGy	1.9 mGy
RECON 1				
Plane	Axial	Axial	Axial	Axial
Algorithm	Bone or Lung	Bone or Lung	Bone or Lung	Bone or Lung
Recon Mode	Full	Full	Full	Full
Thickness (mm)	1.25	1.25	1.25	1.25
Interval (mm)	1.25	1.25	1.25	1.25
ASIR (if used)	SS50	SS50	SS50	SS50
RECON 2				
Plane	***Axial DMPR-create Sag/Cor reformats	**Axial DMPR-create Sag/Cor reformats	**Axial DMPR-create Sag/Cor reformats	**Axial DMPR-create Sag/Cor reformats
Algorithm	Bone or Lung	Bone or Lung	Bone or Lung	Bone or Lung
Recon Mode	Full	Full	Full	Full
Thickness (mm)	0.625	0.625	0.625	0.625
Interval (mm)	0.625	0.625	0.625	0.625
ASIR (if used)	SS50	SS50	SS50	SS50

* For standard sized patient, defined as 5'7", 155 pounds. For small patients, mA may be reduced by as much as 50%; for large patients, mA may be increased by 50-100%

LUNG CANCER SCREENING CT (selected SIEMENS scanners)

(Back to INDE

TOPOGRAM: PA; scan from top of shoulder through mid-liver.

SIEMENS	Sensation 16	Emotion 16	Perspective 64	Sensation 64/ Definition DS (64)[a]
Software version	VB30	VB42	VC28	VB42/VA40
Scan Mode	Spiral	Spiral	Spiral	Spiral
Rotation Time (s)	0.5	0.6	0.6	0.5 / 0.33
Detector Configuration	16 x 0.75 mm	16 x 0.6 mm	*64 x 0.6 mm (32 x 0.6 mm = 19.2 mm)	*64 × 0.6 mm (32 x 0.6 mm = 19.2 mm)
Pitch	1.2	1.0	1.2	1.0
kV	120	110	110	120
Quality ref. mAs	25	20	25	25
CARE Dose4D	ON	ON	ON	ON
CARE kV	NA	NA	NA	OFF
CTDIvol***	1.9 mGy	1.6 mGy	2.0 mGy	1.8 / 1.7 mGy
RECON 1				
Type	Axial	Axial	Axial	Axial
Kernel	B50	B50	B50 I50, strength = 2**	B50 I50, strength = 2**
Slice (mm)	1.0	1.0	1.0	1.0
Increment (mm)	0.7	0.7	0.7	0.7
RECON 2				
Type	Axial MIP	Axial MIP	Axial MIP	Axial MIP
Kernel	B50	B50	B50 I50, strength = 2**	B50 I50, strength = 2**
Slice (mm)	20	20	20	20
Increment (mm)	2.5	2.5	2.5	2.5
RECON 3				
Type	Axial	Axial	Axial	Axial
Kernel	B31	B31	B31 I31, strength = 2**	B31 I31, strength = 2**
Slice (mm)	1.0	1.0	1.0	1.0
Increment (mm)	0.7	0.7	0.7	0.7
RECON 4				
Type	Axial MIP	Axial MIP	Axial MIP	Axial MIP
Kernel	B31	B31	B31 I31, strength = 2**	B32 I31, strength = 2**
Slice (mm)	20	20	20	20
Increment (mm)	2.5	2.5	2.5	2.5

* Indicates that a z-axis "flying focal spot" technique is used to obtain twice as many projections per rotation as detec
rows. This is referred to as IVR (Interleaved Volume Reconstruction) on the Perspective system.

LUNG CANCER SCREENING CT (selected SIEMENS scanners, continued)

(Back to INDEX)

TOPOGRAM: PA; scan from top of shoulder through mid-liver.

SIEMENS	Definition AS+ (128-slice)	Definition Flash (Dual source 128-slice)	Definition Force (Dual source 192-slice)
Software version	VA44	VA44	VA50
Scan Mode	Spiral	Spiral	Spiral
Rotation Time (s)	0.33 or 0.30	0.28	0.25
Detector Configuration	*128 × 0.6 mm (64 x 0.6 mm = 38.4 mm)	*128 × 0.6 mm (64 x 0.6 mm = 38.4 mm)	*192 × 0.6 mm (96 x 0.6 mm = 57.6 mm)
Pitch	1.0	1.0	1.0
kV	120	120	100Sn[c]
Quality ref. mAs	25	25	150[c]
CARE Dose4D	ON	ON	ON
CARE kV	OFF	OFF	Not applicable
CTDIvol***	1.7 mGy	1.7 mGy	0.5 mGy
RECON 1			
Type	Axial	Axial	Axial
Kernel	B50 I50, strength = 2**	B50 I50, strength = 2**	Bv49, strength = 2**
Slice (mm)	1.0	1.0	1.0
Increment (mm)	0.7	0.7	0.7
RECON 2			
Type	Axial MIP	Axial MIP	Axial MIP
Kernel	B50 I50, strength = 2**	B50 I50, strength = 2**	Br54, strength = 2**
Slice (mm)	20	20	20
Increment (mm)	2.5	2.5	2.5
RECON 3			
Type	Axial	Axial	Axial
Kernel	B31	B31	Br40, strength = 2**
Slice (mm)	1.0	1.0	1.0
Increment (mm)	0.7	0.7	0.7
RECON 4			
Type	Axial MIP	Axial MIP	Axial MIP
Kernel	B31	B31	Br40, strength = 2**
Slice (mm)	20	20	20
Increment (mm)	2.5	2.5	2.5

ACR Designated Lung Screening Center

- Announced Spring 2014 (934 facilities already)
- Unit-specific
- All sites applying for this designation must:
- Have active ACR CT accreditation in chest module on designated unit(s).
- AND meet the requirements described in the application
- (yes, it costs $400 per facility)

- http://www.acr.org/Quality-Safety/Lung-Cancer-Screening-Center

ACR Designated Lung Screening Center

- Application:
  - Site Information/Demographics, supervising physician and CT unit info
  - Attestation form
    - NOTE: No Phantom, No Clinical Images, No CTDI measurement spreadsheets (you're welcome!)
  - The facility's lung cancer screening protocol in a clinical data form
  - Fee

- http://www.acr.org/Quality-Safety/Lung-Cancer-Screening-Center

ACR Designated Lung Screening Center

- Attestation form
  - Recommended Screening Population
  - Personnel Qualifications
    - interpreting physicians
    - Medical physicists and radiologic technologists
  - Follow up System
    - structured reporting system
  - Smoking Cessation
  - CT Equipment
  - Quality Control
  - Imaging Protocol will be submitted (next slide)
  - Attestation that ACR-STR Practice Parameter has been reviewed and will be followed

- http://www.acr.org/Quality-Safety/Lung-Cancer-Screening-Center

ACR Designated Lung Screening Center

- Imaging Protocol submission form

LUNG CANCER SCREENING DATA FORM

PRIVILEGED and CONFIDENTIAL • PEER REVIEW

CTAP # _____ Unit # _____ **Site's CT scanner Serial number: _____**

CT scanner manufacturer: _____ **Model name: _____**

Nmax: Maximum number of axial images able to be acquired simultaneously in one rotation (Nmax): _____

Minimum tube rotation time: _____

Acquisition Series only (not reformatted series) NOTE: Standard sized patient (5'7", 154 pounds)	**Scan Sequence 1**
Anatomic scan coverage (start/stop locations)	
Single Breath hold/Full Inspiration (Y/N)	
Scan duration/Acquisition time (through entire lungs)	
kV for standard sized patient	
mA for standard sized patient (do not use mAs, effective mAs or mAs per slice)	
Time per rotation (s)	

Effective mAs (or mAs per slice) as displayed by scanner, for standard sized patient	
Automatic Tube Current Modulation Used (Y/N)	
If yes, list the name of the method (e.g. CareDose4D, Smart mA, Z-Dom, SureExposure, etc.) and Image Quality Reference Parameter (e.g. Noise Index, Quality reference mAs, etc.)	
Automatic kV selection Used (Y/N)	
If Yes, default kV for standard sized patient	
Scan FOV (cm) *Must be reported in cm.*	
Display FOV 1 cm beyond the rib cage (Y/N)	
Reconstruction algorithm/method: conventional (e.g. filtered backprojection) or advanced (e.g. iterative or other advanced)	
Reconstruction parameters: For conventional list the recon filter or kernel name; For advanced, list the recon parameters (e.g. %ASIR, Strength, etc.)	

Detector configuration: Number of data channels actively used (N)	
Detector configuration: Nominal width of each data channel (T, in mm)	
Table feed per 360 degree rotation of the x -ray tube (e.g. table speed, table feed, etc. in mm/rot) - I	
Pitch (IEC definition) Pitch = I/N * T	
Nominal width of reconstructed image along the z axis (e.g. thickness, slice width, in mm, reconstructed scan width (mm)	
Distance between two consecutive reconstructed images (e.g. interval, increment, spacing, in mm, reconstructed scan interval (mm)	
MIPS/MPRs (Y/N)	
CTDIvol (recorded after scanning)for a standard sized patient, using 32 cm CTDI phantom	
DLP (Dose length product) for standard sized patient	
Size specific protocols used (Y/N)	
If Yes, describe method (e.g. manual adjustment, automatic adjustment such as CareDose4D, DoseRight ACS, Smart mA, intelliEC, etc.)	

Data Elements for Registry

- CMS required only the CTDIvol element to be included in the data to be submitted to the registry.
- My suspicion is that most sites will just write this down or do a manual data entry
- But we should not settle for that.
- I will be working with ACR Data Registry to:
  - Accept this required field
  - Allow for expansion to:
    - DLP
    - SSDE (when it becomes available)
    - WED (when it becomes available)
- Remember that as of Jan 2016 your CT scanners must meet XR-29 to receive full Medicare Reimbursement
- This includes RDSR
- Let's DEMAND that manufacturer's implementation of RDSR contain these desired elements (CTDIvol, DLP, WED, SSDE).

Summary

- Low Dose Lung Cancer Screening has been demonstrated to reduced lung cancer related mortality.
- Recently recognized by the broad medical community as a valuable technique in reducing Lung Cancer Mortality
- Now being covered by private and public insurers for the proper patient populations.
- Medical Physicists have an important role to play in the deployment of this practice

Summary

- AAPM has provided substantial resources to its members, to radiologists and primary care physicians to ensure scans are performed with low dose and reasonable image quality
- ACR's Designated Lung Screening Program is one program facilities can utilize to demonstrate that they meet criteria in the practice of lung cancer screening.