QIBA Quantitative CT: Reliability of Reader-based Quantification Methods – Phantom and Clinical Datasets

Anthropomorphic Phantom Data Having Synthetic Lung Nodules

Aim

Estimate intra- and inter-reader bias & variability for the task of measuring phantom lesion size through a reader study

Compare

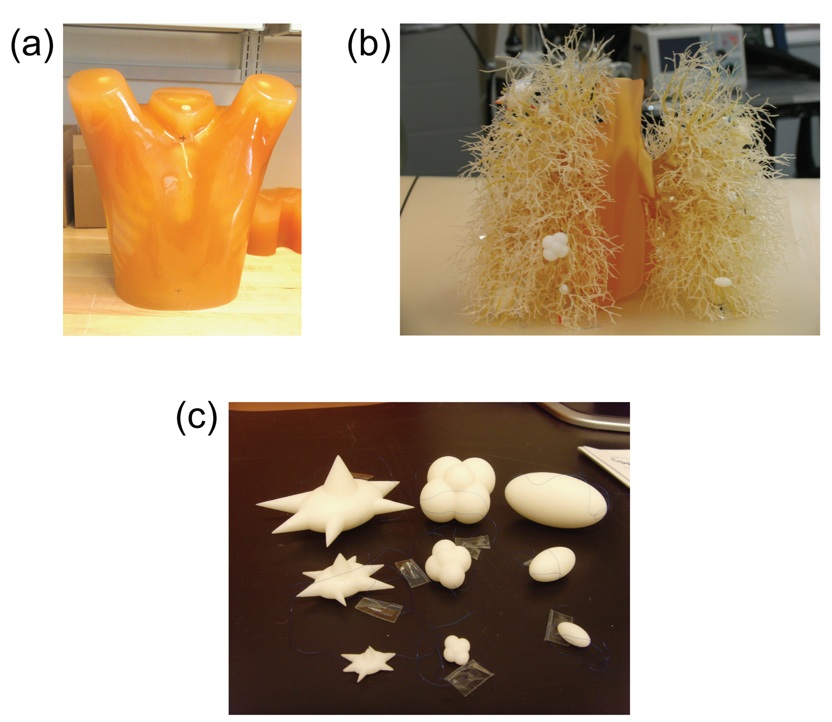
- Manual 1-D (RECIST)
- Manual 2-D (WHO)
- Semi-automated 3-D volume measure

Anthropomorphic Phantom

Reader study used CT data from thorax phantom with imbedded synthetic nodules

10 Phantom Nodules

- Densities: -10HU, +100HU
- Shapes:
  - Spheres: 10, 20 mm diameters
  - Lobulated: Volume of 10 mm sphere
  - Spiculated: Volume of 10 mm sphere
  - Elliptical: Volume of 20 mm sphere

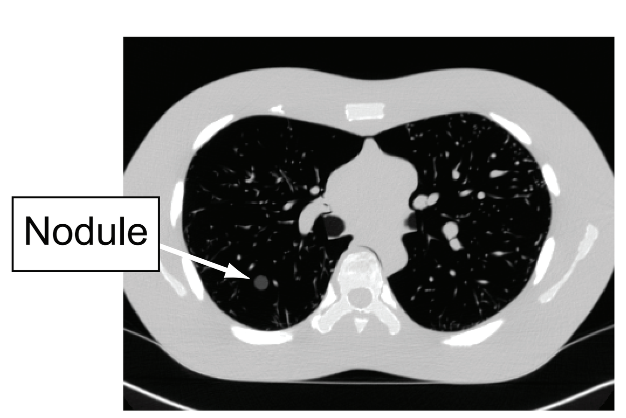


Anthropomorphic phantom (a) exterior, (b) insert with attached nodules, and (c) aspheric nodules used in the reader study

Acquisition of CT Data

40 CT data sets

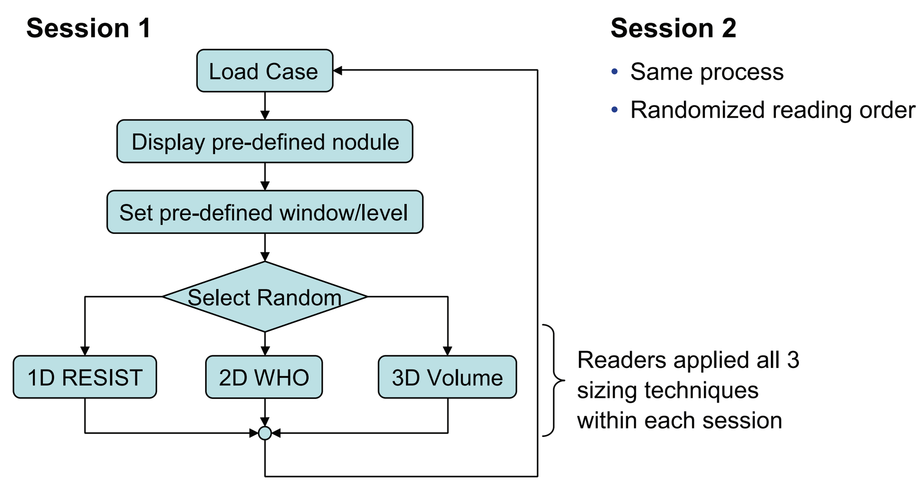
- Scanner: Philips 16-slice MxIDT 8000
- Exposure: 120 kVp, 100 mAs
- Slice thick: 0.8 mm, 5.0 mm
- Recon kernel: detailed filter
- Repeats: 2 for each nodule type



Case 4467

Reader Study Design

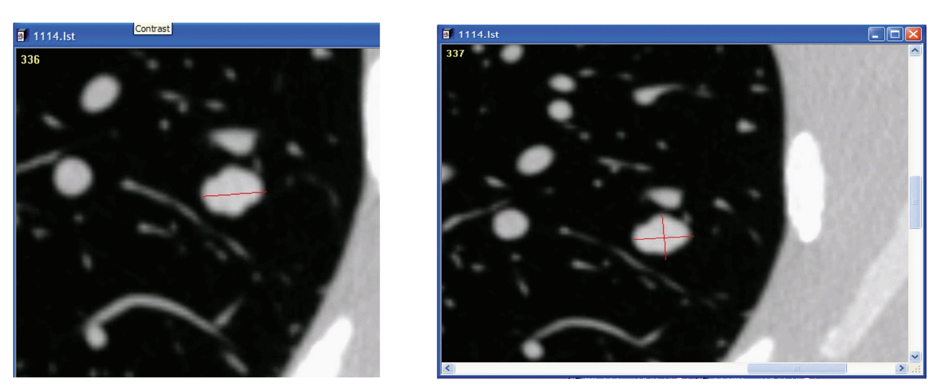
6 radiologists measured each nodule with each sizing technique in 2 reading sessions



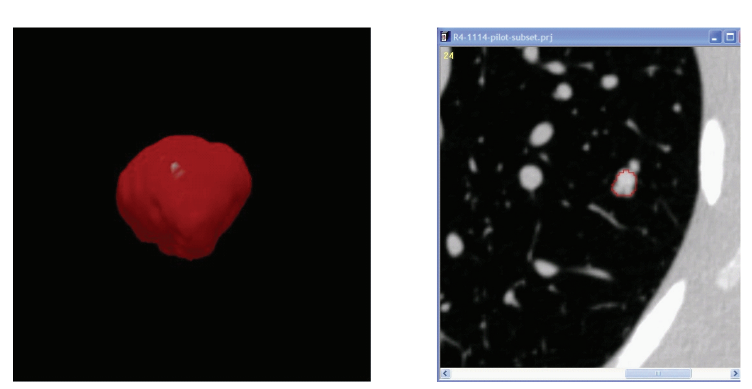
Nodule Sizing by Readers

10 mm Lobulated Nodule

- True size: 12.6 mm X 11.3 mm
- True volume: 520 mm³



Reader 4 RECIST: 11 mm   Reader 4 WHO: 12 mm X 10 mm



Reader 4 Semi-automated volume: 660 mm³

Next Step: Image Analysis of Data

- Estimate bias
- Estimate intra- & inter-reader variability
- Determine significant nodule & acquisition factors through ANOVA

Patient Datasets for Comparing Nodule Sizing Methods

Aims

1. Investigate the min detectable level of change in patient datasets under a "No Change" condition
2. Investigate both bias and variance of both readers and algorithm-assisted readers in measuring volumes, diameters and bi-directional diameters of lesions from Patient datasets

Methods for Experiment 1

Patient Datasets - MSKCC RIDER Coffee Break Experiment

- 32 NSCLC Patients
- Scanned twice over a period < 15 minutes (No Change)

Image Acquisition Protocol

- Same low dose acquisition for both scans
- 1.25 mm slice thickness

Measurements

- 5 readers measure:
  - Longest Diameter as well as Perpendicular Diameter
  - Volume (algorithm assisted)
  - Repeat measurements

Planned Analyses

Variability between different measures (e.g. Volume vs. Diameter)

Intra and inter-reader variation

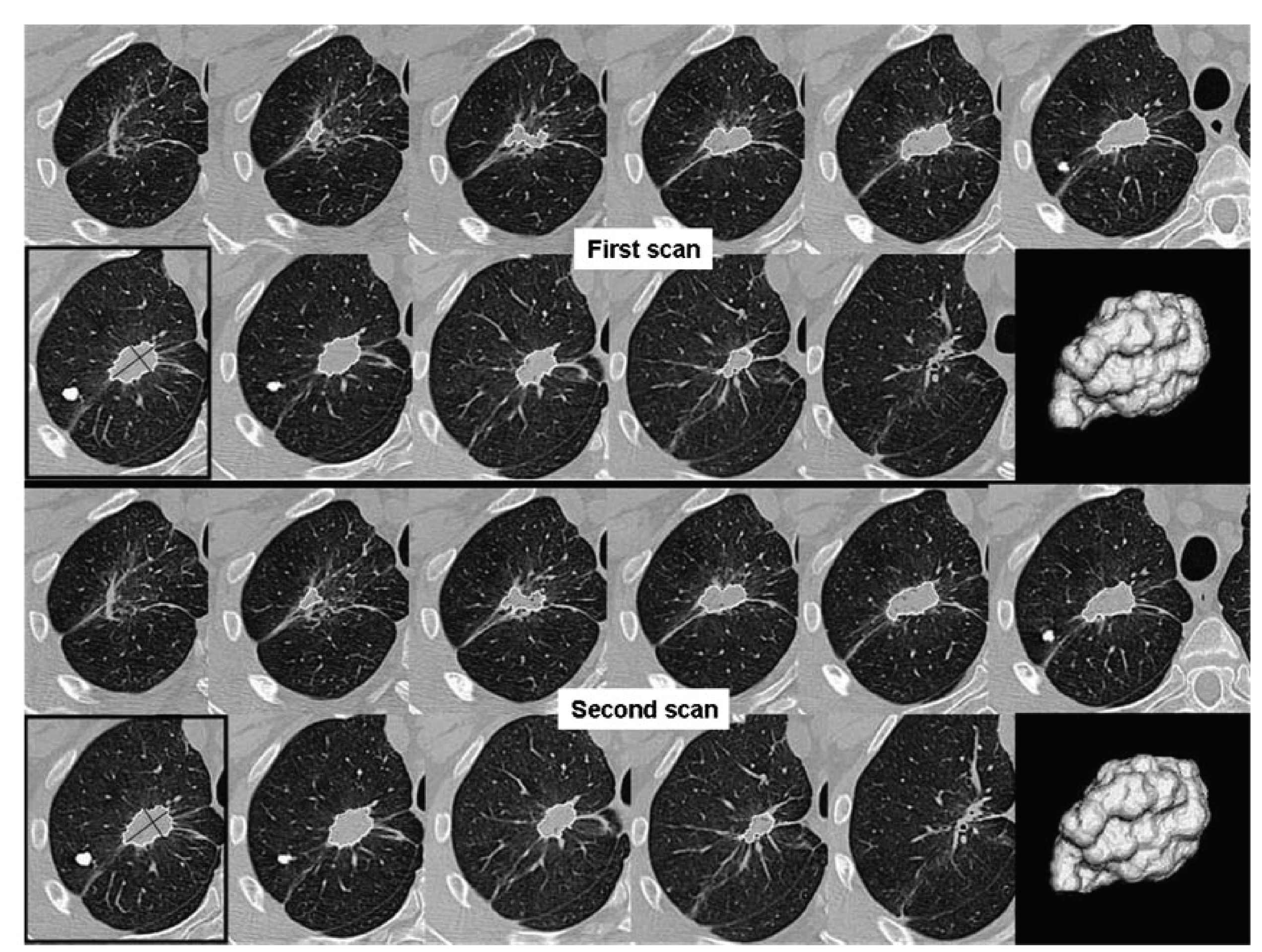


Figure 3 from Zhao et al (Radiology 2009) which shows the same peripheral tumor imaged as part of the coffee break experiment.

Images are shown with computer-generated contours (white lines), two maximal perpendicular diameters (black lines, lower left image), and 3-D views (lower right image).

Differences for this specific case were: 1-D 0.7%, 2-D 0.4%, 3-D 5.3%.

Cross-scanner Imaging of Anthropomorphic Phantom

Aims

1. Determine the effect of CT manufacturer on reader measurement of volume under conventional cross-manufacturer protocol.
2. Develop cross-manufacturer quality measures and determine the impact of leveling quality on uncertainty in nodule sizing.
   - Study protocol to apply **QIBA Volume CT Profile** for nodules and collection parameters appropriate to late-stage lung cancer.
   - Study is to achieve specified quality using ACR phantom imagery and to read lesion sizing on anthropomorphic phantom imagery.

Two Branches of 1-C Protocol

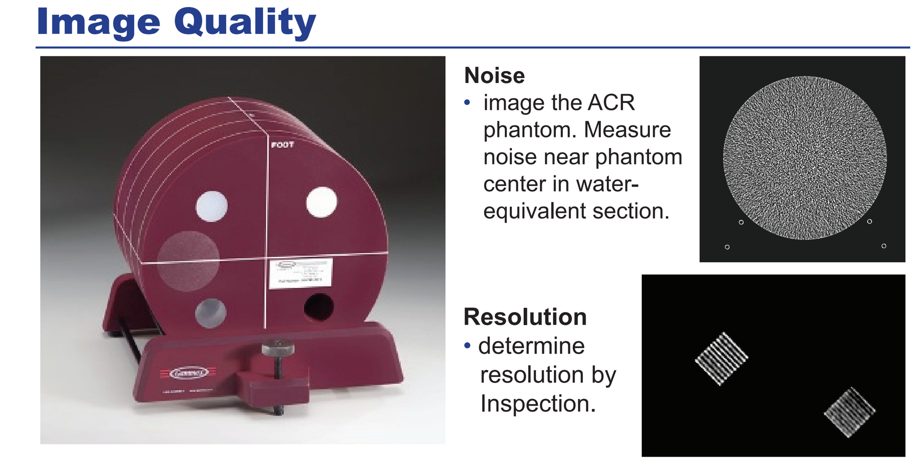
Current-practice Branch

- Specifies narrow range of parameters for each manufacturer's devices, akin to ACRIN 6678.
- Using ACR phantom, measure image quality (resolution and noise, see below).

Performance Branch of 1-C Protocol

- Specifies easily implemented **performance** metrics of resolution and noise
  - Guidance provided on:
    - kVp (affects contrast difference between materials)
    - Slice thickness, recon interval (affects z-axis resolution & noise)
    - Rotation time and pitch (coverage, breath hold, etc.)
  - Performance required on:
    - Recon kernel performance – for example:
      - Choose kernel so you can resolve 7 (but no more than 7) lp/cm on the ACR phantom
    - mA level performance
      - Choose effective mAs level so that, in the water-equivalent section of the ACR phantom, the standard deviation is between 10 and 12 HU

Use of the ACR CT Phantom to Measure Image Quality



Planned Markup and Analysis

1. Readers make algorithm-assisted measurements of Longest Diameter, Perpendicular Diameter, & Volume.
2. Analyze to determine the effects of CT device, image quality, reader, etc. on the variance and bias of the three measurements.

COPD-Asthma Project

CT measurement of lung density & airway morphology

Lung Density

CT measurement of lung have been used in clinical trials to evaluate the progression of emphysema. These trials have demonstrated that lung density of patients with emphysema decrease 1-2% per year. The clinical trials are most effective when repeated measurements on individuals using the same CT scanner, because scanner CT numbers are not consistent from scanner to scanner. The clinical trial researchers believe that lung density measurements will be useful for evaluations of individual patients when:

1. Standard acquisition protocols are used, e.g. slice thickness.
2. Specialized calibration procedures for low CT numbers are used. These are two of the goals of COPD-Asthma Project.

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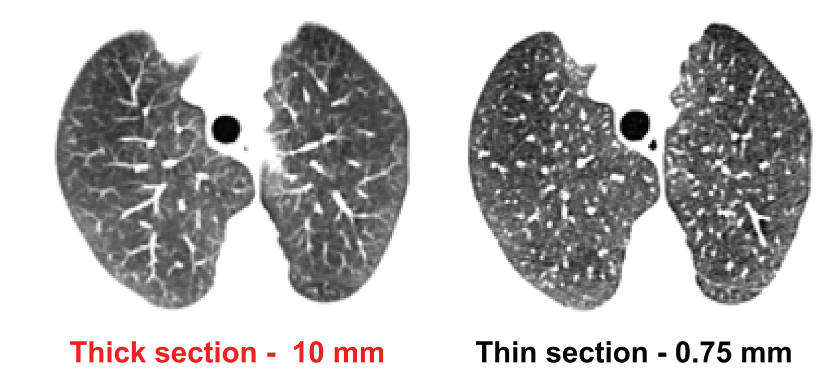
Lung density metrics are determined from the histogram of lung CT numbers. The shape of histograms and histogram parameters are altered by slice thickness.



Airway Morphology

Airway wall parameters measured on CT can provide an index of COPD and asthma severity. However, bronchial lumens and walls are small structures. In particular, bronchial walls are rarely more than 1.2 mm in width, corresponding to about 2 pixels, limiting the precision of measurement. The effects of scanner variations are probably small when effects of the spatial resolution of CT scanner are determined. The strategy to develop an accurate and precise measurement of airway size will be similar to the methods developed in QIBA's Volumetric CT project to develop profiles to measure lung tumor size. The COPD-Asthma Project will determine the precision of airway wall parameters using phantoms.

Histogram of Lung CT Images