

New Data Resources For Accelerating AI Research

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May 9, 2019

Arlington Imaging Artificial Intelligence (AI-AI) Workshop

CT Lung Cancer Decision Support Landscape

Pipeline

Individual Risk Assess, Δ , Monitor

Personalized Early Detection

Differential Diagnosis

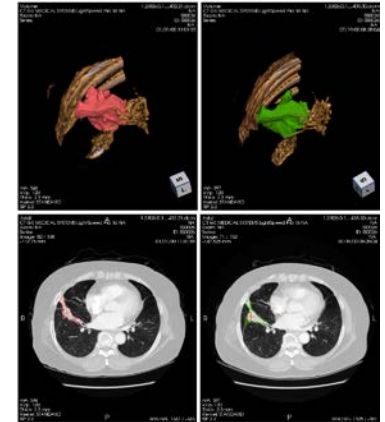
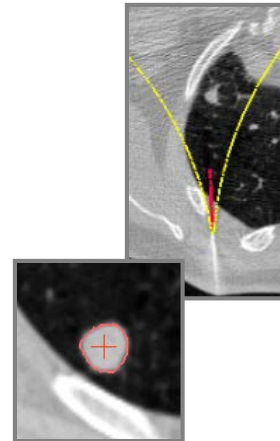
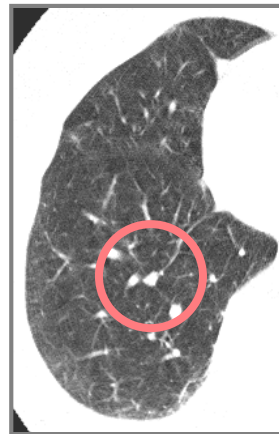
Intervention & Therapy

Image+ Based Risk Analysis

Computer Aided Detection (CAD) + Δ Analysis

Δ Analysis & IG Biopsy

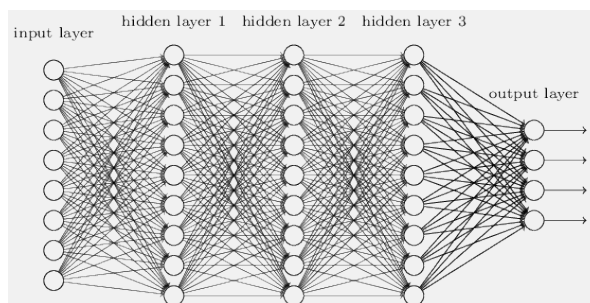
CAD + Δ Analysis



Imaging Opportunities

Deep Learning Challenges

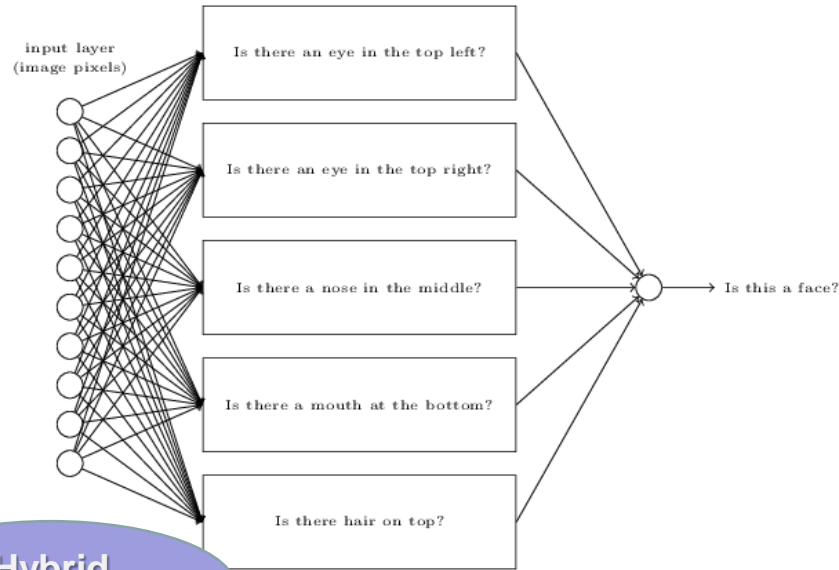
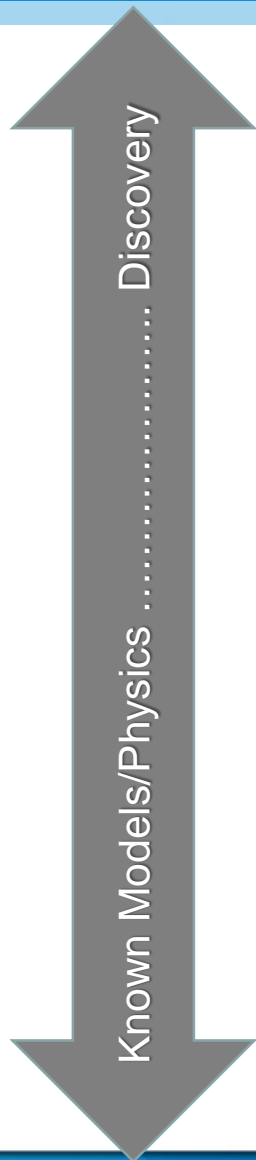
1) What rules/methods/physics/equations did it learn?



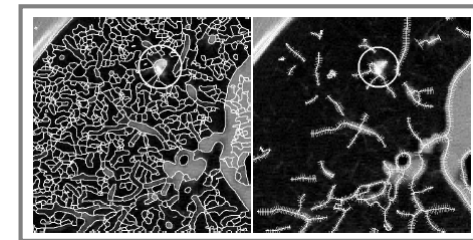
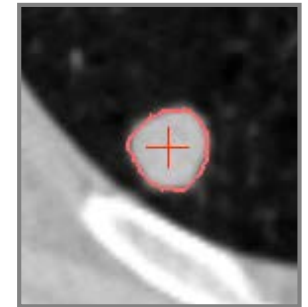
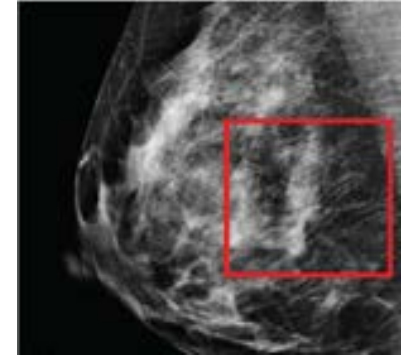
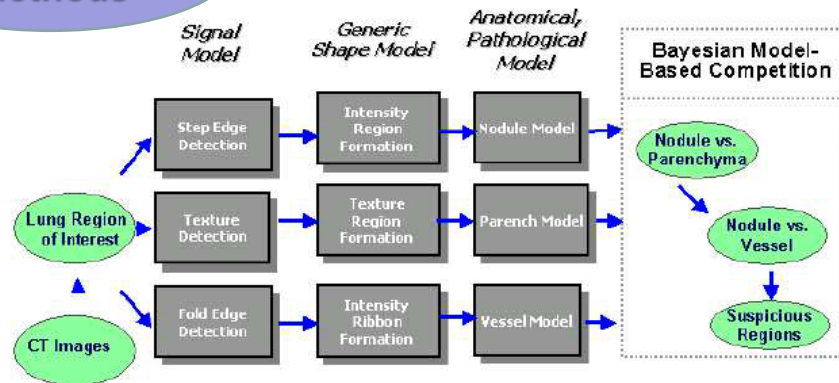
2) Massive representative & labeled datasets are continuously needed for training and validation

3) Image quality matters for many applications and it is changing faster than our ability to acquire large databases

Deep Learning and Model-Based Algorithms



Hybrid Methods



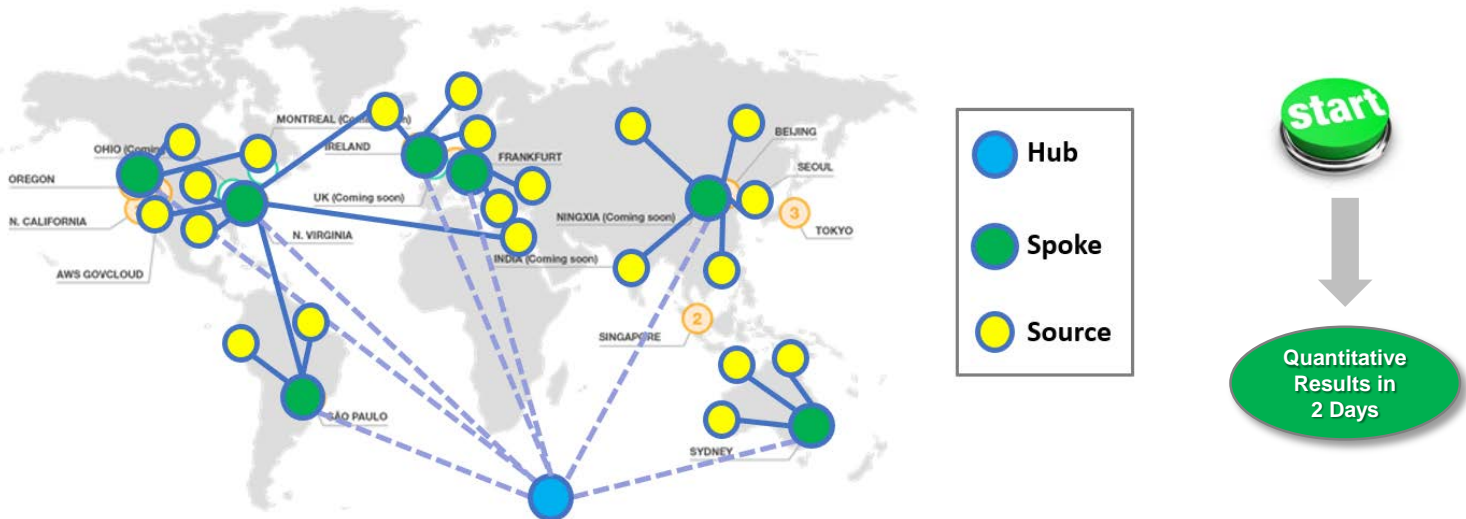
Model-Based Detection of Lung Lesions in CT Exams, CARS 2003

Early Lung Imaging Confederation (ELIC) Project

A New Global Lung Imaging Research Resource

Problem: Many Promising CT Lung Cancer Screening Research Opportunities Including Artificial Intelligence/Deep Learning Require 10x to 100x Larger Datasets (e.g. $10^4 \longrightarrow 10^6$)

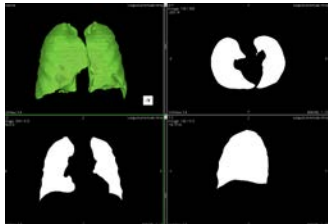
Solution: Create a New and Secure CT Lung Imaging Computing Environment That Removes Barriers to Site Participation and is Populated With De-Identified, High Quality Data



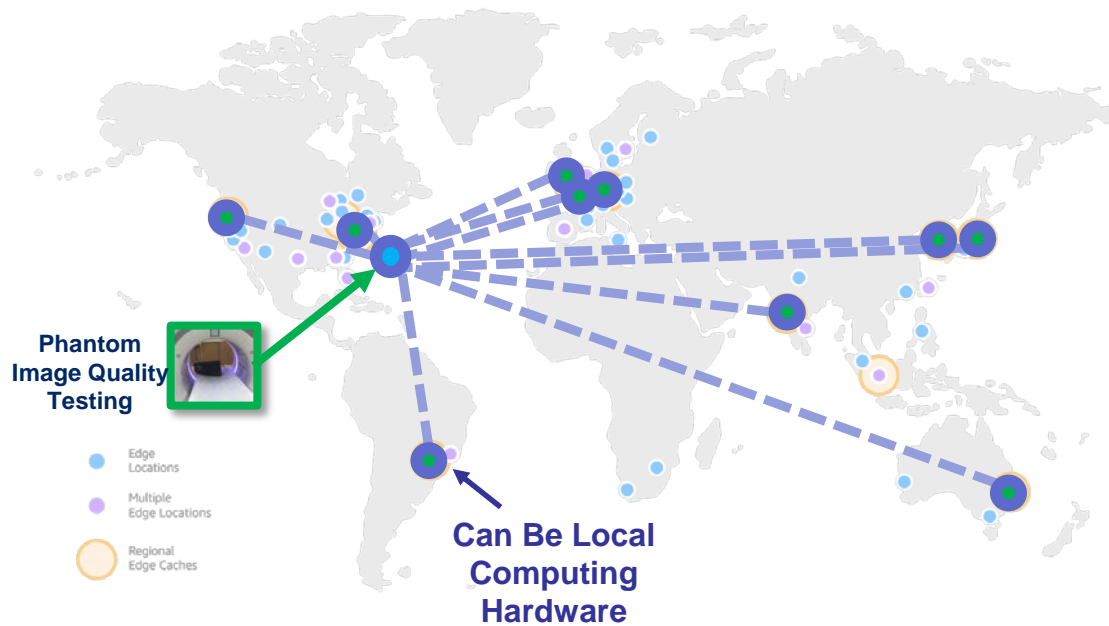
ELIC Live Demonstration Using The Amazon Web Services (AWS) Cloud

Two Algorithms

Lung Volume



Lung Nodule Volume



Hub

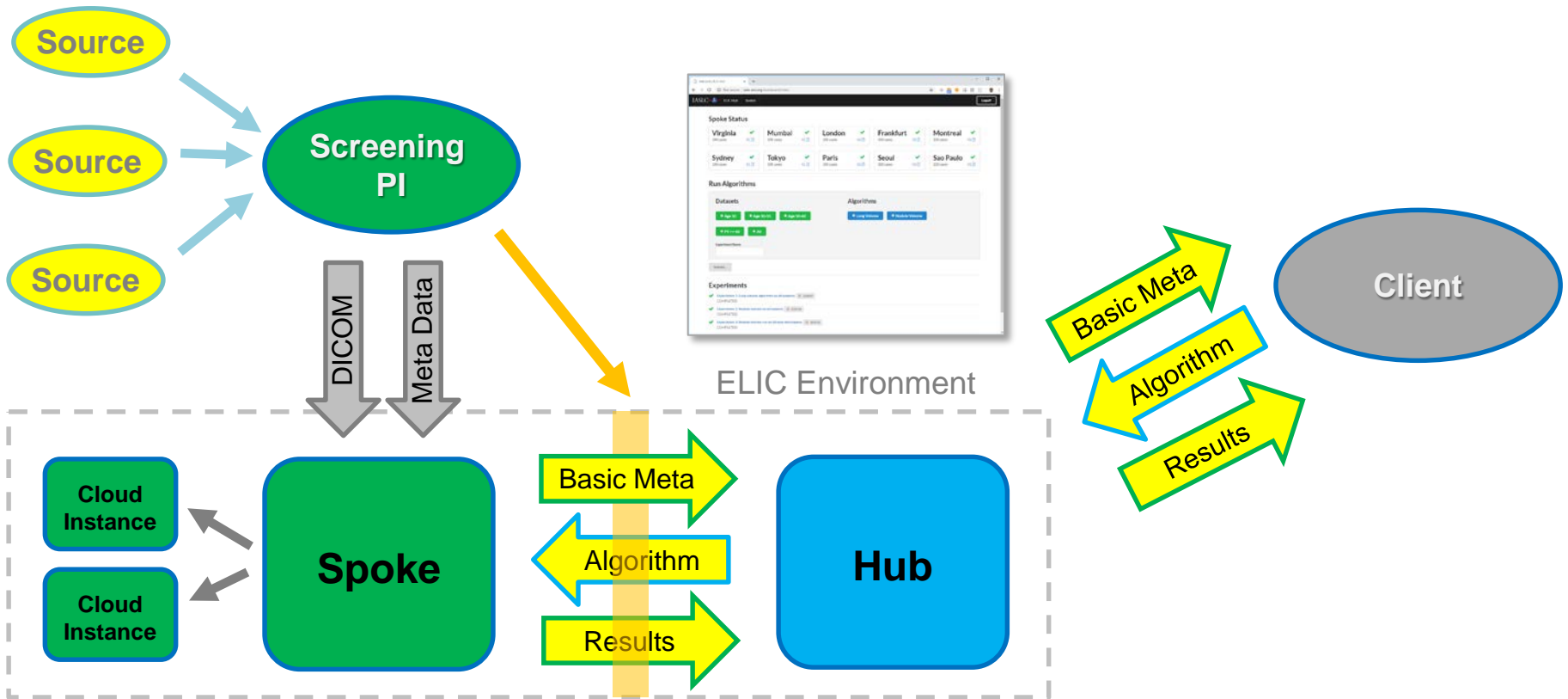
- Virginia, USA

Spokes

1. Virginia, USA
2. Mumbai, India
3. London, UK
4. Frankfurt, Germany
5. Montreal, Canada
6. Sydney, Australia
7. Tokyo, Japan
8. Paris, France
9. Seoul, South Korea
10. Sao Paulo, Brazil

ELIC Live Demonstration Spoke Locations Do Not Indicate ELIC Future Plans

ELIC Stakeholder Participation Overview



ELIC Demonstration @ iaslc-elic.org

Welcome | ELIC Hub

Not secure | iaslc-elic.org/dashboard/index

IASLC ELIC Hub Spokes Logoff

Spoke Status

Virginia 100 cases	Mumbai 100 cases	London 100 cases	Frankfurt 100 cases	Montreal 100 cases
Sydney 100 cases	Tokyo 100 cases	Paris 100 cases	Seoul 100 cases	Sao Paulo 100 cases

Run Algorithms

Datasets: Age 50, Age 50-55, Age 50-60, PY >= 40, All

Algorithms: Lung Volume, Nodule Volume

Experiment Name:

Submit...

Experiments

- Experiment 1: Test COMPLETED 0:22:14
- Experiment 5: Test Lung Volume COMPLETED 0:07:28
- Experiment 6: Test COMPLETED 0:02:29
- Experiment 7: Dom's test COMPLETED 0:02:31
- Experiment 8: Test COMPLETED 0:02:26
- Experiment 9: Linda's Test COMPLETED 0:02:30
- Experiment 10: Test COMPLETED 0:02:27
- Experiment 11: QIBA Test COMPLETED 0:02:32
- Experiment 12: Nodule volume on all subjects COMPLETED 0:22:08
- Experiment 13: Lung nodule volume algorithm on 50 year olds COMPLETED 0:02:31
- Experiment 14: Lung volume algorithm run on 50 year olds COMPLETED 0:07:36
- Experiment 15: test COMPLETED 0:02:31

Version 0.1 | Back to the top

Show experiment | ELIC Hub

Not secure | iaslc-elic.org/experiment/show/13

IASLC ELIC Hub Spokes Logoff

Experiment #13: Lung nodule volume algorithm on 50 year olds

Nodule Volume/Age 50

Summary

COMPLETED 28 cases in 0:02:31

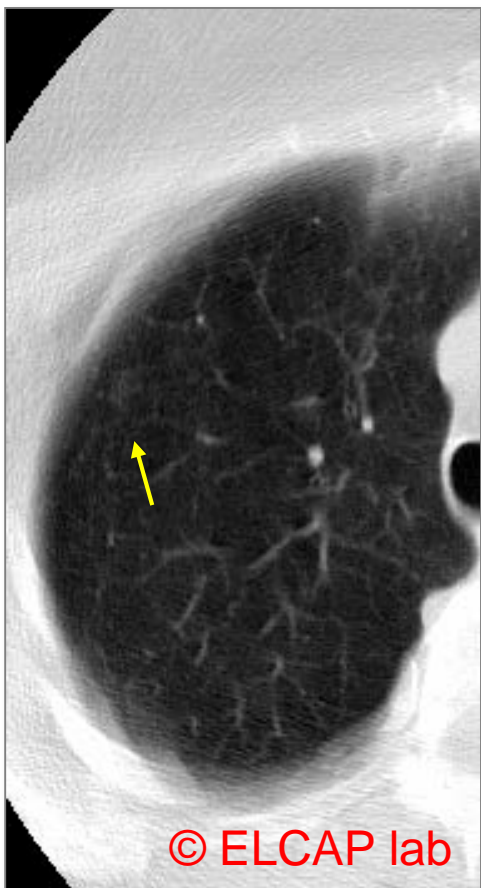
MEAN VOLUME	STANDARD DEVIATION
411.1 mm ³	898.6 mm ³

Results

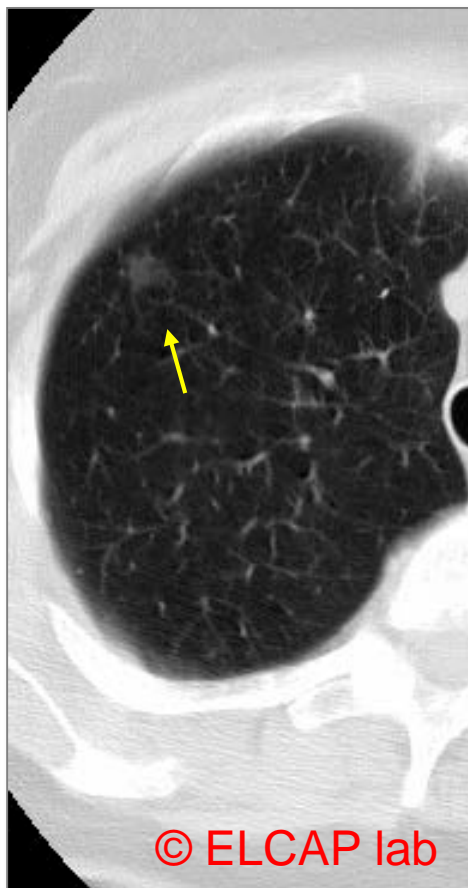
Spoke	Status	Cases Requested	Cases Processed	Mean Volume	Standard Deviation
Spoke 01 Virginia	IDLE	4	4	598.6 mm ³	761.7 mm ³
Spoke 02 Mumbai	IDLE	2	2	250.1 mm ³	62.5 mm ³
Spoke 03 London	IDLE	3	3	75.6 mm ³	44.5 mm ³
Spoke 04 Frankfurt	IDLE	2			
Spoke 05 Montreal	IDLE	1			
Spoke 06 Sydney	IDLE	6			
Spoke 07 Tokyo	IDLE	2			
Spoke 08 Paris	IDLE	3			
Spoke 09 Seoul	IDLE	1			
Spoke 10 Sao Paulo	IDLE	4			

Delete

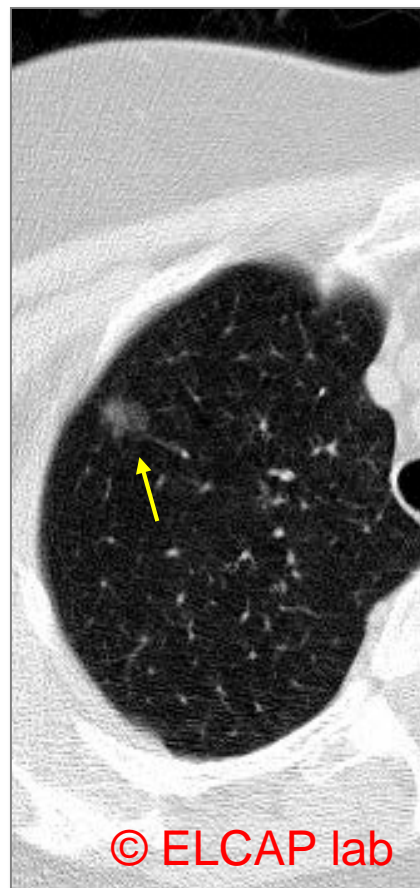
CT Image Quality



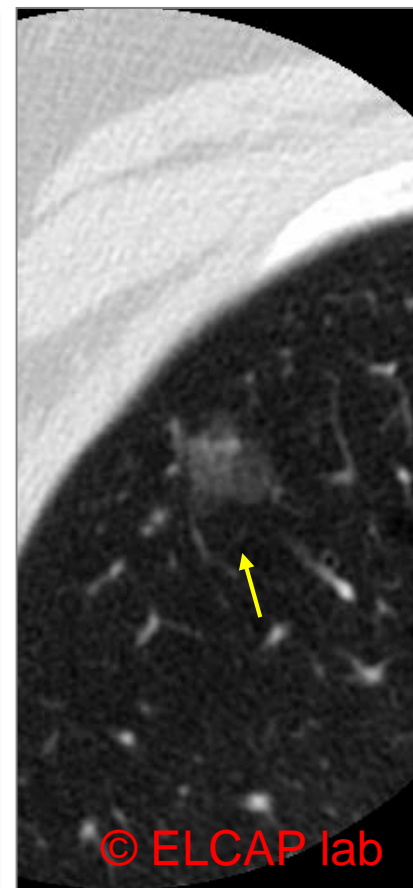
10.0 mm



5.0 mm

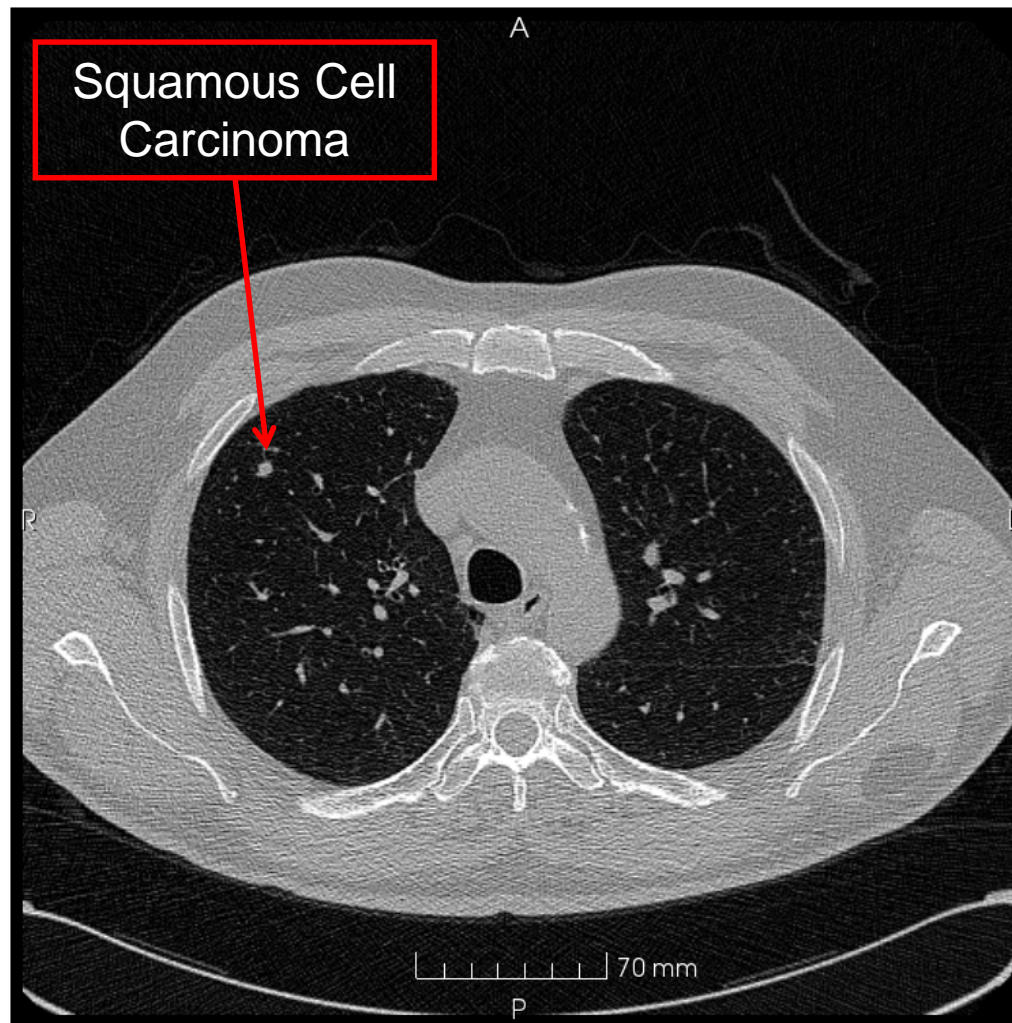


2.5 mm



1.25 mm

Follow-Up Measurement of Small Lung Nodules

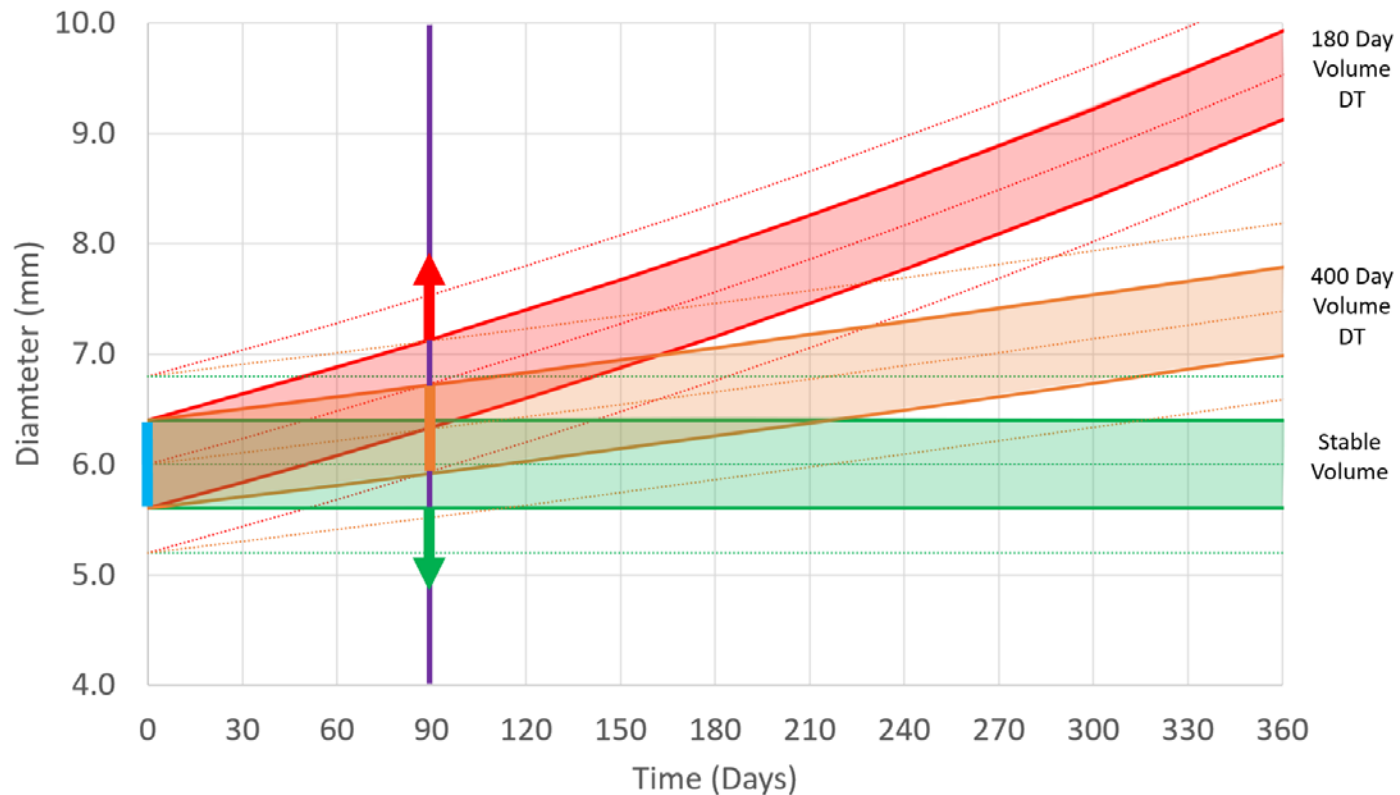


[Dr. Javier Zulueta, University of Navarra]

Precision Follow-up Time

Nodule Diameter Growth

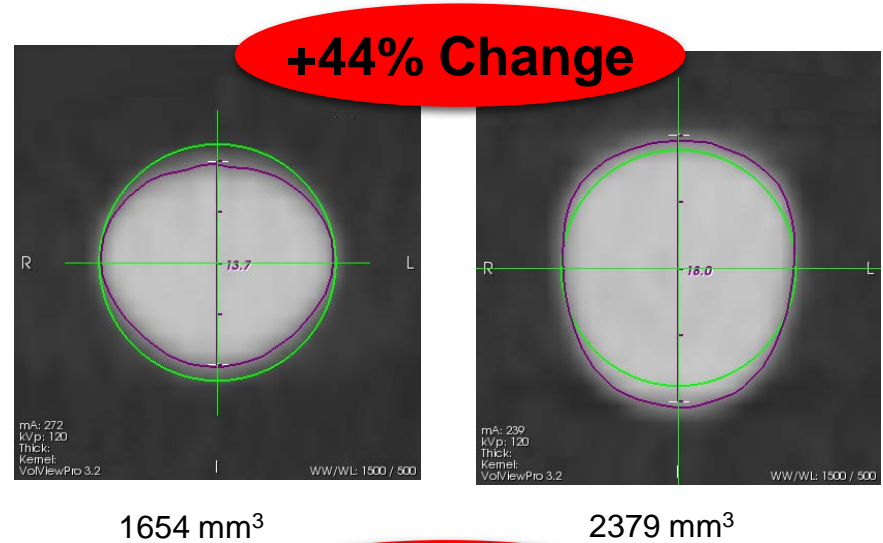
What can we say if we use great CT imaging of a ~6mm nodule at baseline and again after 90 days?



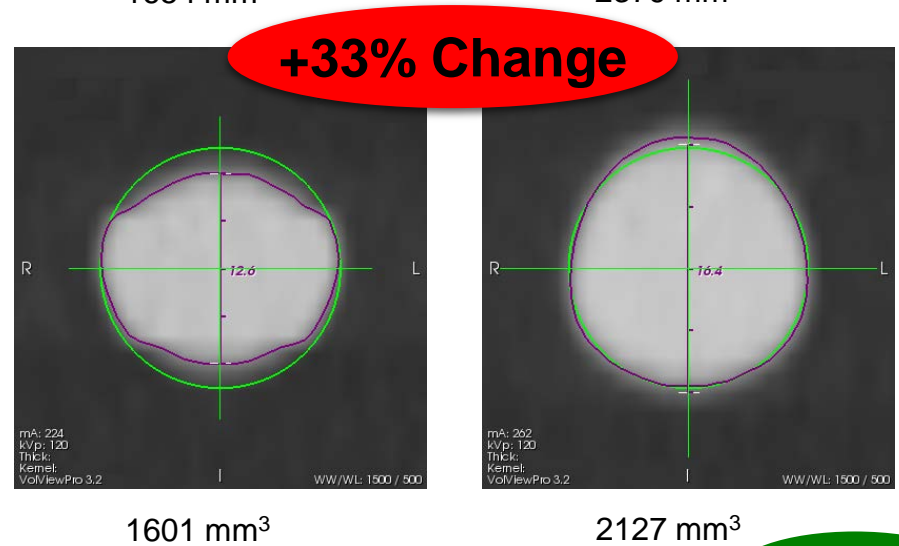
2010: Roche ABIGAIL Study



**Model A
Site 1**

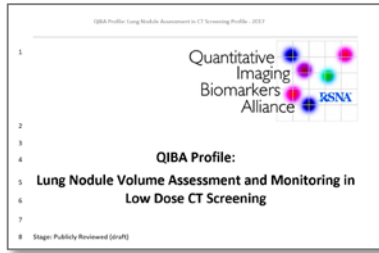


**Model A
Site 2**



CTLX1 Phantom

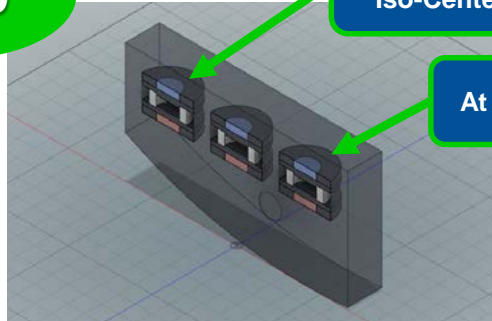
The First Image Quality Phantom To Measure The Full CT Scanner Field of View



\$250

200 mm from
Iso-Center

At Iso-Center



This Ellipsoid Represents The Smallest Size Lung Nodule That a CT Lung Cancer Screening Site Needs To Be Able To Reliably Measure

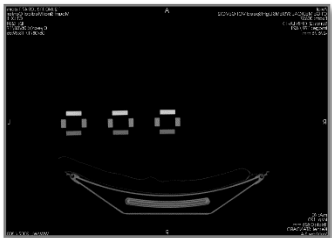
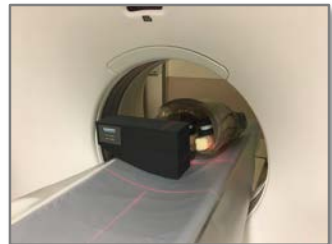
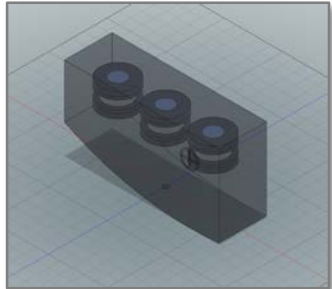
- **Fundamental CT Image Properties**

- 3D Resolution:
 - 3D PSF Ellipsoid Volume $\leq 1.5\text{mm}^3$
- 3D Resolution Aspect:
 - PSF Z/X ≤ 2.0
- Linearity Bias:
 - Air and Acrylic Bias < 35 HU
- Image Noise:
 - Acrylic Noise ≤ 50 HU SD
- Kernel Edge Enhancement:
 - Air to Delrin Enhancement $\leq 5\%$
- 3D Spatial Warping:
 - Delrin Cylinder RMSE ≤ 0.3 mm

- **Lung Nodule Volume Change Performance**

- Verifies That Image Quality Meets or Exceeds The QIBA CT Lung Nodule Profile Volume Change Measurement Recommendations

RSNA/QIBA Conformance Certification Pilot Project Using Cloud-Based Computing Services



http://accumetra.com

Email

Upload

Accumetra
www.accumetra.com

QIBA CT Small Lung Module (SLM) Profile Automated CT Image Quality Conformance Report
Assessment Performed Using The Accumetra QIBA Platform And ACCQA Physician Image Quality Assessment Software Platform (v0.7)

December 18, 2017

Scanner and Protocol Settings

Manufacturer:	GE MEDICAL SYSTEMS	Tube Volt:	125.00
Scanner Model:	REVCT	Tube Amp:	16.00
Scanner Station:	2510050	Beam Thickness:	0.42
Scan Area:	STANDARD	Beam Stray:	0.99

Conformance Assessment Status

The required number of CT/LN phantom modules were scanned.
The DICOM file headers is within acceptable limits for this analysis (i.e. 1.25min).
The DICOM slice spacing is within acceptable limits for this analysis (i.e. slice thickness).
The DICOM slice stack is within acceptable limits for this analysis (i.e. 7.5).
All QIBA CT SLM Profile automated conformance checks have passed for this CT scanner and image acquisition protocol.

Measured Image Quality Characteristics

The QIBA CT Small Lung Module Profile requires that CT image quality performance is verified for six fundamental image quality characteristics throughout the acquired CT image field of view for a CT scanner and image acquisition protocol to be used for early lung cancer detection. The performance of each of these characteristics is reported from the scanner as measured by performance evaluation using the QIBA Small Lung Module Profile image quality performance specifications. Additional information on these image quality characteristics including problems on ongoing performance is available at Accumetra's QIBA Conformance Certification Pilot Project Page.

1) Edge Enhancement

1) Edge Enhancement

Accumetra edge enhancement conformance checks verify the relative of QIBA CT image quality of QIBA SLM Profile image quality performance. We quantitatively tested the level of edge enhancement at five distances from the center and found the values to be within QIBA CT SLM Profile specifications.

2) 10 Resolution

These dimensional resolution checks reference accurate measurement performance of small objects in CT images. We quantitatively tested your 2D resolution at three distances from the center and found the values to be within QIBA CT SLM Profile specifications.

3) Spatial Focusing

Systems working can cause significant issues when performing conformance measurements. We quantitatively tested your levels of spatial focusing at three distances from the center and found the values to be within QIBA CT SLM Profile specifications.

4) 3D Resolution Agent Ratio

Quantitative measurement algorithms can have errors when measuring image quality. We quantitatively tested the 3D resolution ratio of your imaging system at three distances from the center and found the values to be within QIBA CT SLM Profile specifications.

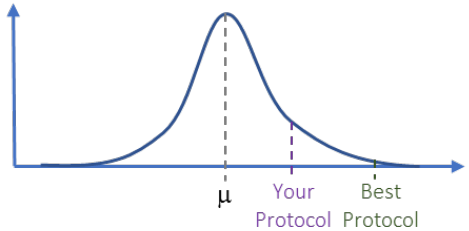
5) HZ Noise

Unintended (Hz) noise levels need to be controlled to perform quantitative measurements of image quality. We quantitatively tested your levels of Hz noise at four distances from the center and found the values to be within QIBA CT SLM Profile specifications.

Optimize

+ Performance Prediction

Check Each Time Scanner or Protocol Changes and Once Per Year



RSNA
Radiological Society of North America

Quantitative Imaging Biomarkers Alliance (QIBA) Conformance Certification Services

QIBA is now offering a new conformance testing tool to help clinical trial investigators... Quantitative Imaging Biomarkers Alliance (QIBA) Conformance Certification Services

International CT Image Quality Monitoring

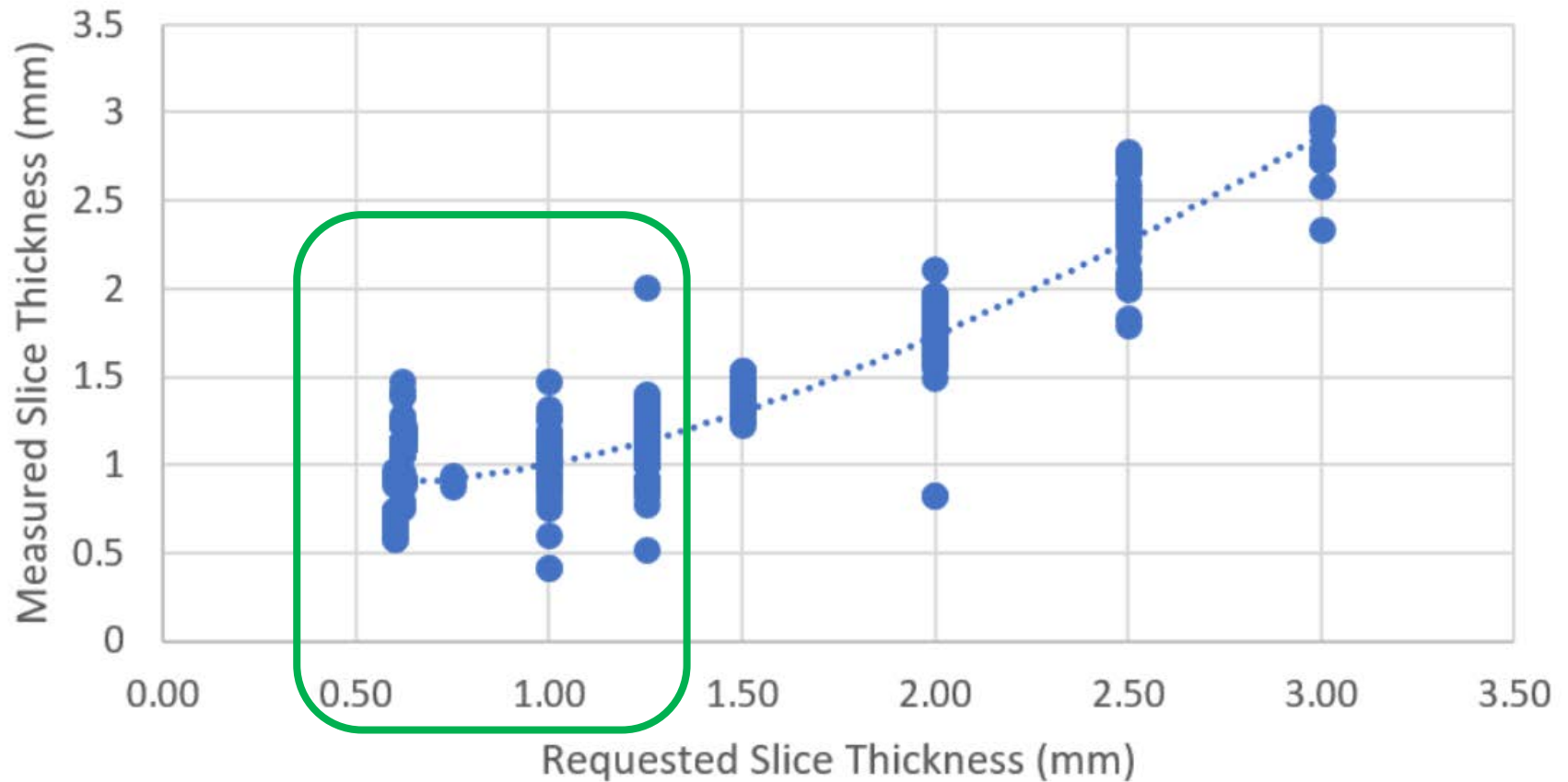
Many Thanks to the Prevent Cancer Foundation

> 700 CTLX1
Scans Received

89 CTLX1 Phantoms Shipped As Of 04/04/2019



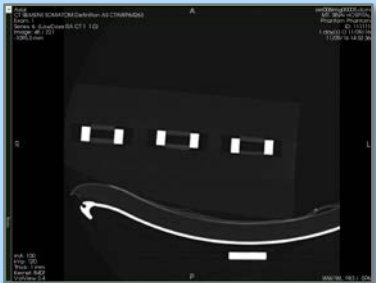
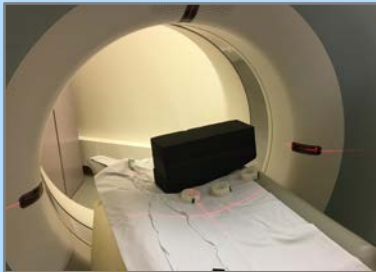
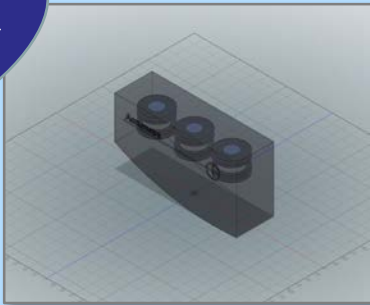
Requested vs Observed Slice Thickness



Cloud-Based and Task-Specific Image Quality Monitoring

CTLX1 Phantom

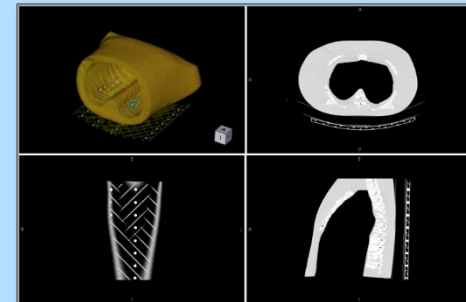
5 min



Protocol Optimization

CT Table Phantom

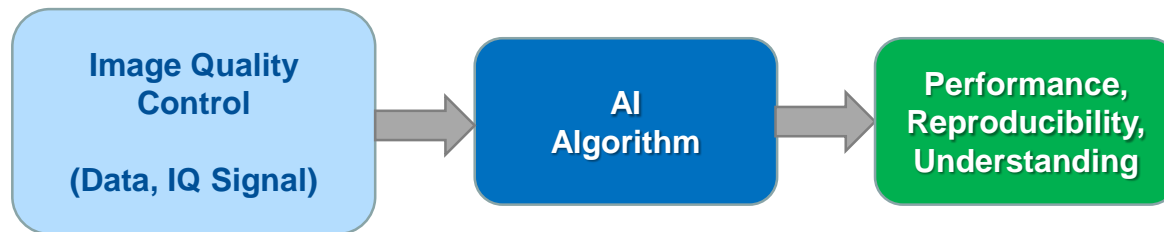
0 min



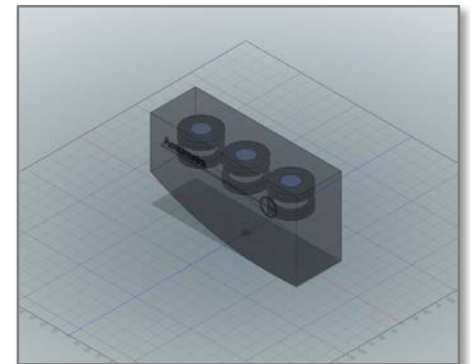
Real-Time Continuous

Opportunity For AI

Careful Monitoring and Optimization of CT Image Quality Will Help Build and Maintain Better AI Systems:



1. Efficiently Eliminate Low Quality CT Scans
2. Provide New Opportunities For AI Methods To Detect New Features
3. Help ID Protocol & Scanner Changes That Can Influence/Lower AI Results



Summary

- **Early Lung Imaging Confederation**

- **A First ELIC Environment Software Has Been Created & Tested That Is Designed To Support Store/Compute on Millions of Cases Using The Cloud.**
- **Early Testing of the ELIC Environment With Two Open Source CT Lung Measurement Algorithms Provided a Proof of Concept.**
- **The ELIC Environment Has the Potential to Accelerate & Improve Artificial Intelligence Lung Cancer Research and Method Development.**

- **CT Image Quality Monitoring and Control**

- **CT Image Quality is Clinical Task Dependent and Fundamentally Influences the Performance of All Computational Methods Including AI Methods.**
- **Without CT Image Quality Control, Many Image Quality Changes Are Happening Without AI Algorithm Investigator Understanding.**
- **Global Image Quality Control Has Been Set Up For Low Dose CT Lung Screening.**
- **RSNA's QIBA Conformance Certification Is Now Providing Tools and Services.**
- **Adding Fundamental CT Image Quality Data To a Deep Learning System Is a Near Term Opportunity.**

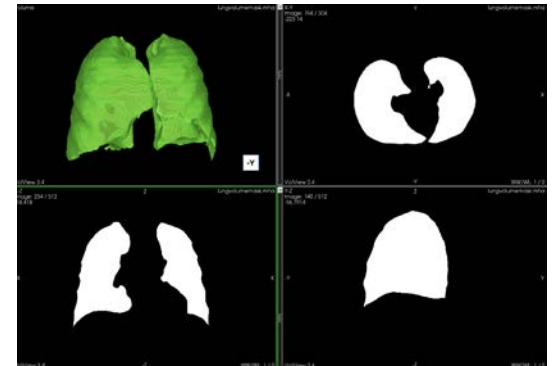
Thank You

Extra Slides

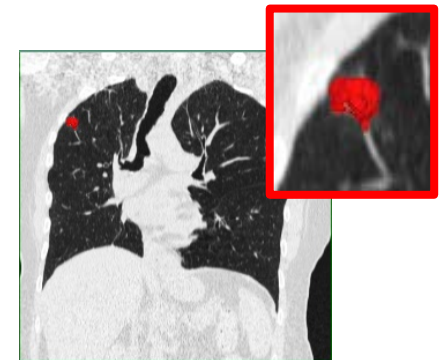
2018 ELIC Pilot Project (3 months)

- Create a First Version of the ELIC Hub and Spoke Environment
- Run ELIC on the Amazon Cloud With 10 Global Spokes Each Providing 100 De-identified CT Lung Images (N = 1,000)
- Develop and Run Two Open Source Lung Measurement Algorithms
- Perform a Live ELIC Demo at the 19th WCLC (Toronto, 9/22) Showing Running of Computational Experiments at 10 ELIC Spokes
- Demonstrate That Prospective CT Image Quality Can Be Monitored and Optimized With the RSNA/QIBA CT Small Lung Nodule Profile
- Distribute All Code Developed as Free and Open Source Software – Global Sites Can Contribute To Software Development

Lung Volume



Lung Nodule Volume

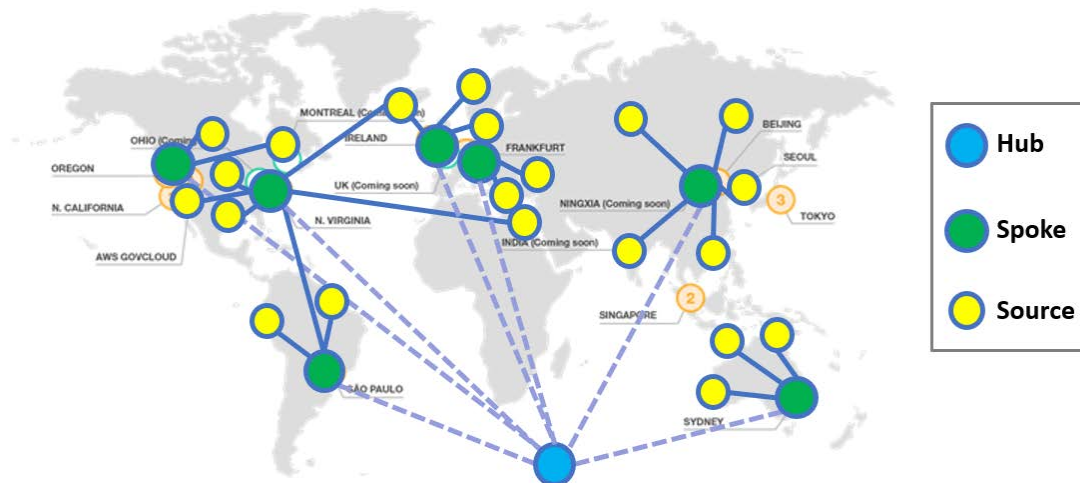


Early Lung Imaging Confederation (ELIC) Project

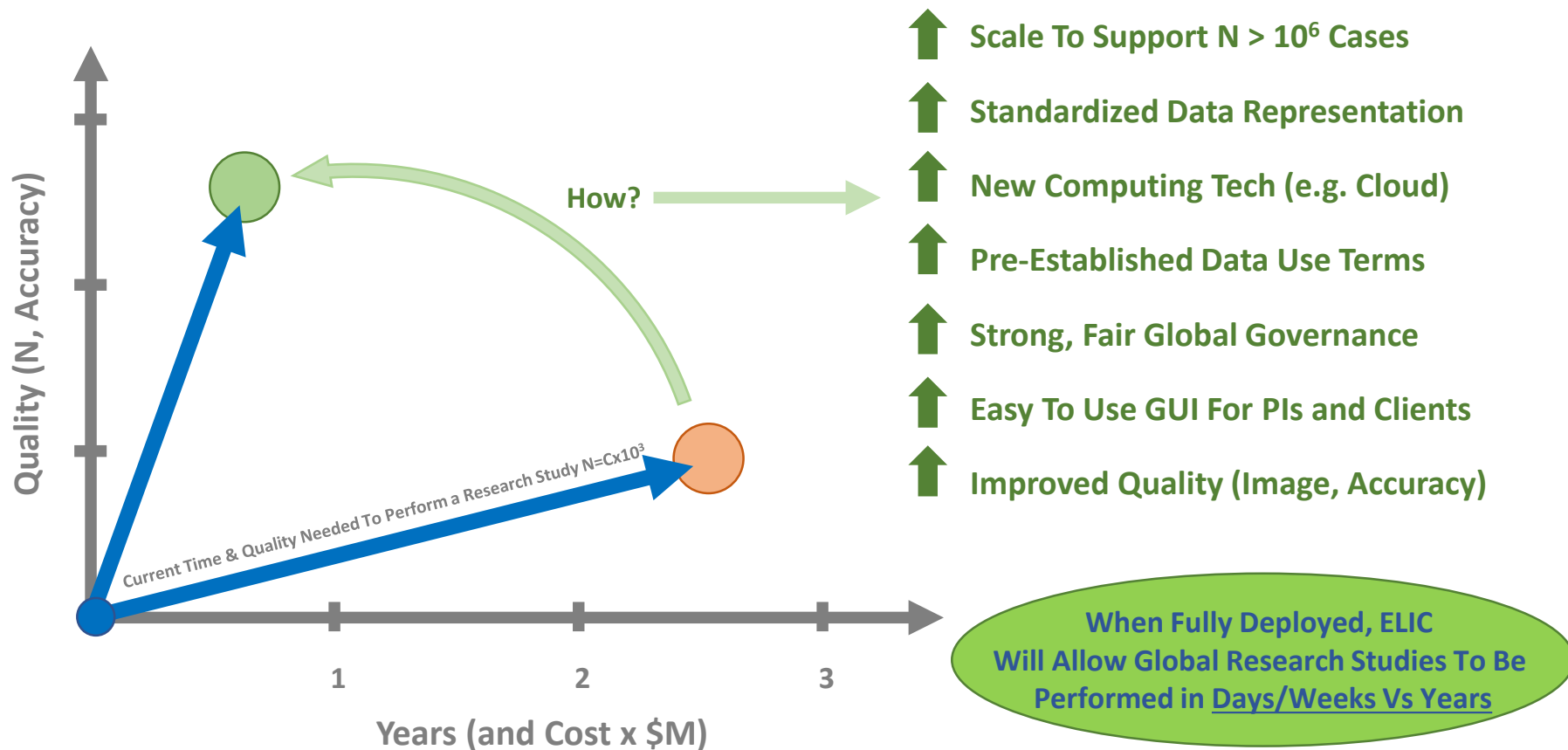
A New Global Lung Imaging Research Resource

Critical Requirements:

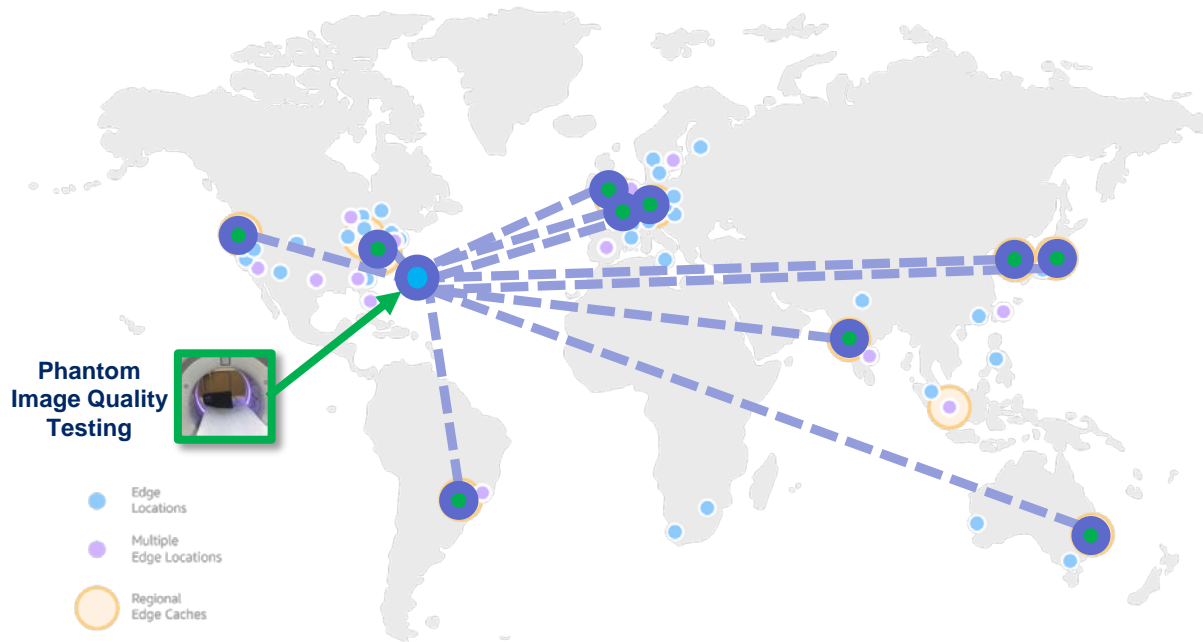
- Keep CT Image Data Locally and Send Algorithms To Spokes To Perform Analysis
- Make Setup and Secure Running of Spokes Automated, Easy, and Efficient
- Have Strong Governance and Pre-Established Data Use Agreements
- Leverage The Latest Computing Resources & Best Practices (Cloud, Open Source, ...)
- Provide CT Image Quality Monitoring and Optimization Tools To Ensure High Quality Data



Early Lung Imaging Confederation (ELIC): Improving The Time, Cost, & Quality of Computational Studies



ELIC Environment



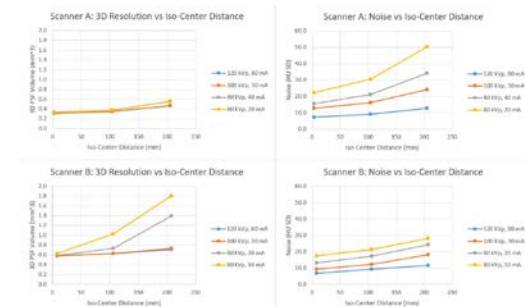
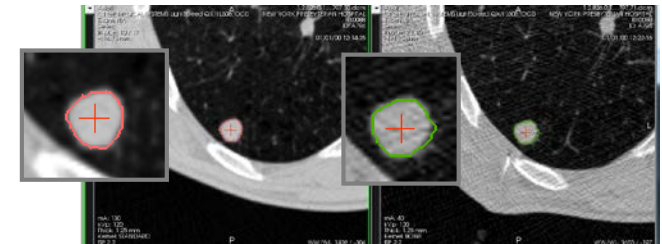
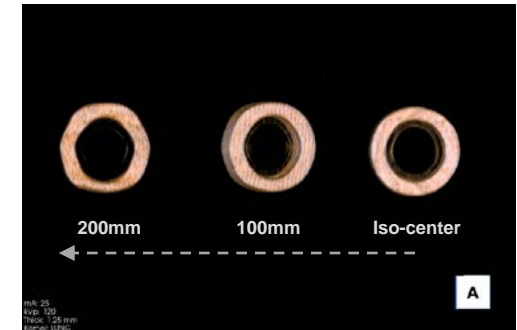
Opportunities

- Global Research Studies
- Regional Analyses
- Artificial Intelligence
- Technology Surveillance
- Global Quality Monitoring

The ELIC Architecture Is Designed To Efficiently Support Storage and Analysis of Millions of Subjects

Quality of Lung Nodule Measurements: What Have We Learned Over The Last 15 years?

- While studies have shown great results, major quality issues persist & impact small (6-10mm) lung nodule measurements:
 - CT Image quality can greatly degrade in the periphery
 - 3D spatial warping can give the appearance of $\pm 40\%$ Δ (JMI 2016)
 - Some recon kernels can bias HU values by > 50 HU
 - Lowering dose can result in resolution losses of $> 200\%$
 - Many institutions continue to use thick slices
 - Difficult to determine if a segmentation is “good enough”
 - ...
- CT imaging technology is constantly changing
 - Scanner geometries and detectors
 - “Standard” reconstruction kernels
 - Iterative reconstruction algorithms
 - New AI-based measurement methods
 - Measurement equipment is being replaced/repared and protocols are changing across lung nodule follow-ups
 - ...



**We need to constantly measure and monitor
CT acquisition and measurement equipment**

Solution: QIBA CT Small Lung Nodule Profile + Conformance Phantom & Online Software



QIBA Profile: Lung Nodule Assessment in CT Screening Profile - 2017

Quantitative
Imaging
Biomarkers
Alliance



2

3

4

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6

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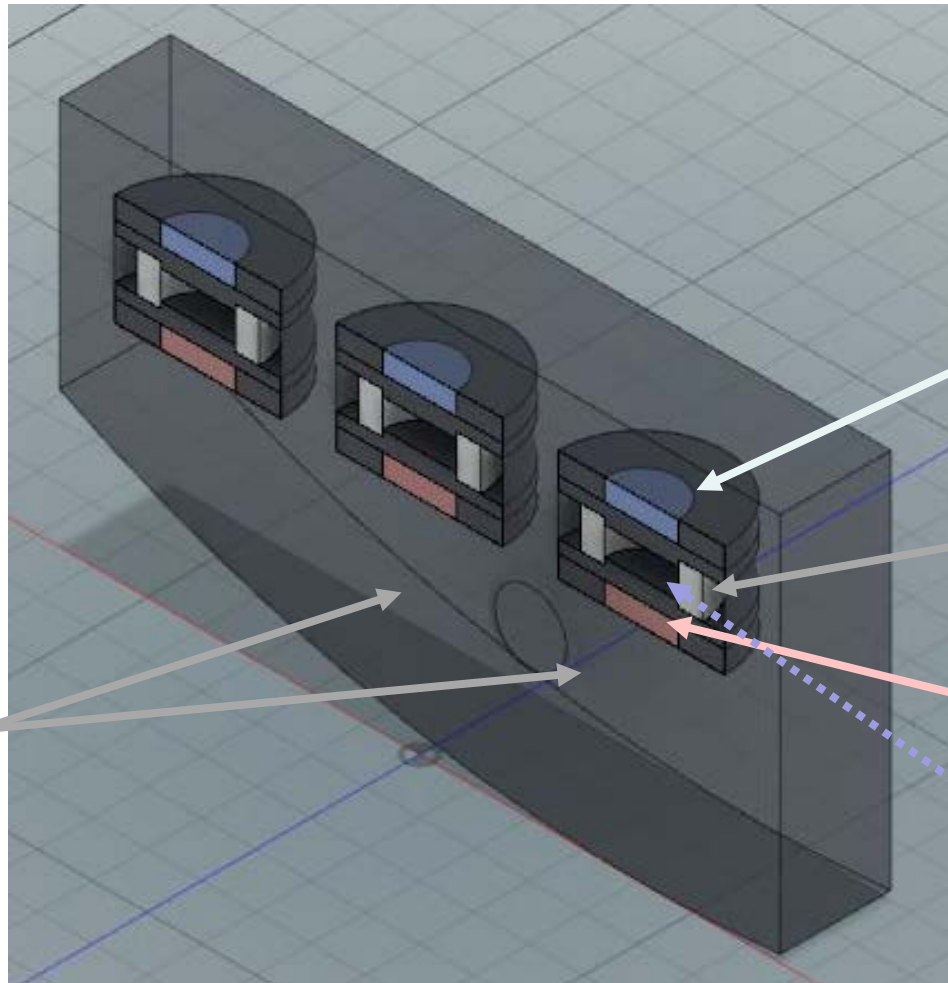
8

QIBA Profile: Lung Nodule Volume Assessment and Monitoring in Low Dose CT Screening

Stage: Publicly Reviewed (draft)

QIBA Small Lung Nodule Phantom

First CT Image Quality Phantom To Measure From Iso-Center to Periphery



Teflon (~950 HU)
Cylinder

Delrin (~340 HU)
Concentric Cyl

Acrylic (~120 HU)
Cylinder

Air (-1000 HU)

Room For
Other
Compartments

PCF Grant International Sites

Canada



China



Italy

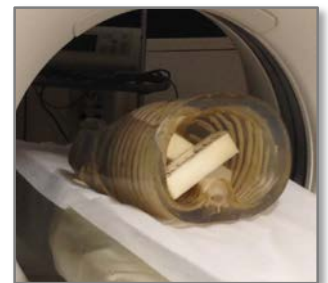
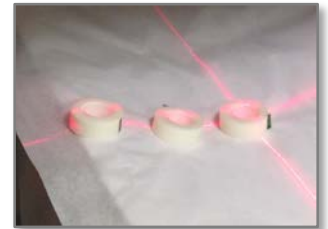
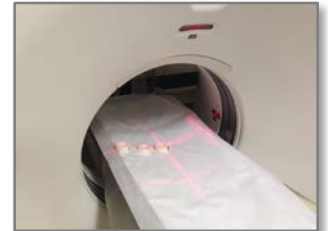


Poland



Validation Study: Predicted vs Measured

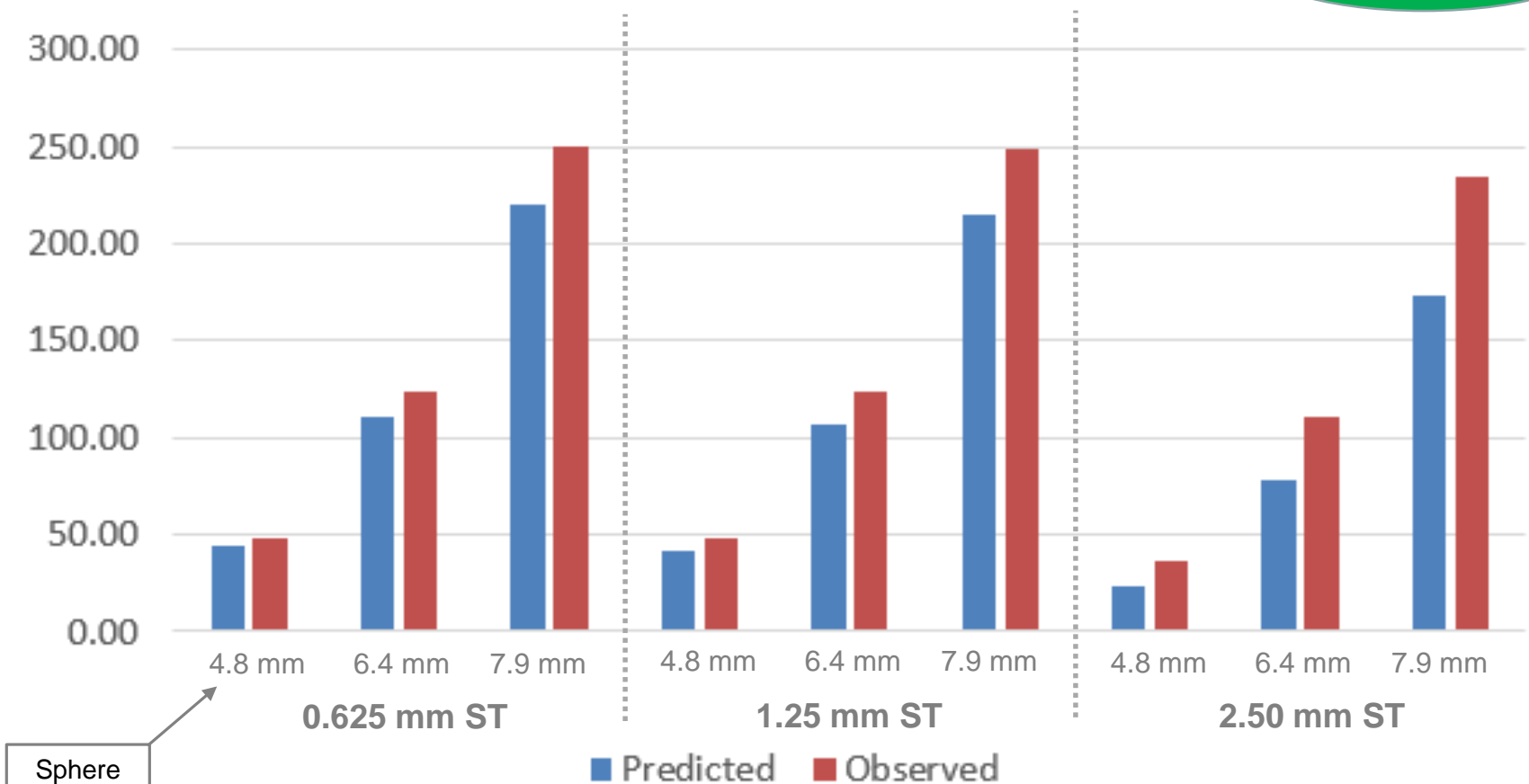
- CT Scanner
 - GE LightSpeed VCT
- Scan Protocol
 - Lung screening protocol with standard kernel, 0.625, 1.25, and 2.5mm slice thickness and spacing
- Objects
 - 1 scan of 3 rolls of 3M Scotch Tape $\frac{3}{4}$ x 1000 inch
 - 10 scans of Teflon spheres inside low density foam inside an anthropomorphic chest phantom, phantom was moved slightly each time
- Analysis
 - Automated analysis of scotch tape scan including estimated volume measurement performance
 - Independent algorithm for the detection and volume measurement of spheres
- Comparison
 - Plot predicted volume performance vs actual measurements



Predicted vs Observed Sphere Volume

SPIE 2017

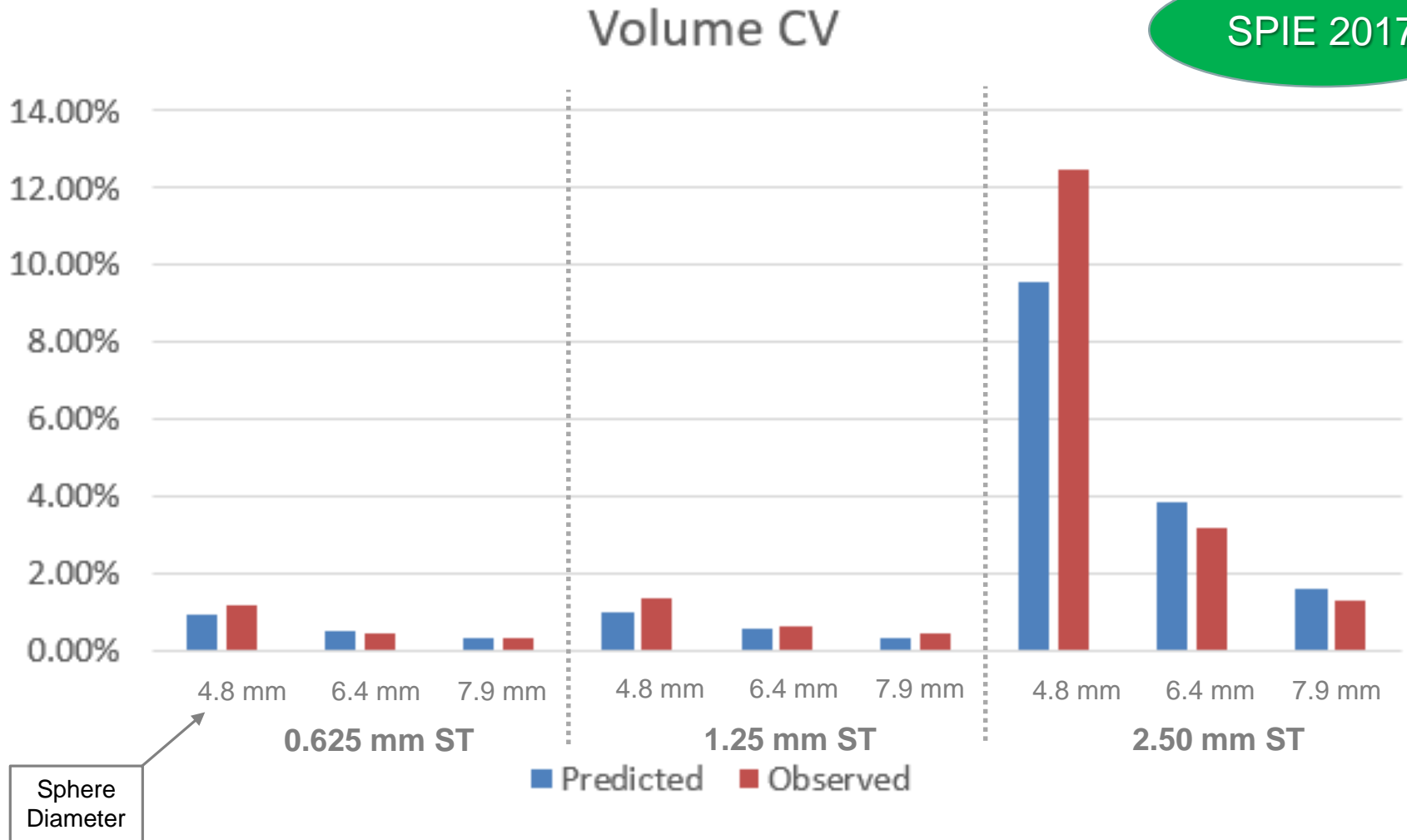
Volume Mean



Sphere Diameter

Predicted vs Observed Sphere Volume

SPIE 2017



Prevent Cancer Foundation International Grant

RSNA/QIBA & Accumetra received PCF grant to globally improve image quality for CT lung cancer screening.

- Project ran from 8/2017 to 2/2019
- Major project goals:
 1. Set up an additional cloud-based CT image quality phantom analysis service in Frankfurt, Germany
 2. Manufacture and distribute ≥ 40 phantoms to international sites.
 3. Estimate improvement in small lung nodule volume measurement performance and publish 2 papers (1 clinical, 1 technical)

**Frankfurt Cloud
Analysis Server Setup
January 2018**

**42 CTLX1 Phantoms
Globally Distributed By
December 2018**

**34 International
CT Scanners Tested
10 (27%) Passed on 1st Day
21 (63%) Passed on Last Day**

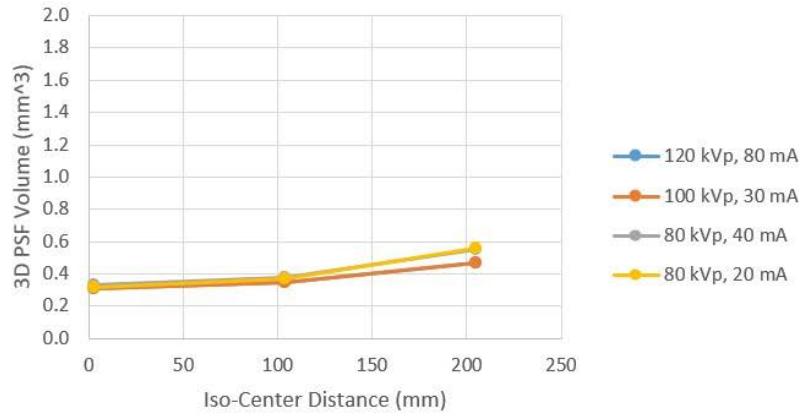
**Set Up The First Global CT Image Quality Monitoring and
Optimization System For CT Lung Cancer Screening**

PCF International Grant Phantom Distribution

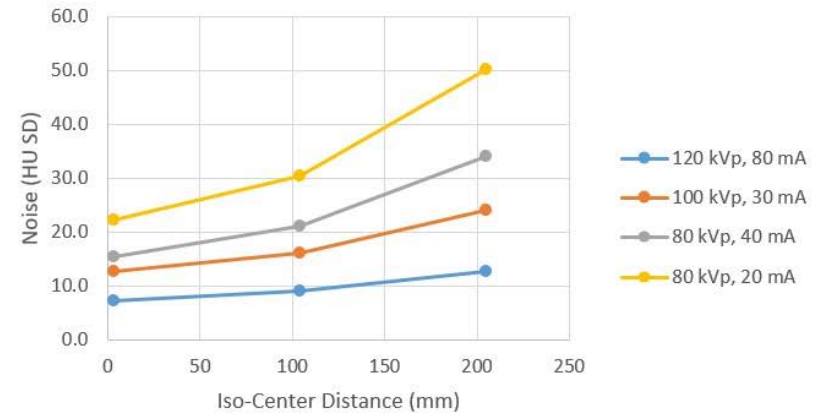
Count	Country	Number of Phantoms
1	Australia	6
2	China	10
3	Canada	7
4	Hong Kong	2
5	Italy	2
6	Israel	3
7	Japan	1
8	Netherlands	3
9	Poland	1
10	Spain	3
11	United Kingdom	4
	Total # Phantoms	42

Radiation Dose and Resolution

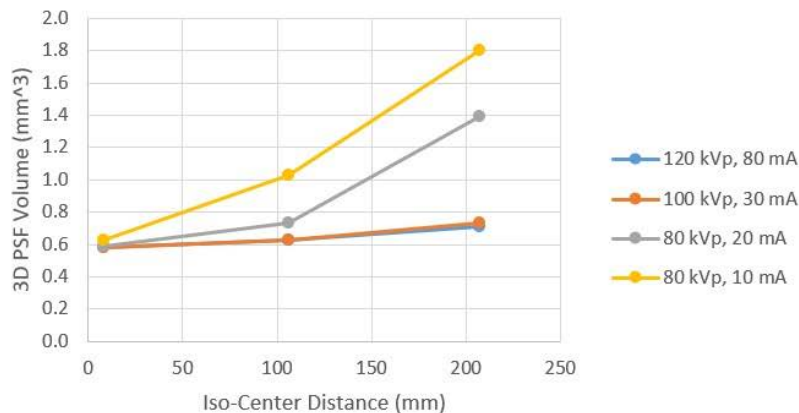
Scanner A: 3D Resolution vs Iso-Center Distance



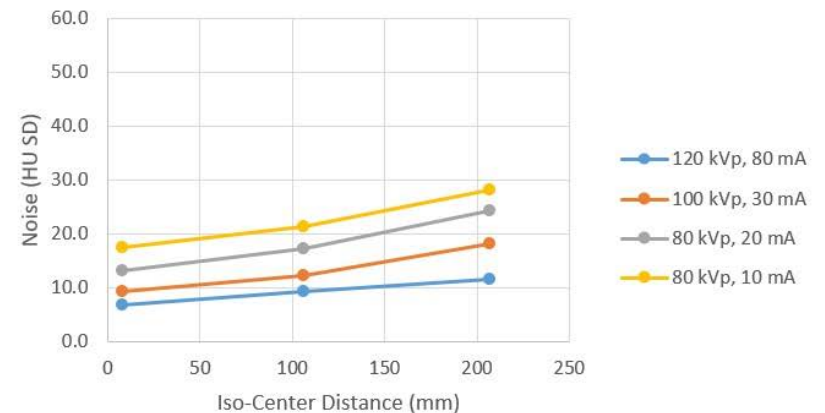
Scanner A: Noise vs Iso-Center Distance



Scanner B: 3D Resolution vs Iso-Center Distance



Scanner B: Noise vs Iso-Center Distance



RSNA/QIBA Conformance Certification

RSNA®
Radiological Society
of North America

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Science

LEADING SCIENTIFIC ADVANCEMENTS IN MEDICAL IMAGING

Quantitative Imaging Biomarkers Alliance (QIBA) Conformance Certification Services

QIBA® is now offering a new conformance testing service to help clinical sites demonstrate they can achieve high-quality quantitative imaging results. A clinical site that achieves QIBA Profile specifications will receive a QIBA® Conformance Certification Mark that can be used to distinguish itself as performing quantitative imaging studies with high levels of precision. Scanner and analysis software vendors can also obtain the QIBA® Conformance Certification Mark to demonstrate their specific medical device(s) or software has been tested and has demonstrated conformance with a given QIBA Profile. QIBA Conformance Certification Services, including an image quality assessment phantom and online phantom analysis services, are currently only available for the QIBA CT Small Lung Nodule Volume Assessment and Monitoring in Low-Dose Screening Profile.

Quantitative Imaging Biomarkers Alliance

TELL US HOW WE'RE DOING! »

Benefits of obtaining a QIBA® Conformance Certification Mark for a Clinical Site:

- Confirm that your clinical site is delivering high quality CT lung nodule imaging measurements to patients.
- Quantitatively identify, optimize and monitor any potential CT image quality performance issues.
- Obtain high-quality measurements based on fundamental CT image quality characteristics and lung imaging protocols which can be useful when conducting clinical trials and algorithmic imaging research.
- Promote your high-performance, quantitative imaging capability by posting the QIBA® Conformance Certification Mark to your website and imaging site materials.
- Participation will help improve future CT lung cancer imaging guidelines.

Benefits of obtaining a QIBA® Conformance Certification Mark for a Scanner or Software Vendor:

- Demonstrate to your current and potential customers that your medical device or software meets the thorough specifications outlined in a QIBA® Profile.
- Annually verify the performance of your medical device helping ensure that the high performance remains consistent under a variety of acquisition and measurement conditions.
- Provide quantitative and independently confirmed device data to your customers on the best methods and protocols to use with your medical device.
- Promote your high-performance, quantitative imaging capability by posting the QIBA® Conformance Certification Mark to your medical device or software web pages and promotional materials.
- Participation will help improve future CT lung cancer imaging guidelines.

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Advancing the Science

OF IMAGE-BASED DECISION MAKING

Accumetra is committed to advancing the science of image-based decision making. We provide new and advanced tools to better understand, optimize, and monitor image quality and expert consultation to help quantitatively improve clinical site performance. Accumetra is now working with the Radiological Society of North America® (RSNA) Quantitative Imaging Biomarkers Alliance® (QIBA) to provide conformance certification services to clinical sites, CT scanner vendors, and analysis software vendors. These new services enable organizations to achieve conformance with QIBA's CT Small Lung Nodule Profile and receive a new QIBA Conformance Certification Mark. The new QIBA Conformance Certification service provides an easy-to-use phantom and cloud-based quantitative analysis tools that allow institutions to thoroughly understand and optimize CT image quality for specific clinical measurement tasks. Learn more about this ground-breaking new approach to achieving high levels of CT lung nodule measurement performance through the link below.

SIGN UP FOR THE NEW QIBA CONFORMANCE CERTIFICATION SERVICE

Once conformance certification has been achieved, your institution can use these Conformance Certification Marks to demonstrate the achievement to customers and collaborators

CLINICAL SITE CONFORMANCE MARK

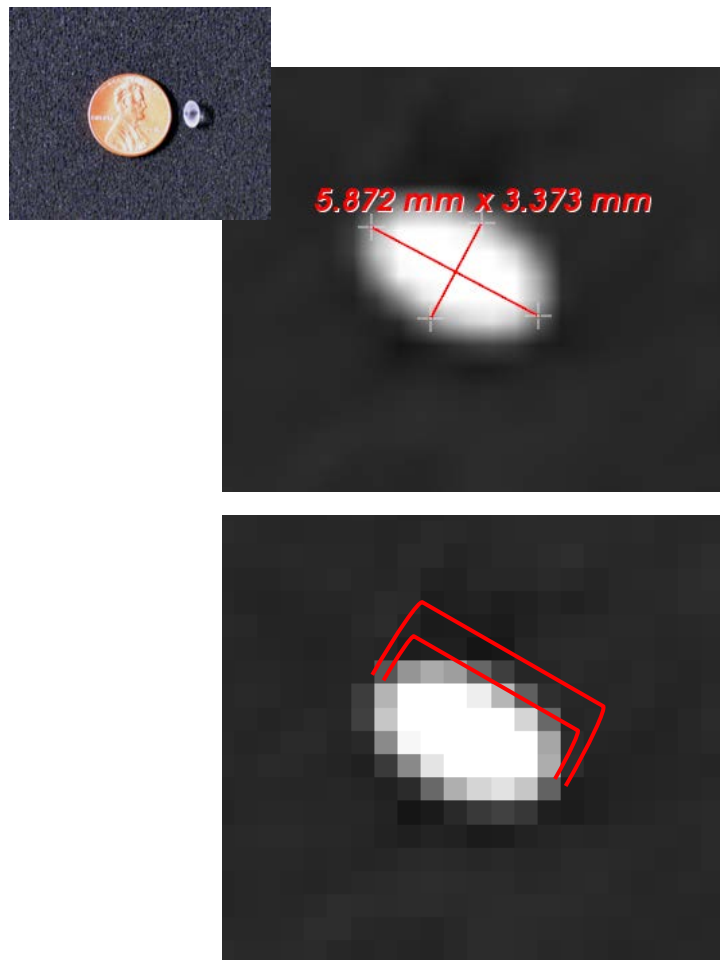
CT SCANNER VENDOR CONFORMANCE MARK

CT SOFTWARE VENDOR CONFORMANCE MARK

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accumetra.com/qiba-conformance-certification/

Small Lung Nodule Measurement



For a 6.0 x 3.6 x 3.6 mm Lung Nodule:

We are working with axial CT images with a maximum nodule diameter of between 6 and 9 pixels

+1mm Max Diameter Increase

Nodule Diameter	Diameter Change %	Volume Change %
6.0	17%	59%
7.0	14%	49%
8.0	13%	42%
9.0	11%	37%
10.0	10%	33%

If This Is TRULY a +1.0 mm Max Diameter Increase Over 6 Months, This Is a > 250% Volume Increase Over A Year

(640% for 3m)

Numerous CT Image Quality Issues Can Bias This Measurement

Use of Precise and Quality Controlled Quantitative Image Measurement Tools Is Critical

CTLX2 Phantom

Will Contain
3 Small
Modules
Similar To
The CTLX1

+ Outer
Channel
To Add
Varying
Amounts
Of Water

+ An
Additional
Access
Port

+ Additional
Components
Including
Some
Spheres and
Ellipsoids

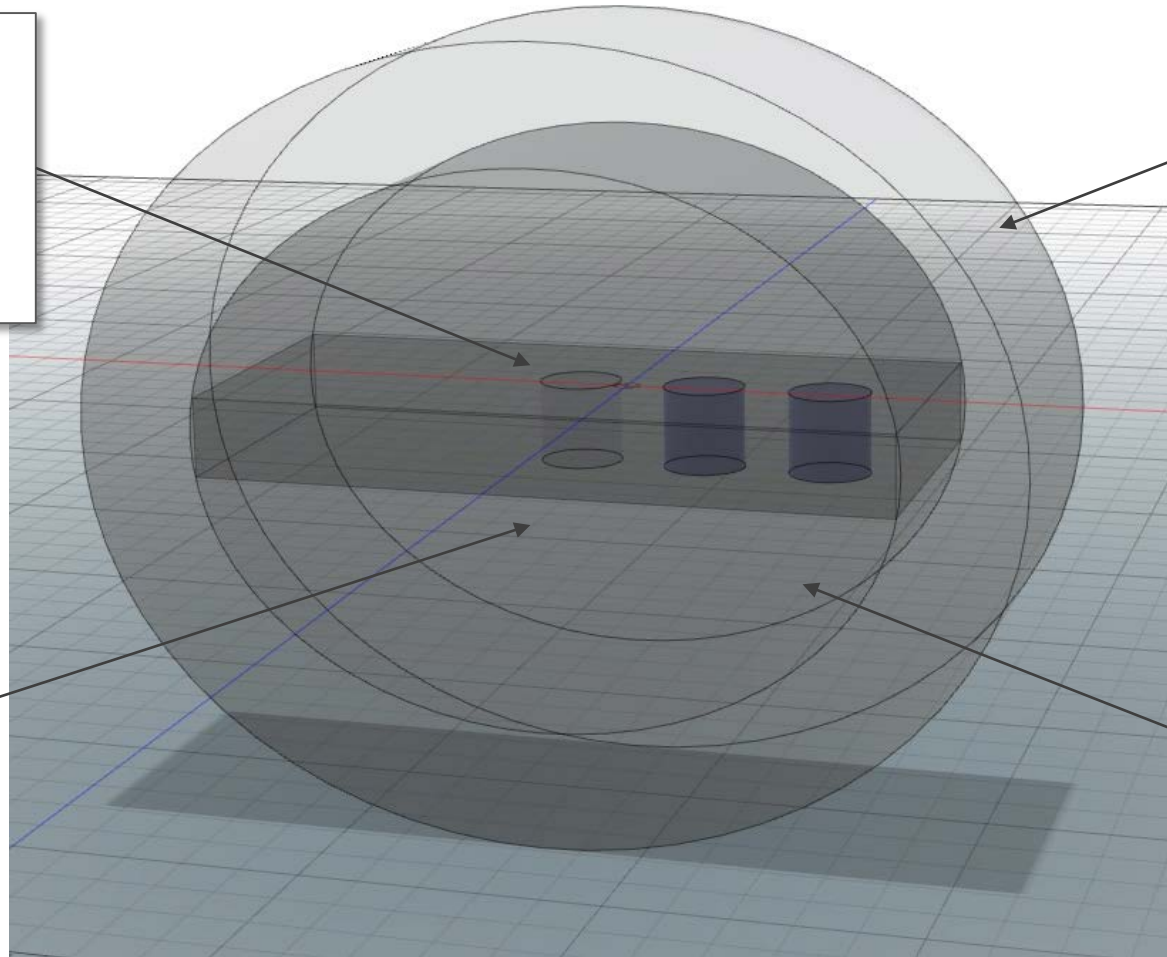


Table Phantom Scanning

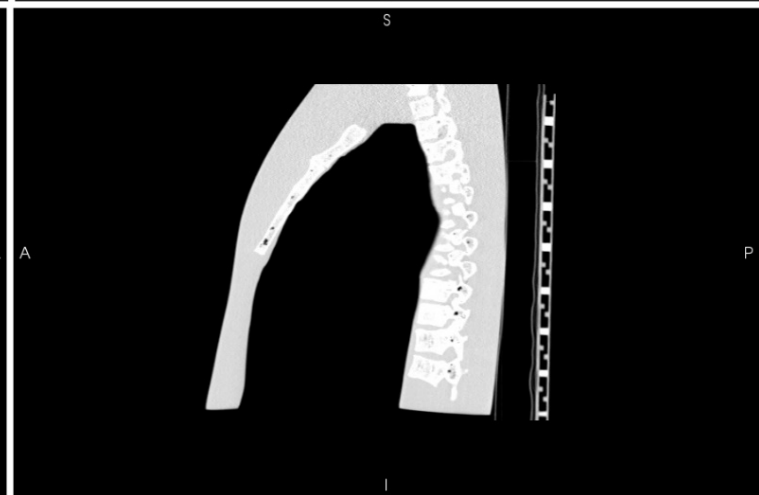
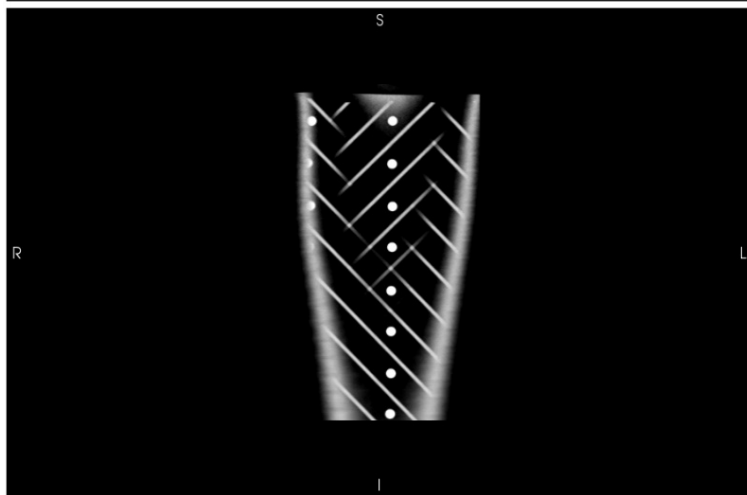
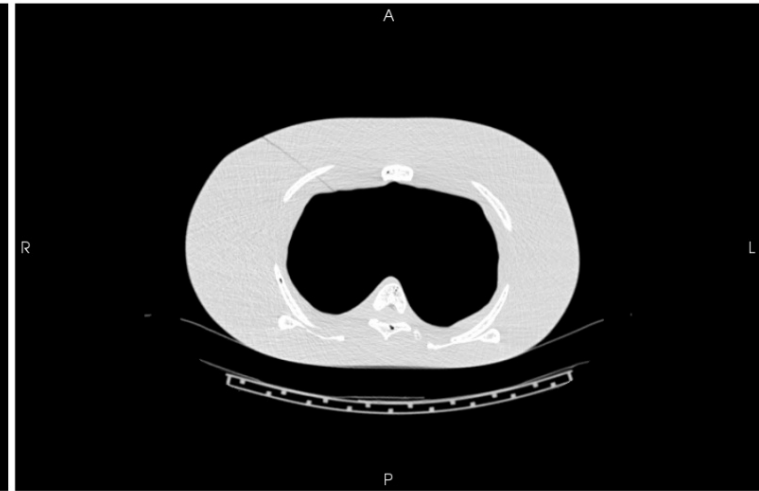
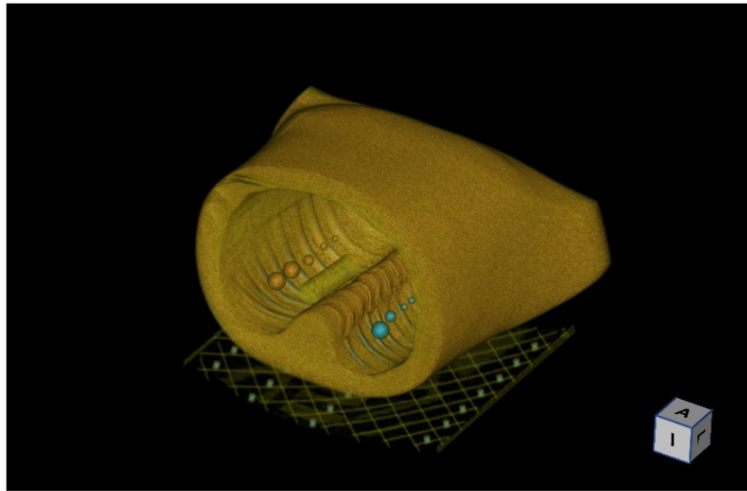
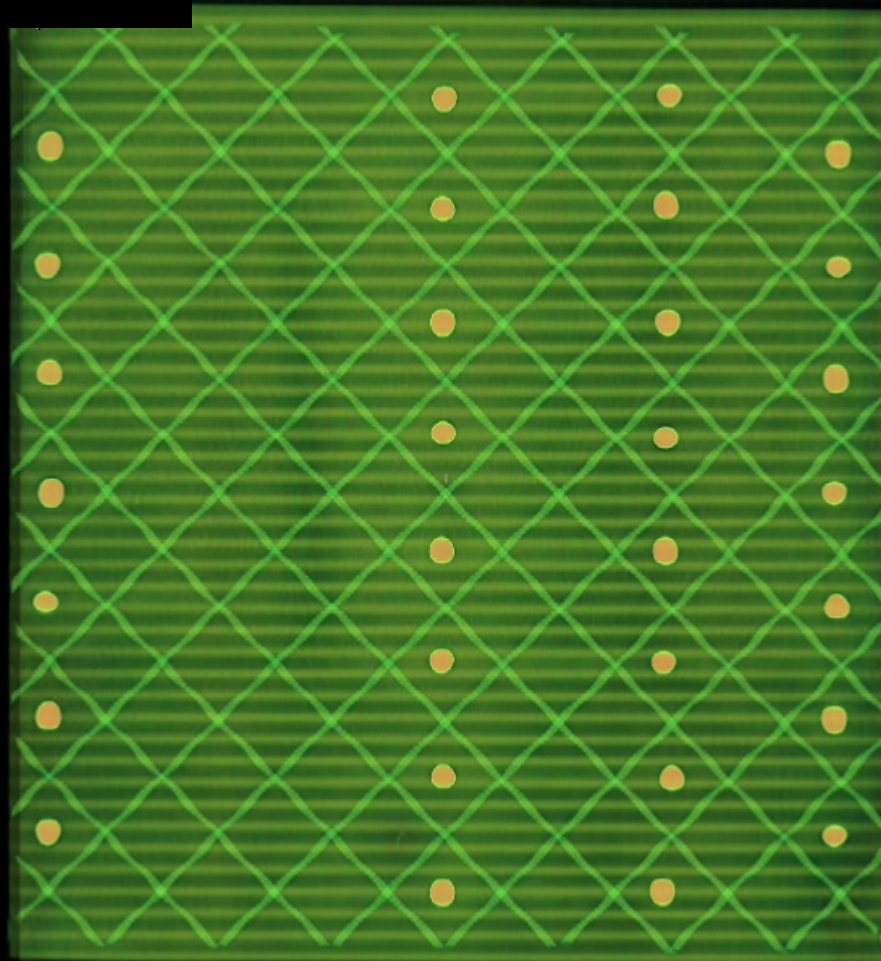


Table Phantom Scanning

Exam: 30754
Series: 2 (phantom)

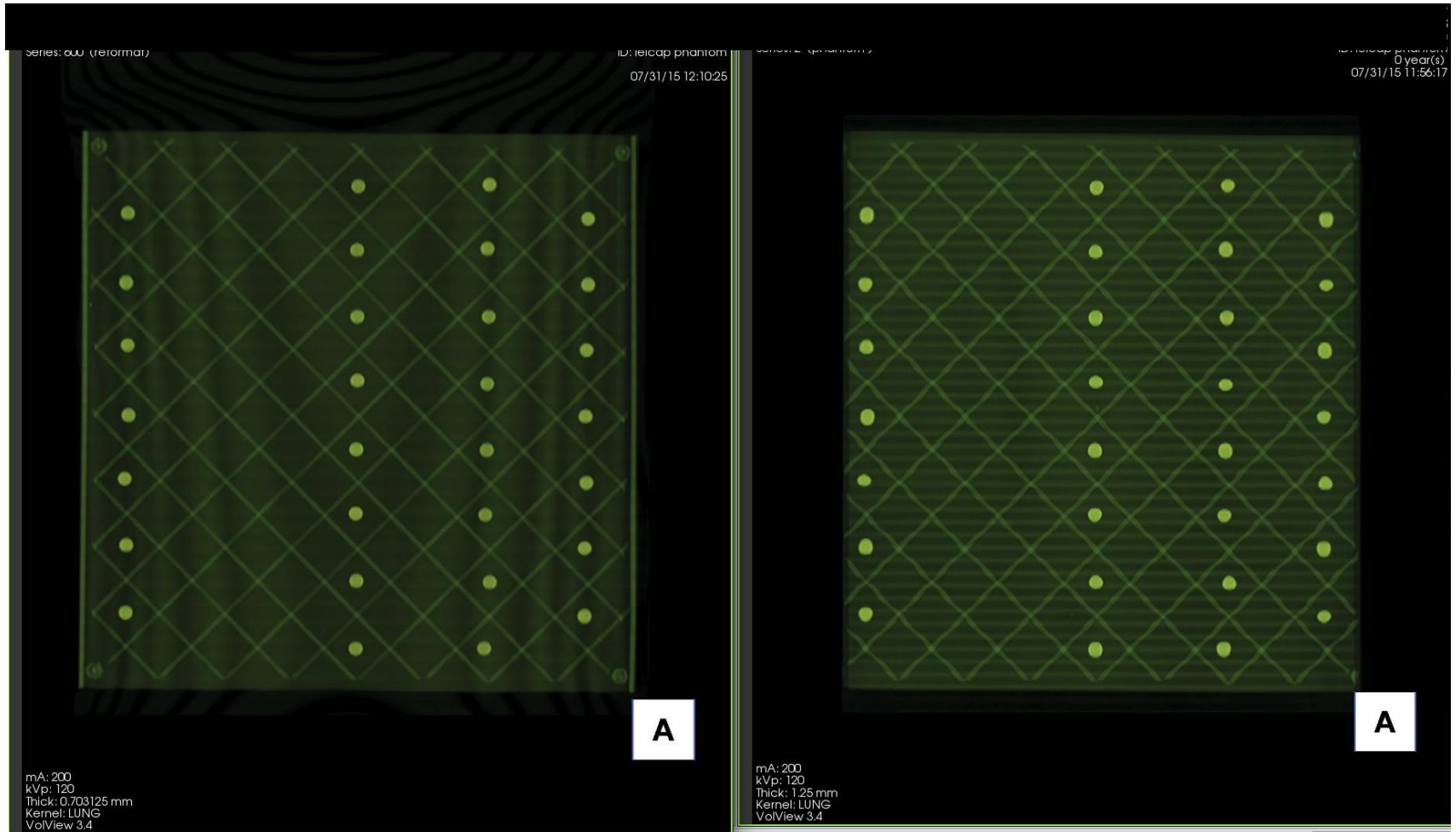


IM6
Clinical Radiologists SS
ielcap phantom
ID: ielcap phantom
0 year(s)
07/31/15 11:56:17

mA: 200
kVp: 120
Thick: 1.25
Kernel: LUNG
VolView 3.4

A

Table Phantom Scanning



Step & Shoot Acquisition

Helical Acquisition

