Why Quantitative Imaging is Important to CT & How QIBA is Addressing This Need in 2019:1

Jocelyn Hoye, BS; Nancy Obuchowski, PhD; Ehsan Samei, PhD; Jenifer Siegelman, MD, MPH; Rudresh Jarecha, MBBS, DMRE, DNB; Samuel G. Armato, III, PhD; David Gierada, MD; James L. Mulshine, MD

Quantitative Imaging Biomarkers Alliance® RSNA®

Simulated Lesions for Thoracic CT Volumetry: The Results of an International Challenge

Reference CT image datasets containing lung nodule models were for both physical phantoms and clinical patient cases by creating hybrid datasets using three different methods. The nodules were analyzed by 17 international groups that each applied volume estimation algorithms to both real and hybrid images with nodules.

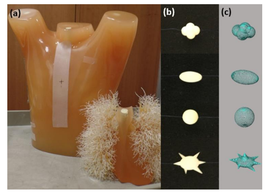

Fig. 1. (a) An anthropomorphic lung phantom with lesions imbedded (b). (c) Computational versions of the lesions were created for simulations.

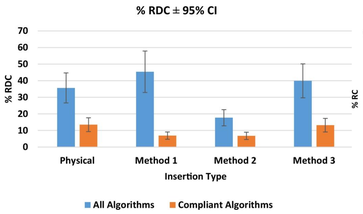

Fig. 2. The reproducibility coefficient (%) for all algorithms (blue) and compliant algorithms (orange) applied to the phantom data for all three methods of hybrid CT image creation.

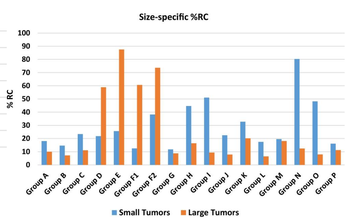

Fig. 3. The reproducibility coefficient (%) for all algorithms applied to the clinical data for small tumors (blue) and large tumors (orange).

Robins et al, Academic Radiology *2018*

Minimum Detectable Difference of Morphological Features

Purpose: to quantify the minimum detectable difference in radiomics features from one imaging condition to another based on measured radiomics features from pairs of sequentially synthesized CT images acquired under variable CT scan settings.

Motivation: oftentimes patients are imaged for follow-up after treatment on different scanners and with different acquisition protocol attributes.

Hoye et al, SPIE *2019*

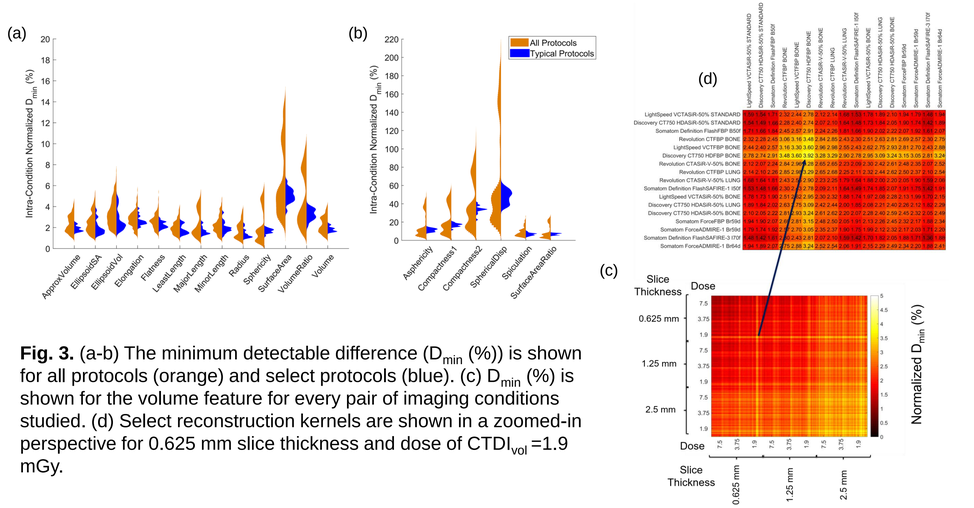

Fig. 3. (a-b) The minimum detectable difference (D_{min} (%)) is shown for all protocols (orange) and select protocols (blue). (c) D_{min} (%) is shown for the volume feature for every pair of imaging conditions studied. (d) Select reconstruction kernels are shown in a zoomed-in perspective for 0.625 mm slice thickness and dose of $CTDI_{vol}$ =1.9 mGy.

Statistical Considerations for Clinical Trials with Quantitative Imaging Biomarkers

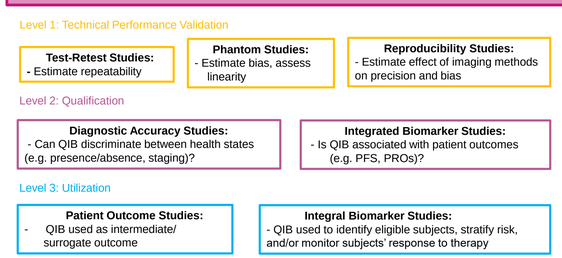

Fig. 4. The hierarchy of QIB studies grouped by validation, quantification, and utilization.

Obuchowski et al, JNCI *2019*

QIBs are now commonly used for subject selection, response assessment, and safety monitoring. Estimates of the precision and bias of a QIB are important for properly designing clinical trials and establishing the level of imaging standardization required.

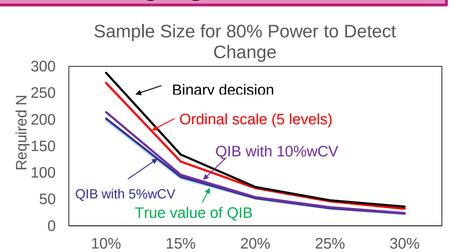

Fig. 5. The required number of cases to detect different true changes in QIBs with 80% power.

Small Lung Nodule (≤10 mm) Automated CT Volumetry in Lung Cancer Screening

Potential Advantages

- More reliable determination of nodule size and need for work-up before next annual screen
- Earlier detection of nodule growth (Fig. 6)
- Estimation of volume doubling time (Fig. 6)
- Improved reader agreement (Table 1 and Fig. 6)

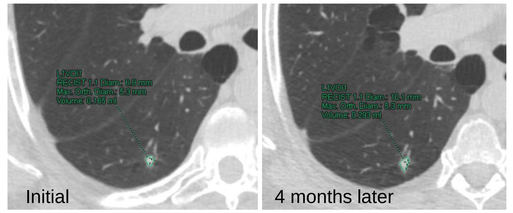

Fig. 6. Asymmetric 6 mm nodule with borderline 1.5 mm increase in average diameter measured manually at 4 months. Automated volumetry revealed 78% volume increase and 145-day volume doubling time consistent with malignant growth rate (typically 20-400 days). Diagnosis was adenocarcinoma.

	Manual Diameter in mm (LungRADS category)			Automated Volume in mm^3 (LungRADS category)		
	Reader 1	Reader 2	Reader 3	Reader 1	Reader 2	Reader 3
N1	7 (3)	7 (3)	8 (4A)	214 (3)	211 (3)	211 (3)
N2	8 (4A)	8 (4A)	7 (3)	293 (4A)	287 (4A)	287 (4A)
N3	16 (4B)	19 (4B)	18 (4B)	1760 (4A)	1631 (4A)	1208 (4A)

Table 1. Measurements from reader agreement exercise demonstrate improved interobserver agreement with automated volumetry.

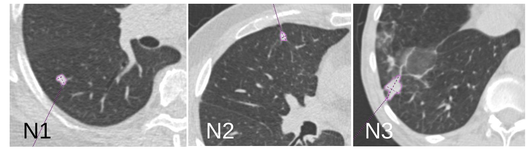

Figure 7. Examples from reader agreement exercise demonstrate improved interobserver agreement (Table 1) with automated volumetry.

Interpreting Quantitative Measurements

- Measurement accuracy is affected by (Table 2)
  - Nodule characteristics
  - Inherent resolution of the CT scanner
  - Acquisition and reconstruction parameters
  - Nodule analysis software performance
- Measurement variability (uncertainty in a given measurement)
  - Increases for small nodules as size decreases (Table 3)
  - Used to determine if a measured change is biologic vs. measurement artifact

Parameter	QIBA Specification
Lung nodule	Solid 6-10 mm diameter at first time point Shortest:longest diameter ≥ 0.6
Slice thickness	≤ 1.25 mm
Slice interval	≤ Slice thickness
Reconstruction kernel	Non-edge enhancing
Analysis software	Unbiased (±5% of true volume) Linear across all volumes

Table 2. Factors affecting nodule volumetry accuracy and conditions needed to achieve measurement variability in Table 3.

Nodule Diameter (mm)	Equivalent Sphere Volume (mm^3)	Coefficient of Variation	True Volume 95% Confidence Limits (mm^3)	Minimum Measured Change Considered Real
6	113	0.29	± 64	80.3%
7	154	0.23	± 69	63.7%
8	268	0.19	± 100	52.6%
9	382	0.16	± 120	44.3%
10	524	0.14	± 144	38.8%

Table 3. Measurement variability based on nodule size at first time point when Table 2 conditions are met. Larger variability for smaller nodules means measured percent volume change must be greater than for larger nodules to have 95% confidence that the measured change is real.

Role of QIBA

- Define the optimal technical conditions (Table 2) readily achievable in clinical CT screening practice and the associated measurement variability (Table 3)
- Facilitate optimization of scanner performance at screening centers through QIBA conformance procedures
- Promote and encourage technical developments that improve small nodule resolution with low-dose CT

More information available at https://tinyurl.com/QIBA-Small-Lung-Nodule-Profile and https://tinyurl.com/Nodule-Calculator and https://tinyurl.com/Conformance-Certification