QIBA 2016 CT Volumetry Biomarker Committee: Overview and Status Update

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Quantitative Imaging Biomarkers Alliance RSNA

CT Tumor Volume Change for Advanced Disease (CTVAD) Profile
Consensus Profile Published

Reproducible measurement of tumors in the chest, abdomen and pelvis is vital to assessing treatment response. QIBA's CT Volumetry for Advanced Disease Profile proposes standards and processes, based on evidence and expert consensus, for measurement of change in tumor volume in metastatic disease.

Following the Profile results in reproducible, confident measurement of change in tumor volume

Baseline Diameter (Volume)	Subsequent Diameter (Volume)	Volume Change Confidence Interval Calculation	95% Confidence Interval of True Volume Change
100mm (524 cm³)	50mm (65 cm³)	-459 cm³ ± 88 cm³	[-547 cm³, -371 cm³]
40mm (34 cm³)	80mm (268 cm³)	234 cm³ ± 45 cm³	[189 cm³, 279 cm³]
10mm (0.5 cm³)	20mm (4.2 cm³)	3.7 cm³ ± 1.2 cm³	[2.5 cm³, 4.9 cm³]

Profile Claims (examples):

Claim 1: A true change in tumor volume has occurred with 95% confidence if the measured change is larger than 24% and the longest in-plane diameter is initially 50-100mm.

Claim 2: A true change in tumor volume has occurred with 95% confidence if the measured change is larger than 29% and the longest in-plane diameter is initially 35-49mm.

These and additional claims and formulae accessible online (see QR below)

Partner with QIBA
Current Opportunities

Doctor/ Technologist/ Physicist: time needed 4-24 hrs

Perform Feasibility Testing of Advanced Disease Profile (see flyer) and get the inside track on QIBA compliant protocols

Provide Public Comment on the Small Nodule Profile

Startup/Vendor/ Researcher: time needed 8-40 hrs

Evaluate Feasibility of profile steps from your commercial/ research perspective

Government / CRO/ Pharma: time needed 6-8 hrs

Determine if QIBA Profiles are useful for your clinical trial design

All Interested:
Join QIBA, Meet Virtually, Create Consensus Profiles

Attend Live Sessions at RSNA
1. Liver Lesion: Thurs. Dec 1. @12:15pm (16004627, Session: PH260-SD-THA3)
2. Virtual (lesion) Clinical Trial: Thurs, Dec 1, @1030am (Room S403B)

We acknowledge the contributions of committee participants and RSNA Staff: Joseph Koudelik, Julie Lisiecki, Fiona Miller

For supplemental materials, and to add your name for consideration as a test site
Find us at:
http://qibawiki.rsna.org/index.php/Invitation_to_Participate

Low Contrast Volume Measurement: Dynamic Contrast-Enhanced Liver CT

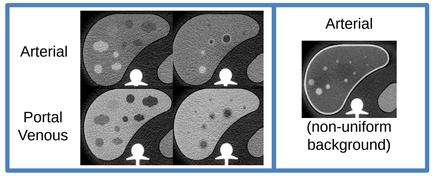
Clinically accurate and precise liver lesion sizing depends on anatomical complexity, underlying disease, patient physiology, contrast injection, CT acquisition

Groundwork Project Aims:

- To create phantoms emulating clinical conditions in sizing low contrast hepatic lesions
- To understand the impact of CT scanning conditions (acquisition, reconstruction) on hepatic lesion size measurement error (size/shape/contrast)

Methods:

1. Design Phantom



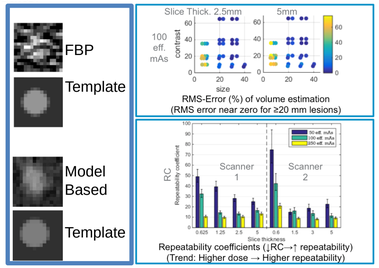
2. Perform CT Scan

2 scanners, 3 doses, 2 pitches, 4 slice thicknesses, Reconstruction Algorithms: FBP, Stat IR, MBIR

3. Estimate Volume

Estimate lesion volume with parameterized low-bias 3D templates from forward CT model

Results:



Performance across reconstructions algorithms
(IR has lower variance, Model-based IR has higher bias)

	FBP	Stat30	Stat50	Stat70	Model
% Bias	11.7	10.5	12.2	-9.0	19.8
% StdDev	43.4	37.1	37.1	36.2	26.7

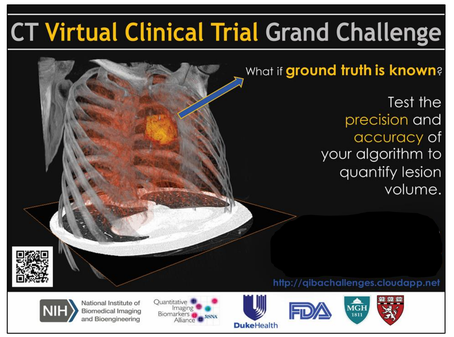
Conclusions:

- Measurement of low contrast objects are reproducible with QIBA Profile adherence
- Good repeatability (low RC) for slice thickness ≥1.5mm
- Poor measurability for lesions ≤10mm

Ongoing work:

- Detectability in IR • Test sizes 7-14mm • 3D-print realistic HU phantom

Comparative Effectiveness of Image Analysis Tools: Commercial and Research Product Comparison



Groundwork Project Aims:

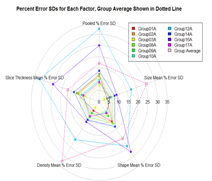
- To quantitatively benchmark volume estimation performance of image analysis tools
- To provide a quantitative understanding of differences between approaches.

Methods: Nodules virtually inserted using three methods:
Technique A is a projection-domain insertion method
Techniques B and C are image-domain insertion methods
Image-based segmentation on datasets generated using
(1) an anthropomorphic phantom with synthetic and virtually inserted nodules
(2) clinical images containing real lung lesions and virtually inserted lesion models.

Results: Data analyzed for bias and precision of estimated volumes. Aggregate data will be published and used as a gauge of quantitative variability across segmentation methods.

Inter-algorithm Performance Study

Groundwork Project Aim: Estimate bias and variance in absolute volumes using CT phantom data



Results: Percent error for all participants

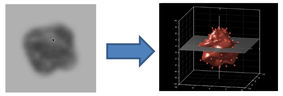
Using nodules that met QIBA CT profile requirements, the standard deviation for all 10 participants are shown by the dotted pink polygon. The pooled standard deviation of all 10 participants is shown as polygons of various colors.

Conclusion: QIBA profile-conformant measurements produce results where 68% confidence interval for systematic deviation between estimate and true value (i.e., +/- 1-sigma) < 15%.

Tumor Insertion without Risk: Image Creation for CT Volumetry Testing

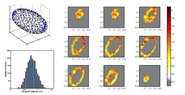
Groundwork Project Aim: Creation of a set of blended CT scans that "look and feel" like actual clinical scans of patients with tumors. Will allow testing of algorithms for measurement of tumors with known volumes.

1. Simulate heterogeneous structures (texture) within lesions



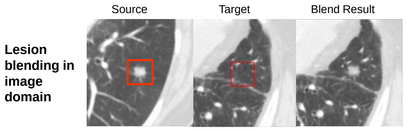
Cross-sectional view of a realistic non-spherical textured lesion > 3D modeled lesion rendition.

2. Develop a framework to analyze scanner-based shape deformation

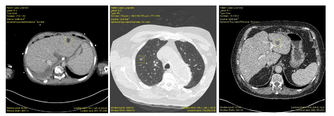


Concentric models of simulated and segmented lesion oriented at lesion center (top left), distribution of Hausdorff distances (HD) between the two lesions (bottom left), and a 3D difference map of HD for the lesions.

3. Use projection and image-domain lesion insertion tools to **virtually insert** lung and liver lesions of known shape, volume, and texture into clinical CT images

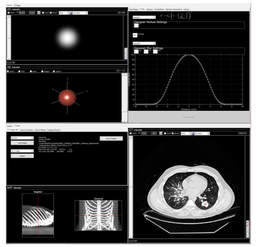


4. Develop datasets of clinical CT scans with virtually inserted lesions for quantitative verification and conformance assessment



5. Disseminate lesion insertion software

Dynamic datasets can be created using Duke Lesion Tool based on *a priori* statistical definitions for the formation of variable datasets. Datasets are designed to be used to conduct evaluation of quantitative performance across commercial and research software for lesion volumetry, texture and morphology analysis.



Duke Lesion Tool: used for modeling lesions and providing a platform for lesion insertion for creating a dynamic hybrid dataset.

The database will be made **publically available** so institutions can test volumetry, texture and morphology software using a validated reference clinical set without the need for additional image acquisition.

QIBA Small Nodule Profile
Lung Cancer Screening
Profile Receiving Public Comment

This profile proposes evidence-based consensus standards and processes for measurement of volume and size change in solid lung nodules. Accuracy in measuring nodule size is critical to reducing work-up cost and potential harms with lung cancer screening.

Overview: The profile addresses accuracy/precision of CT volumetry for solid lung nodules 6-10 mm

Profile Claim 1: For a measured **nodule volume** of Y, and a CV as specified in the table below, the 95% confidence interval for the true nodule volume is Y ± (1.96 □ Y □ CV).

Profile Claim 2: A measured **change in nodule volume** of X% indicates that a true change in nodule volume has occurred if X > (2.77 x CV1 x 100), with 95% confidence.

To quantify the amount of change, if Y1 and Y2 are the volume measurements at the two time points, and CV1 and CV2 are the corresponding values from the table below, then the 95% confidence interval for the true change is $(Y_2\text{-}Y_1) \pm 1.96 \square \square([Y_1 \square CV1]^2 + [Y_2 \square CV2]^2)$.

Nodule Diameter (mm)	Nodule Volume (mm³)	Coefficient of Variation (CV)
≥ 6 and < 8 mm	≥ 113 and < 268	0.29
≥ 8 and < 10 mm	≥ 268 and < 524	0.19
≥ 10 and < 12 mm	≥ 524 and < 905	0.14
> 12 mm	> 905	0.11

Proposed Steps to Validate Compliance:

1. **CT Scanner and Lung Nodule Analysis Software**
   a) Verify CT scanner model is QIBA approved.
   b) Verify ACR CT accreditation is being followed.
   c) Verify lung nodule analysis software is QIBA approved.
2. **Lung Screening Protocol**
   a) Establish and save a CT Lung Screening Protocol.
   b) CT scan low cost QIBA lung nodule phantom with saved Protocol.
   c) Submit phantom data online and obtain a passing protocol report.
3. **CT Data Acquisition, Lung Nodule, and Segmentation**
   a) Visually verify that nodule is solid, not attached to structures, has a diameter 6 - 10mm, and that the saved Protocol was used at all time points to be volume measured.
   b) Visually verify artifacts (e.g. motion, streaking) absent and image noise is not excessive
   c) Visually verify measurement of nodule is free of segmentation issues.
4. **Obtain Volumetric Nodule Measurement Guidance**
   a) Use online QIBA calculator to obtain the latest measurement guidance.

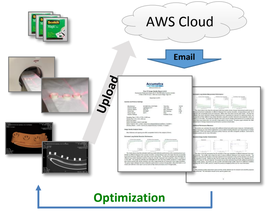
Crowd-Sourcing

Online Calculator

www.accumetra.com/NoduleCalculator.html

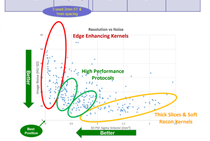
Proof of Concept: A Crowd Sourced Challenge
Can QIBA Compliance Improve Uniformity?

Aim: To quantitatively determine the most effective lung cancer screening CT scanners and protocols using an ultra-low cost, crowd-sourced approach.



- **Two month data collection period**
- **27 international sites participated**
- **54 CT scanners evaluated**
- **63% followed general screening slice thickness guidelines**
- **19% followed QIBA nodule guidelines**
- **Obtained fundamental image quality information at 3 distances from iso-center** (resolution, noise, linearity…)
- **Found numerous opportunities to improve protocols**

Slice Thickness	Sites	Soft Recon	Medium Recon	Edge En. Recon
<= 0.625	4 (15%)	0	3	1
0.8, 1.0, 1.25	13 (48%)	7	2	4
>= 1.5	10 (37%)	6	3	1



Conclusion: Crowd-sourcing with ultra-low-cost reference objects and cloud based image quality services can rapidly validate and optimize imaging protocols.

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