

National Cancer Institute

# NCI Quantitative Imaging Network (QIN): Update 2011

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QIBA Meeting May 24-15<sup>th</sup> 2011




## CIP Branch: Research Mission

### Open Science: Validation Strategies

Development and validation of current and next-generation of imaging platforms, methods and public web based resources, as required for cancer research and future multi center clinical trials using RFA's, PA's and Contracts

- **Current Generation: PET CT**      **Next Generation: Optical-US System 5 mm**






## QIN Teams Funded April 2011

1. University of Pittsburgh: James Mountz, MD, PhD
2. H. Lee Moffitt Cancer Center: Robert Gillies, PhD
3. Stanford University: Daniel Rubin, MD
4. Vanderbilt University: Thomas Yankeelov, PhD
5. University of Iowa, John Buatti, MD
6. University of Washington, Paul Kinahan, PhD
7. Brigham & Women's, Fiona Fennessy, MD, PhD
8. Columbia University: Larry Schwartz, MD
9. Massachusetts General Hospital, Greg Sorensen, MD

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## QIN Working Groups 2010

1. Data Collection  
Fernando Boada & Robert Doot
2. Image Analysis & Performance Metrics  
Milan Sonka & Sandy Napel
3. Bioinformatics/IT & Data Sharing  
Daniel Rubin & Steven Eschrich
4. Clinical Trial Design & Development  
Brenda Kurland & Ethan Argiris
5. Outreach: External/Industrial Relations  
Dennis Nelson

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## QIN: Range of Imaging Methods

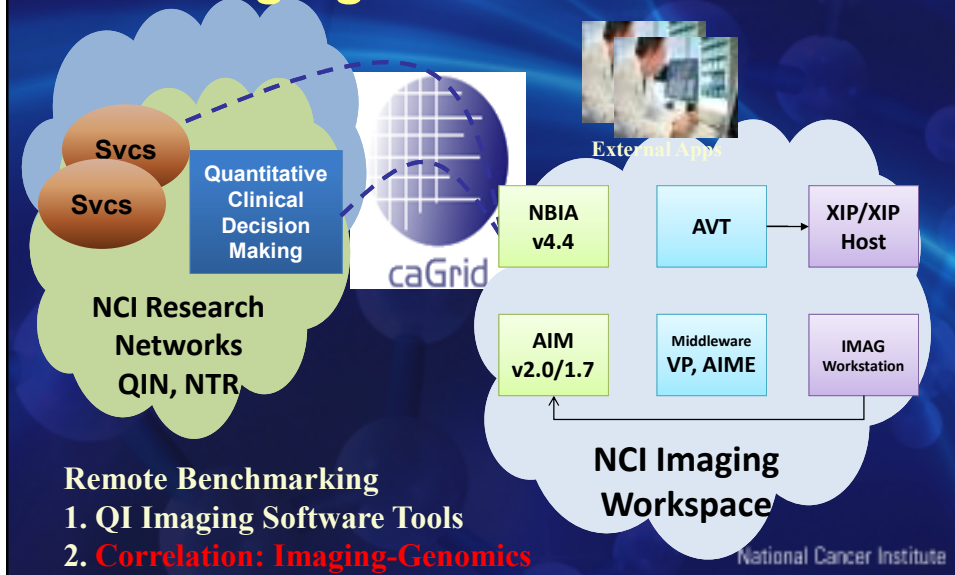
### Phantom Repeat-Longitudinal Studies

### Patient Repeat-Longitudinal Studies

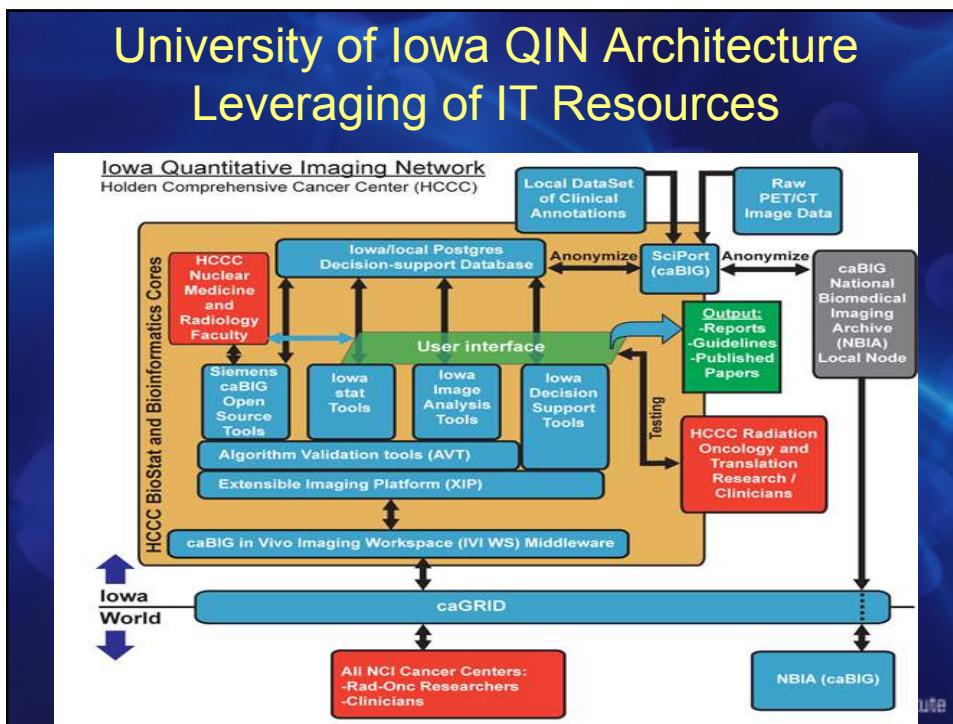
Institute	Cancer Problem	Imaging Method	Imaging Method	Other
University of Iowa	Head & Neck	PET/CT	MRI/MRSI	Phantoms, database
Brigham & Women's	Prostate	MRI		
Moffitt Cancer Center	Lung	PET/CT		
Univ. of Washington	Breast & Prostate	PET/CT		Phantoms
Univ. of Pittsburgh	Head & Neck	PET/CT	MRI	
Stanford Univ.	Metastatic Colon	CT	MRI	
Columbia Univ.	Lung, liver, lymph	CT		
MGH	Head & Neck	MRI		DCE methods
Vanderbilt Univ.	Breast	MRI	PET	CT

## GRID Computing-Web Services

### Leveraging of QIN IT Resources



## University of Iowa QIN Architecture Leveraging of IT Resources



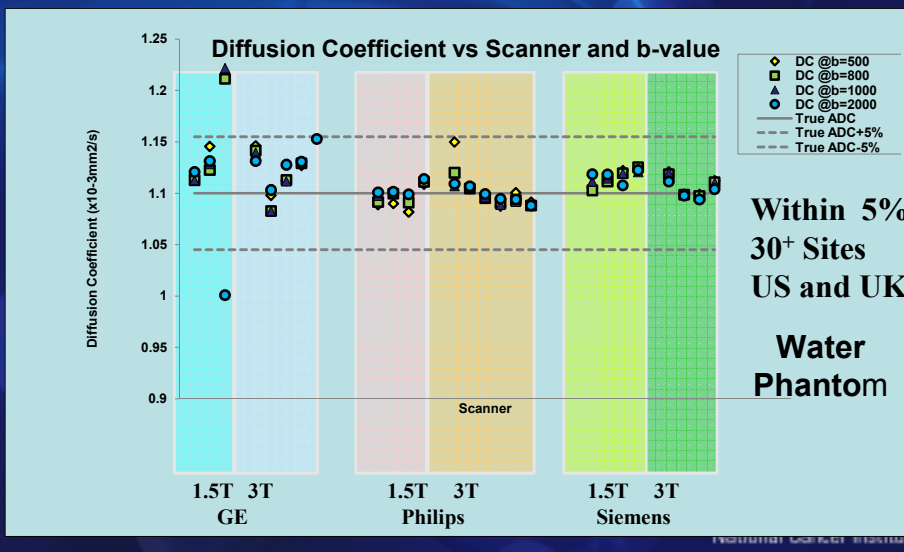
## QIN IT Workshop Nov 2010: Leveraging of Resources iPad: Ontology-Based Image Annotation


Lesion type	Cyst	Metastasis	Hemangioma	Hepatocellular Carcinoma
Feature				
Shape	-round	-round	-ovoid	-irregularly shaped
Margin	-smooth	-lobulated	-lobulated	-poorly defined
Density	-hypodense	-hypodense	-mixed density	-mixed density
Enhancement	-water density -nonenhancing	-soft tissue density -enhancing	-enhancing	-enhancing
		-homogeneous	-peripheral nodular	-heterogeneous

**Imaging phenotype = quantitative + semantic features**

Imaging Phenotype:  $f_1, f_2, f_3$  (Texture) |  $f_4, f_5, f_6$  (Shape) |  $f_7, f_8, f_9$  (Boundary) |  $f_{10}, f_{11}, f_{12}, f_{13}$  (Semantic)

# RIDER DWI: Minimize Platform Dependence (GE, Siemens, Philips) : NCI and CR UK Diffusion Coefficient of Water @ 0°C Measured at 4 b values






**Icewater for Quality Control of Diffusion Measurements in Multi-Center Trials**

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T. D. Johnson<sup>2</sup>, A. Rehemtulla<sup>3</sup>, and B. D. Ross<sup>1</sup>

<sup>1</sup>Radiology, <sup>2</sup>Biostatistics, <sup>3</sup>Radiation Oncology, University of Michigan, Ann Arbor, MI, United States

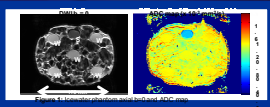


### Introduction

Apparent diffusion coefficient (ADC) is sensitive to therapy-induced change in tumor vascularity. However, ADC has been proposed as a treatment response biomarker. Prerequisites for use of ADC, as well as any image-based biomarker in multi-center trials, is standardization of data acquisition/analysis, and certification of measurements via quantitative measurements on known test objects [1]. A variety of diffusion phantoms have been proposed [2,3], although consensus in design and materials has not been achieved to date. Regardless of the choice of off-axis media, control and/or determination of temperature is required since diffusion is a function of temperature. The objective of this study is to assess reproducibility of ADC measurements performed at multiple sites on various clinical phantoms using a simple universal temperature-controlled fluid - ice-water.

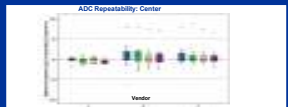
### Materials & Methods

A 17x47x200mm test object was designed to hold five 20mm diameter tubes filled with distilled water suspended within ice-water (Figure 1). Once thermal equilibrium is reached, the ice-water maintains the measurement volume in the tubes at 0°C for an extended period thus providing a fluid at a known diffusion coefficient (1.1x10<sup>-3</sup> mm<sup>2</sup>/s). A tube filled with a sucrose solution was also included to provide ADC contrast. Twenty test objects were constructed and distributed to institutions in North America and Europe with explicit imaging and scan instructions. The scan protocol was designed for compatibility across most modern clinical MRI systems: DW SS-EPI, TR/TE = 8000/100/10ms, 128x128 acquisition matrix, 30cm FOV, 2G, Green slices at 0 x (500,800,1000,2000) mm<sup>2</sup>. Head- and torso-coil scans were performed including scans with the test object offset in a normal or 180° in RL direction to further assess spatial dependence. Matlab scripts were developed to import DICOM DWI regardless of vendor brand and image sort order for conversion to a uniform structure format for reduction to ADC maps and ROI analysis.



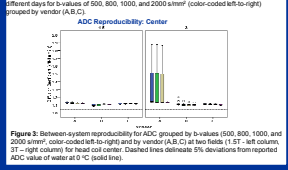
### Results

Data were returned from 34 MRI systems, 5 were dropped due to major protocol discrepancies, leaving 29 usable datasets from Vendor A (1.5T N=2, 3T N=3), Vendor B (1.5T N=2, 3T N=10), Vendor C (1.5T N=3, 3T N=4). Results of ADC reproducibility and reproducibility between systems measured from circular ROIs of the central tube on center slices are illustrated in Figures 2 and 3. B-values are separated by vendor, b-value pairs and field strength (1.5T and 3T). Horizontal dashed lines represent ±5% from the assumed correct diffusion value of 1.1x10<sup>-3</sup> mm<sup>2</sup>/s, and illustrate that 27 of the 29 systems produced diffusion values within 3% of the correct value (Fig 2). One system (a Vendor A, 3T) was a clear outlier (~70% error) for 3 of 4 b-value pairs. Excluding this outlier, the standard deviation over all measurements (vendor, b-value pair, and field strength) was below 3% of the correct value. However, significant spatial non-uniformity even (10%) was observed for off-center measurements as illustrated in Figure 4. Systematic spatial dependence of measured diffusion as exemplified by one system in Figure 5 was consistent with gradient non-linearity.



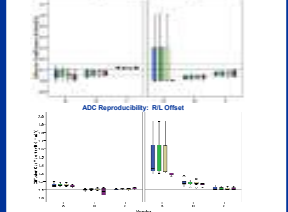
**ADC Reproducibility: Center**

Figure 2: Summary of day-to-day repeatability for multi-site results (head coil center) pooled over field strength plotted as a percent difference in ADC measurements taken on two different days for b-values of 500, 800, 1000, and 2000 mm<sup>2</sup> (color-coded left-to-right) grouped by vendor (A,B,C).



**ADC Reproducibility: Center**

Figure 3: Between-system reproducibility for ADC grouped by b-values (500, 800, 1000, and 2000 mm<sup>2</sup>) color-coded left-to-right and by vendor (A,B,C) at two fields (1.5T: left column, 3T - right column) for head coil center. Dashed lines delineate 5% deviations from reported ADC value of water at 0°C (bold line).



**ADC Reproducibility: SI Offset**

**ADC Reproducibility: RL Offset**

Figure 4: Effect of off-center shift on between-system reproducibility for ADC grouped similar to Figure 3 for superior-inferior offset (top panels) and right-to-left offset (lower panels). Dashed lines delineate 5% deviations from the ADC value of water at 0°C (bold line).

### RL Spatial Dependence

**Measured ADC**

**Gain in b-value**

Figure 5: Significant systematic spatial dependence of measured diffusion (left panel) by one system is consistent with observed gradient non-linearity (right panel) for RL (top) and SI (lower panel) offsets.

### SI Spatial Dependence

**Measured ADC**

**Gain in b-value**

Figure 6: Significant systematic spatial dependence of measured diffusion (left panel) by one system is consistent with observed gradient non-linearity (right panel) for RL (top) and SI (lower panel) offsets.

### Conclusion

For lack of an established diffusion phantom standard, this study utilized ice-water for initial assessment of ADC reproducibility across clinical MRI platforms. Certification of system buffers and 3% reproducibility in diffusion coefficient measurement exclusive of offsets was demonstrated. Large (> 10%) systematic spatial-dependence error was also demonstrated. Much of this error is the result of gradient non-linearity manifesting as a spatially-dependent b-value. The suggested protocol for standardization and quantitative quality control of ADC measurements is universally applicable for multi-center clinical trials.

### Acknowledgments

This work was supported in part by the following research grants from the National Institutes of Health (NIH): P01-CA85476; P50-CA93990; and NINCI SAC contract 20X1951.

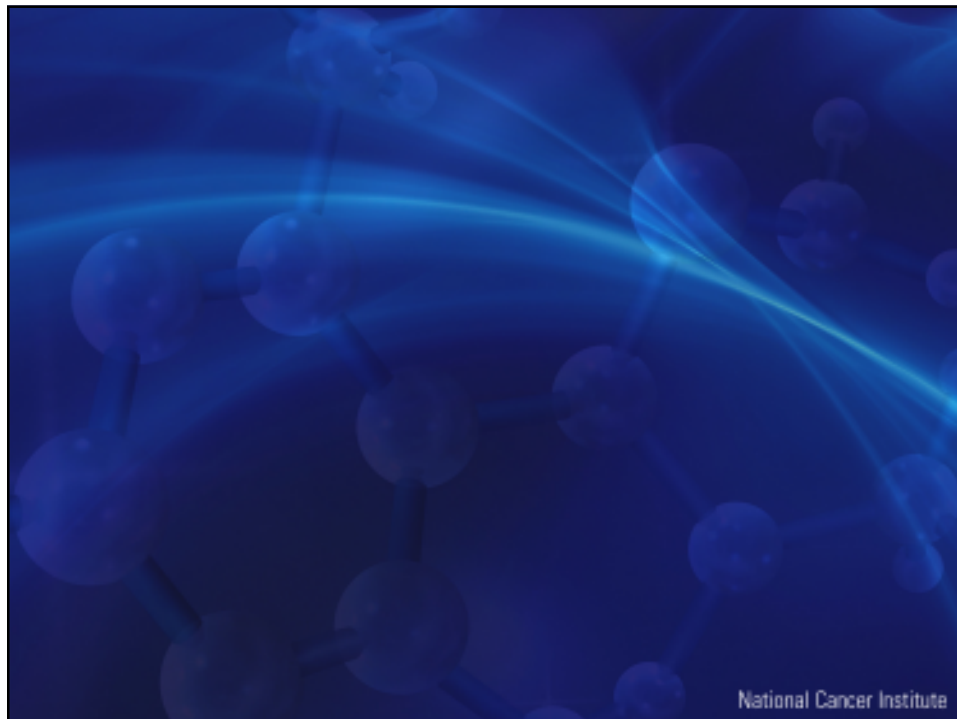
### References

1. Pothner AJ et al. *Neoplasia* 2005; 7:1102-10.
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3. Dwyer J et al. *Phys Med Biol* 2004; 49:1429-1432.
4. Lonsdale H et al. *J Magn Reson Imaging* 1998; 8:1049-1054.
5. Pierpaoli C et al. *Proc Int Soc Mag Reson Med* 17 (2009) 1414.

## QIN: Summary

- QIN is an example of NCI's open science validation strategy for current generation of imaging platforms.
- QIN will provide technical resources to support optimized methods for quantitative imaging for all NCI and other clinical trial groups
- QIN is encouraging the imaging industry to promote platform independent methods for data collection –analysis
- QIN is supporting quantitative correlation of imaging with genomics-proteomics
- QIN is an open science model for international collaboration with other cancer funding agencies
  - CR UK, Canada CIHR, EU Framework,
  - Workshop : Summer 2011 (Canadian Embassy London).

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