2014 AAPM Scientific Meeting

Quantitative Imaging Symposium

Quantitative Imaging:
Techniques, Applications, and Challenges
Modality Specific QI: CT

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- Instructor, CT Physics course, UT-MD Anderson Cancer Center

Example: How Big Is This Lesion?

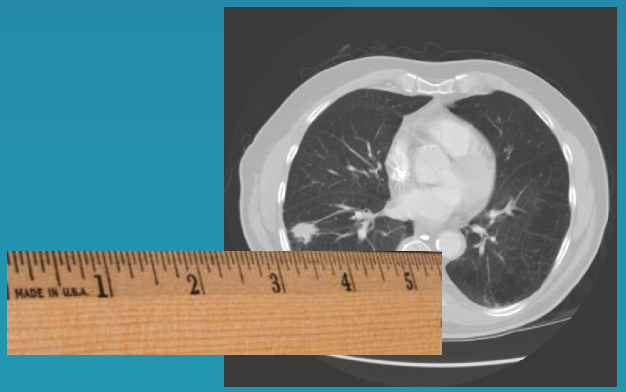
What size metric should we use? Currently use one or two linear measurements

Quantitative Imaging

- What does it take to make Imaging Quantitative?
- Go from making an Image

- To

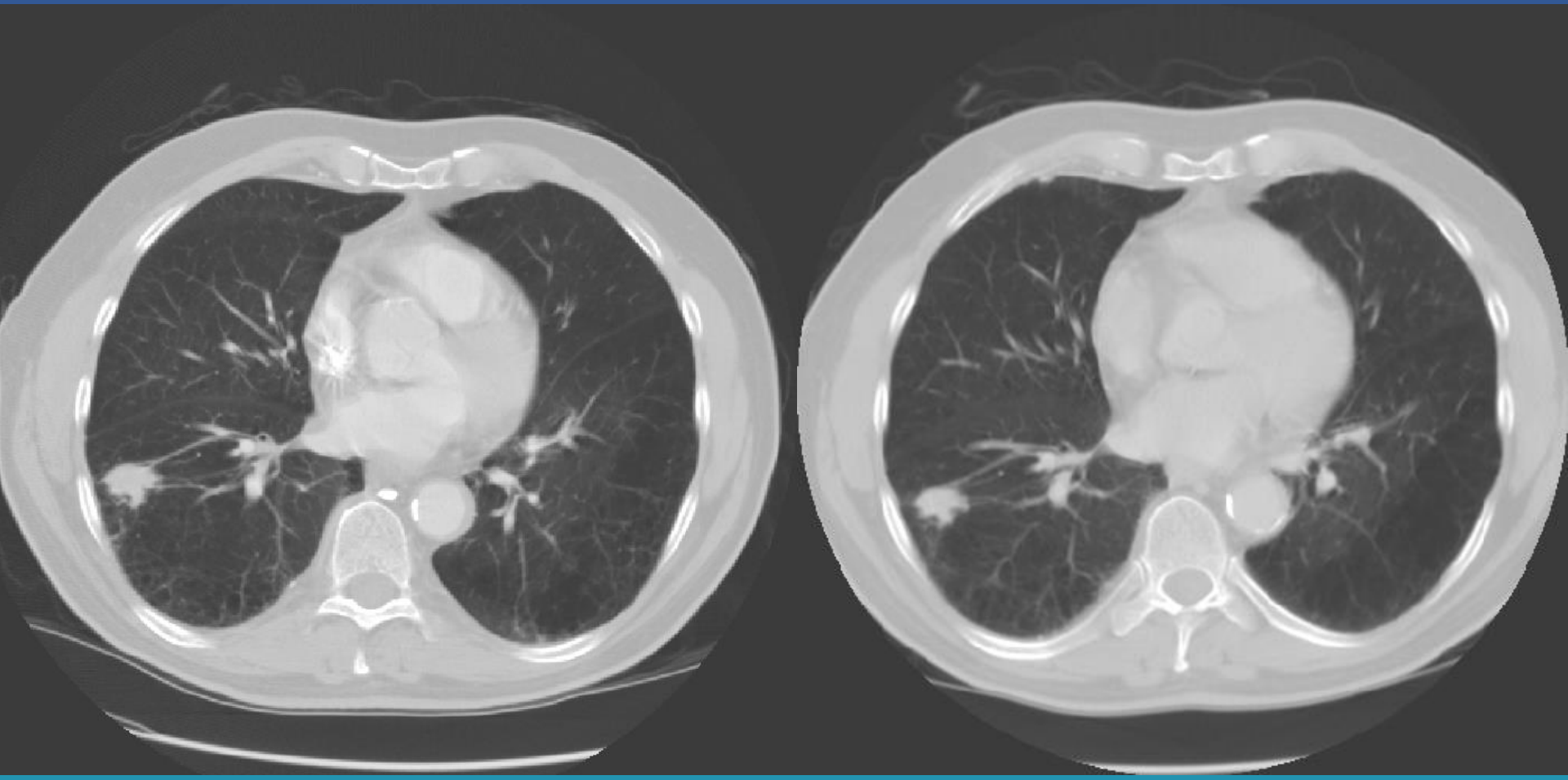
- Making a Measurement



Example: How Big is This Lesion?

What size metric should we use? Currently use one or two linear measurements

Example: Did Lesion Change in Size?



Time 1

Time 2

Measurements

- Should have “minimal” bias
  - Should provide a good estimate of true value
  - No consistent offset (no overestimate, no underestimate)
- Should have “minimal” variance
  - Random effects
  - Non-random effects
- Should be repeatable and reproducible

Terminology

From Recent QIBA Annual Meeting

"Ten Things to Remember from the QIBA Metrology Workshop" by Nancy Obuchowski, PhD

"1. Do not use *repeatability* and *reproducibility* interchangeably"

Repeatability

- This is the *within-subject* variability
- It is the agreement between measurements made within a short period of time (test-retest) holding variables constant
  - Example: Coffee Break Experiments
- Includes variability due to scanner adjustment, image noise, subject positioning

Reproducibility

- The observations are performed on the same subject (usually) over a short period of time, ***but the location, operator and/or measuring system differs***

Examples of Desired Quantitative Imaging Applications

- Screening followup – once a nodule has been detected, the growth of that nodule over time has been suggested as metric to identify cancers.
- Assessing individual responses to therapy
  - Detect small changes and make early decisions about whether therapy is working or not
- Developing / testing new therapies
  - Again, detect small changes and make early decisions about whether therapy is working or not

CT to Measure Change

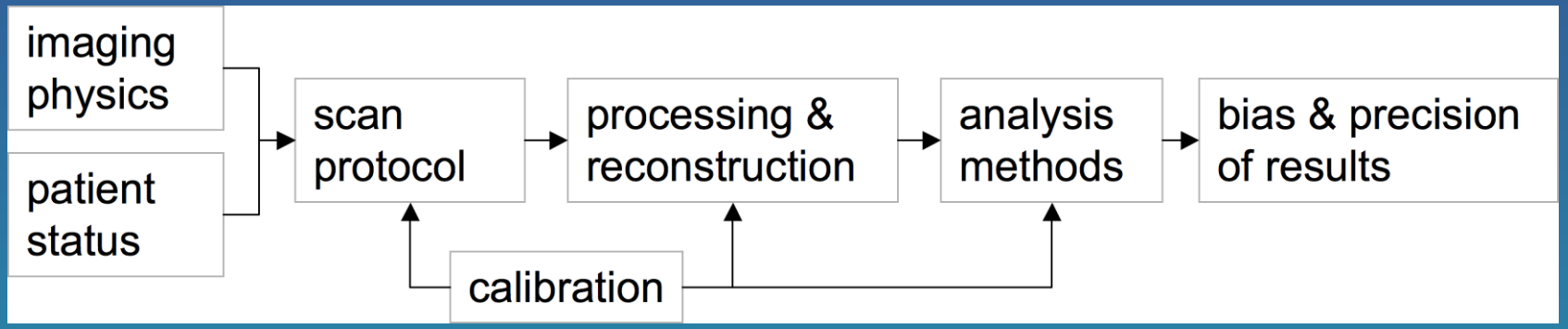
- Change in Size
- Change in Density
- Change in Texture
- Change in Function (Perfusion, etc.)

- Can we measure these Changes Reliably?
  - Good enough to aid Dx?
  - Or Assess Treatment Efficacy?

CT to Measure Change

- Can we do this in a robust fashion
  - Across scanners
  - Across centers
  - Across patients (with similar condition/disease)

Workflow to Measure Change



CT Imaging Physics Considerations

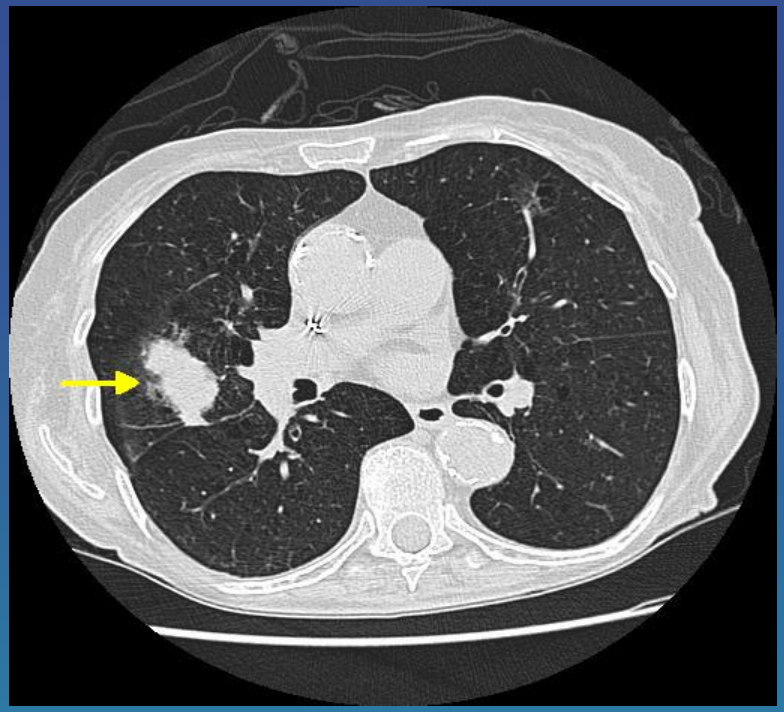
- Scanner Design
  - Geometry e.g. Number of Detector Rows
- Scanner Operation
  - kV, mAs, pitch
- Image reconstruction
  - Reconstructed Image Thickness
  - Reconstruction Filter
  - Reconstruction Method (FBP vs. IR)

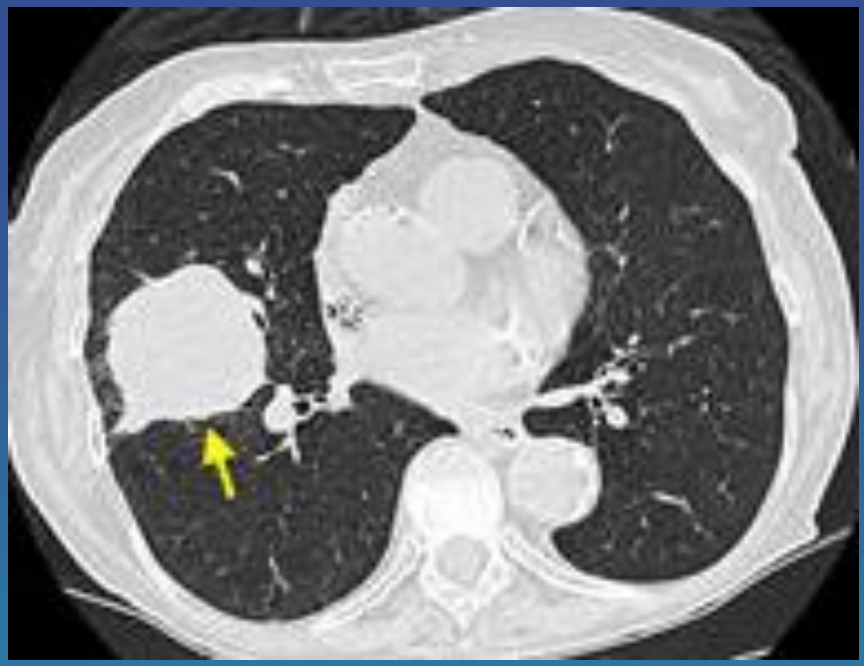
Patient Considerations

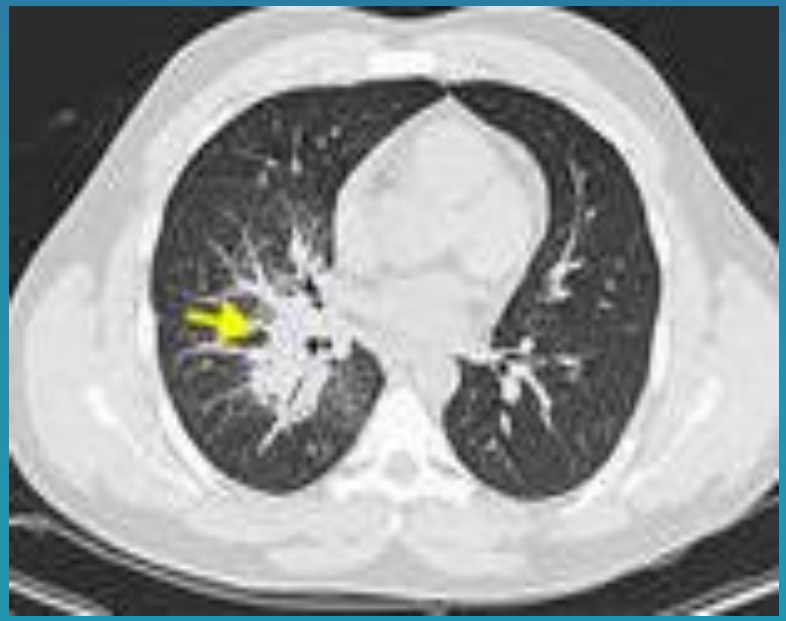
- Health Status of Individual patient
  - Ability to breathhold if required
  - Ability to use oral or IV contrast
  - Ability to perform study without motion
- Abnormalities and Concomitant Disease
  - Inflammation which may mask progression
  - Patient Health Status during trial

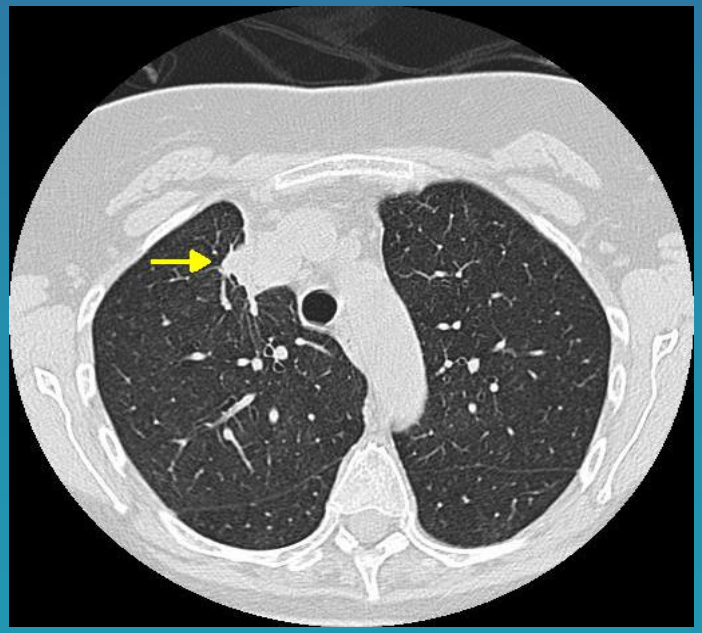
Tumor Related Considerations

- Complexity of Tumor
  - Shape (Spherical or Complex) can make determining boundaries “difficult” (i.e. not reproducible)
  - Location
  - Physiology (contrast uptake, washout)





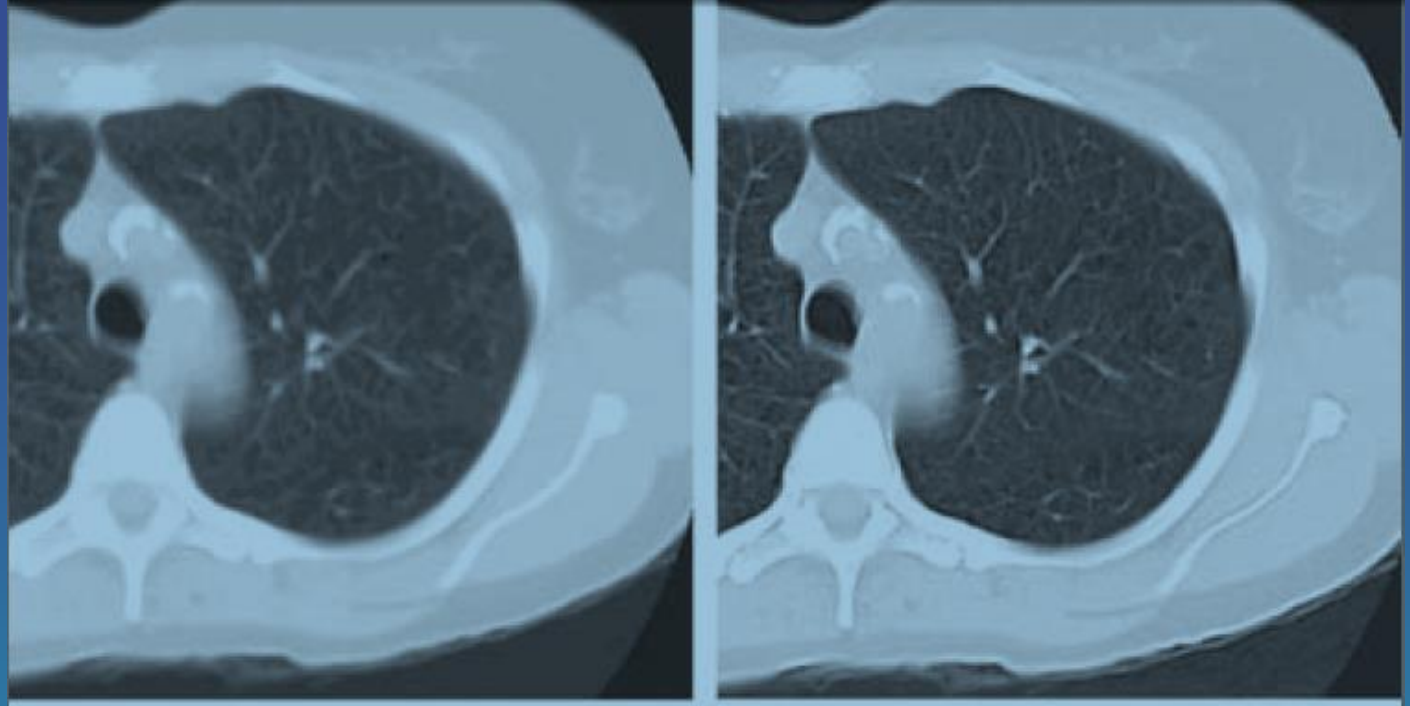




Processing and Reconstruction

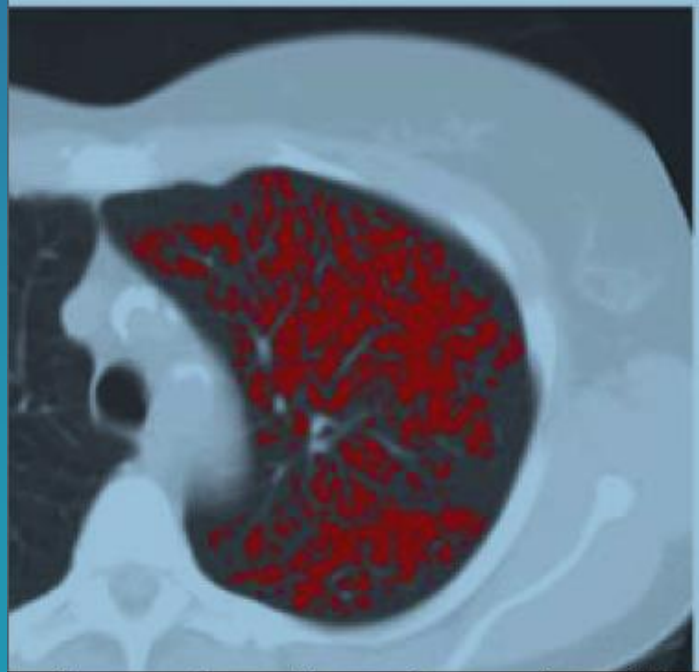
- Reconstructed image thickness
- Reconstructed image interval
- Reconstruction filter

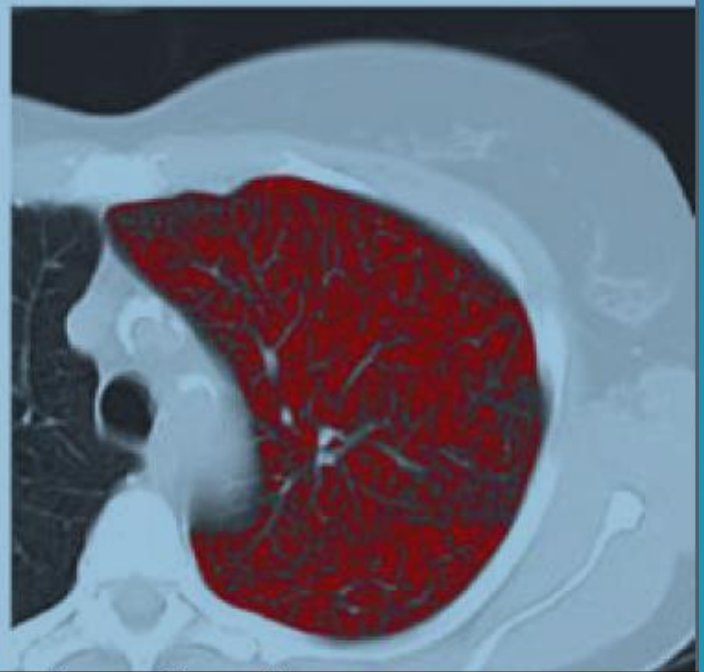
- Resolution and Noise



a.

b.





Analysis Method

- Fully Automated
- Some human intervention
  - Radiologist measuring diameter
  - Contouring boundary
- Measurement itself
  - Diameter
  - Volume
  - Mass/density
- Registration method if change is measured

Tumor Related Considerations

- Complexity of Tumor
  - Shape (Spherical or Complex) can make determining boundaries “difficult” (i.e. not reproducible)
  - Location
  - Physiology (contrast uptake, washout)

Underlying Issues

- Measurements need some standardization
- Who is responsible for each of these parts
  - Manufacturers
  - Physicians
  - Technologists
  - Physicist
- Each has a role along this measurement path

Some Attempts at Standardization

- National Lung Screening Trial (NLST)
- Protocol Chart
- ACRIN 6678
- COPD/Gene

From Cagnon et al Academic Radiology, 2006

RSNA's Quantitative Imaging Biomarker Alliance (QIBA)

- CT committee
  - Tumor Volumetrics (Change in tumor size)
  - Lung Density (COPD)
- Some experiments to
  - help identify sources of variance (and bias)
  - Mitigation measures
- Develop a "Profile" to describe best practices in making tumor volumetric measurements

Phantom Measurements of size

See Petrick et al. Acad Rad. 2014

Lessons

- For Spherical Lesions
  - Diameters and thick slice images are good enough
- For non-Spherical Lesions
  - Thin section images and volumetrics are better than diameters, even at thin sections

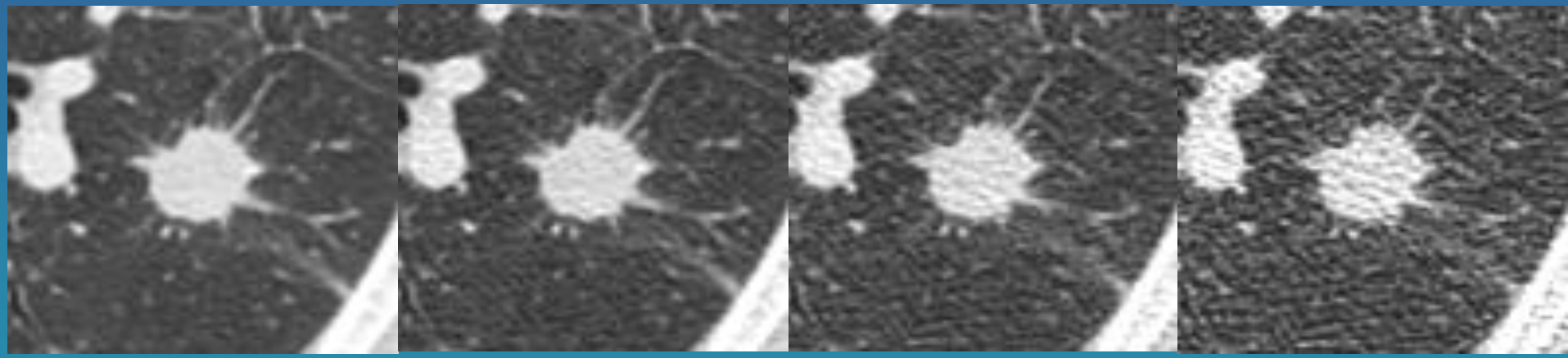
Immediate/Future Challenges

- Technological Advances
  - Iterative Reconstruction (Dose reduction)

What Are Effects of Reducing Dose?

Clinical Dose

Reduced Dose



Measuring Size?
Measuring Density?
Measuring Texture?

Conclusions for Quantitative Imaging for CT

- Making an image to making a measurement
- LOTS of variables (scanner, patient)
- To make a measurement, need standardization
  - Not complete and rigid standardization
  - But that reduces variance in measurement
- Some significant efforts to address this
  - RSNA QIBA

Conclusions for Quantitative Imaging for CT

- Immediate Goal
  - Reduce Variance
  - Reducing Bias too, but harder to assess
- Rewards:
  - More precise assessments
  - Tighter tolerances
  - Earlier detection of change
  - Smaller sample sizes

(Partial) Reading List

- Goodsitt, M.M., H.P. Chan, T.W. Way, S.C. Larson, E.G. Christodoulou, and J. Kim, *Accuracy of the CT numbers of simulated lung nodules imaged with multi-detector CT scanners.* Med Phys, 2006. **33**(8): p. 3006-17.
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- 3A-Working-Group. *Study 3A: Inter-method Study with Test-retest Clincal Data: Study Design Second Challenge* 2013; Available from: http://qibawiki.rsna.org/images/7/7b/3A_study_design%2C_second_challenge%2C_0.3.PDF.
- Petrick N, Kim HJ, Clunie D, Borradaile K, Ford R, Zeng R, Gavrielides MA, McNitt-Gray MF, Lu ZQ, Fenimore C, Zhao B, Buckler AJ. Comparison of 1D, 2D, and 3D nodule sizing methods by radiologists for spherical and complex nodules on thoracic CT phantom images Acad Radiol. 2014 Jan;21(1):30-40. doi: 10.1016/j.acra.2013.09.020.