

Evaluation of 1D, 2D and 3D nodule size estimation by radiologists for spherical and non-spherical nodules through CT thoracic phantom imaging

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Outline

- Objectives
- Study Design
 - Dataset
 - Reading protocol
 - Analysis method
- Results
- Summary

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QIBA

- Quantitative Imaging Biomarker Alliance (QIBA)
 - To investigate the role of quantitative imaging methods as potential biomarkers in evaluating disease and responses to treatment
 - Current Technical Committees
 - Volumetric CT (vCT)
 - COPD CT
 - DCE-MRI
 - fMRI
 - FDG PET-CT

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Objectives

- Overall Objective of QIBA vCT Effort
 - To develop groundwork data evaluating quantitative CT tumor sizing methods as imaging biomarkers
 - Clinical Trials
 - Clinical Practice
- Current study is QIBA vCT Part 1A groundwork effort
 - Objective
 - To estimate bias/variance of radiologists estimating the size of synthetic nodules from CT scans of an anthropomorphic phantom

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Dataset (Nodules)

- 10 synthetic nodules
 - 5 shapes X 2 densities
- Shape (volume equivalent to sphere of given diameter)
 - 10 mm Sphere
 - 20 mm Sphere
 - 20 mm Ellipsoid
 - 10 mm Lobulated
 - 10 mm Spiculated
- Density
 - -10 HU
 - +100HU



Spherical



Ellipsoid

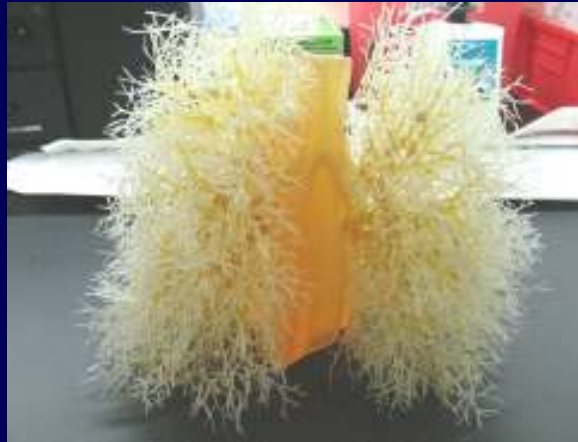


Lobulated



Spiculated

Dataset (Thorax Phantom)



Anthropomorphic thorax phantom (Kyotokagaku Incorporated, Tokyo, Japan)

Dataset (Nodule Attachment)

- Nodules attached to synthetic vasculature



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Dataset (CT Scanning)

- CT Scanner
 - Philips 16-slice MxIDT 8000 scanner
- Acquisition Parameters
 - Exposure (120 kVp): 100 mAs/slice
 - Pitch: 1.2
 - Recon kernel: Detailed
 - Slice thickness (50% overlap):
 - 0.8 mm (16X0.75 collimation)
 - 5.0 mm (16X1.5 collimation)
 - Repeat Exposures: 2 scans for each nodule

Dataset

- 40 total datasets for segmentation
 - 10 nodules X 2 slice thickness X 2 repeat scans

Reading Protocol

- Reader
 - 6 radiologists
 - Familiar with evaluating lesion response in drug trials
- Sizing Methods
 - 1D technique (linear distance)
 - Largest in-slice diameter for the lesion
 - Based on RECIST criteria
 - 2D technique (area)
 - Largest in-slice diameter for the lesion
 - Largest perpendicular diameter within same slice
 - Based on WHO criteria
 - 3D technique (volume)
 - Semi-automated volumetric measurement tool

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Reading Protocol

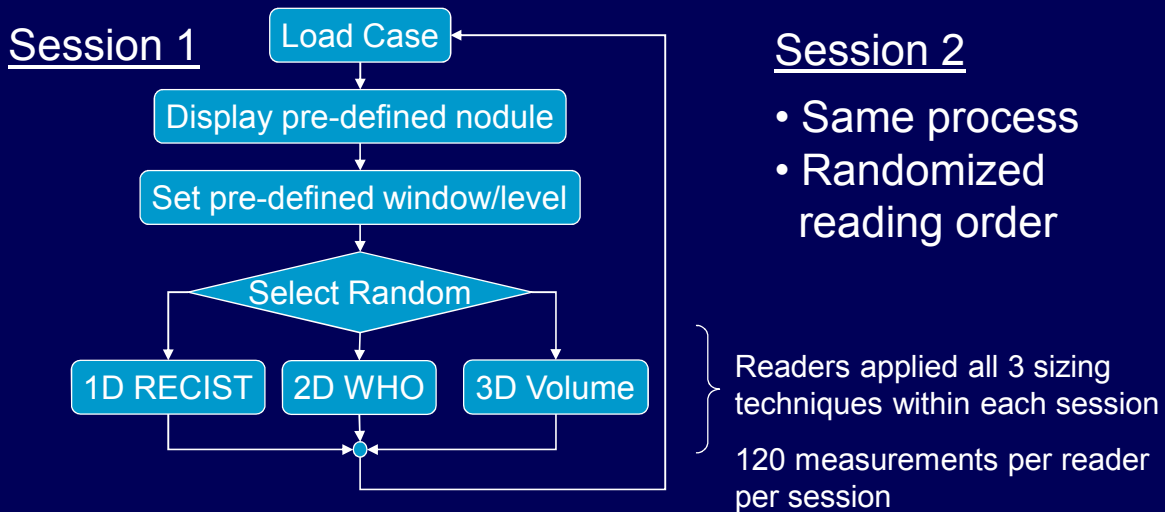
- 3D sizing protocol
 - 1) Define seed strokes
 - 2) Apply segmentation tool
 - 3) Evaluate quality of segmentation
 - 4) Refine (adding/subtracting) seed strokes & segmentation
 - 5) Repeat 3-4 until reader satisfied
- Software provided volume estimate

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Reading Protocol



Reading Protocol

- All readings sessions took place at CRO central facility
 - Proprietary software application
 - Consumer color LCD monitors
 - DICOM Grayscale Standard Display Function calibration
 - Lung window/level (1200 HU/-600 HU)
- Each measurement technique was independently applied (readers did not see their previous measurements concurrently)

Analysis

- Compare bias/variability between methods

$$Size_{Rel} = \frac{Size_{Est} - Size_{True}}{Size_{True}} \bullet 100\%$$

$$Bias_{Rel} = Bias(Size_{Rel})$$

$$Std_{Rel} = \frac{Std_{Est}}{Size_{True}}$$

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Truth

- 1D
 - Longest diameter (calipers)
- 2D
 - Longest diameter (calipers)
 - Longest perpendicular diameter (calipers)
- 3D (weight-density method)
 - Measured weight (precision scale)
 - Density (from manufacturer)

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Regression Model

- Mixed-effects linear regression
 - Model relative bias
 - **Fixed Effects**
 - Nodule shape/size, nodule density, slice thickness
 - **Random effect**
 - Readers
- Compare bias
 - 1D vs. 2D
 - 1D vs. 3D
 - 2D vs. 3D

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Example Case

- 10 mm spiculated
 - True longest diameter
 - **22 mm**
 - True area
 - **343 mm²**
 - True volume
 - **529 mm³**

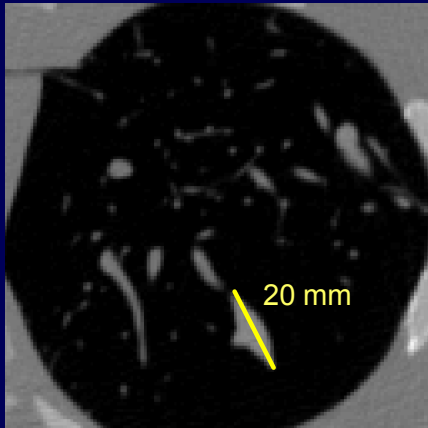


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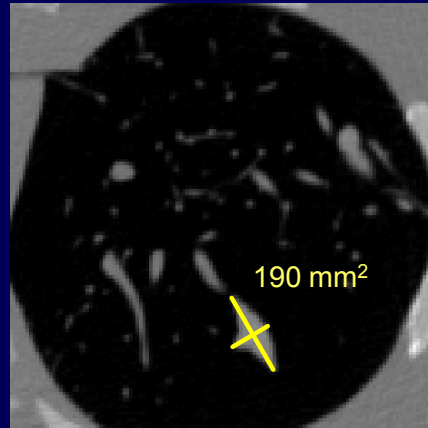
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Example Case

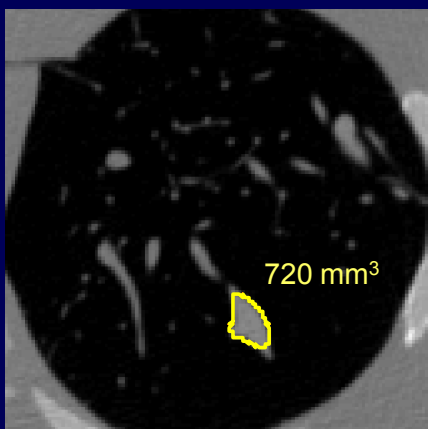


1D Size_{Rel} = -9.1%

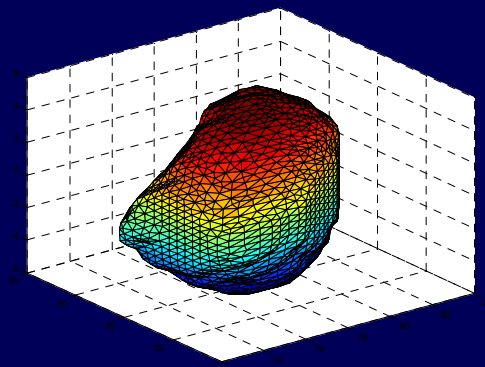


2D Size_{Rel} = -44.6%

Example Case



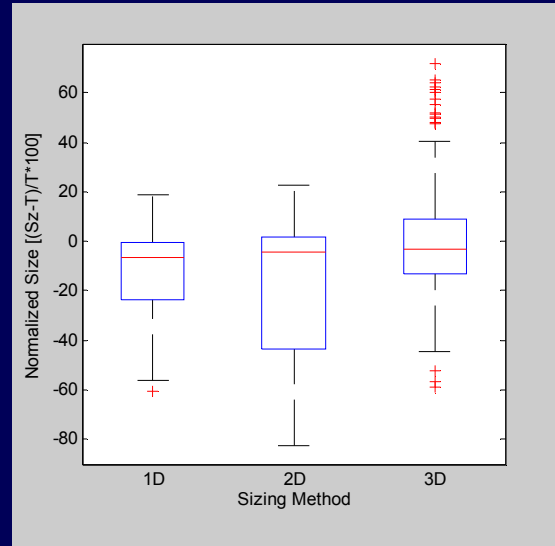
3D In-slice



3D Size_{Rel} = +36.1%

Combined Results

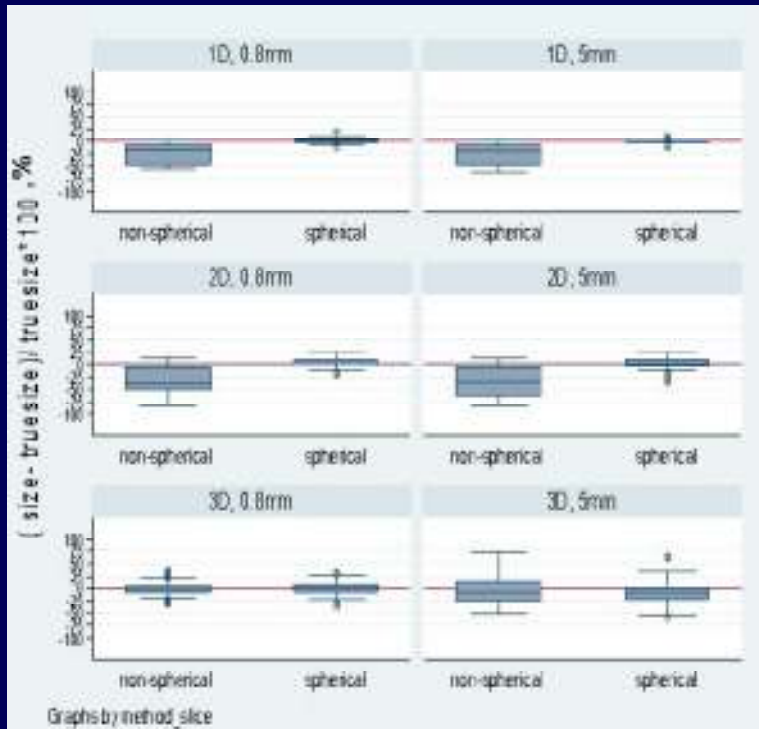
Size Method	Relative Bias	Relative Std. Deviation
1D	-14.6%	20.4%
2D	-18.8%	28.3%
3D	-1.3%	21.9%



Comparison of Biases

- 1D vs. 2D
 - -14.6% vs. -18.8%, $p < 0.001$
- 3D vs. 1D
 - -1.3% vs. -14.6%, $p < 0.001$
- 3D vs. 2D
 - -1.3% vs. -18.8%, $p < 0.001$

- By shape
 - Spherical
 - Non-spherical
- And slice thickness
 - 0.8 mm
 - 5 mm



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Bias and Variance

Size Method	Spherical Nodules		Non-spherical Nodules	
	0.8 mm	5.0 mm	0.8 mm	5.0 mm
1D	2% (± 5)	0% (± 4)	-23% (± 20)	-27% (± 21)
2D	4% (± 10)	0% (± 11)	-33% (± 26)	-33% (± 29)
3D	1% (± 12)	5% (± 23)	0% (± 14)	-2% (± 30)

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Summary

- 3D volume provides a low bias estimate of nodule volume
 - For spherical and non-spherical nodules
 - 1D and 2D low bias only for spherical nodules
- Variance analysis shows similar relative precision between 1D & 3D
 - 2D method larger relative standard deviation
- **3D volume at 0.8 mm slices, low bias and low variance**
 - Independent of shape

Future Work

- Statistical analysis stratified by nodule and CT acquisition characteristics
- Statistical comparison of precision (variability)
 - Intra- and inter-reader
- Analysis of reader segmentation data
 - STAPLE or similar type of analysis

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