Joint Imaging-Therapy Scientific Symposium – August 3, 2017
Advancements in MRI and MR-Guided Interventions
TH-EF-FS4-0

The Translation from Qualitative Assessments to Quantitative Measurements: Why and How

Edward F. Jackson, PhD
Professor and Chair, Department of Medical Physics
Professor of Radiology and Human Oncology
School of Medicine and Public Health
UNIVERSITY OF WISCONSIN-MADISON

Declaration of Financial Interests or Relationships

Speaker Name: Edward F. Jackson, PhD

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Objectives

1. Understand the various approaches in development of 4D-MRI and their pros and cons.
2. Understand the principles and clinical applications of ultra-resolution diffusion MRI.
3. Understand the important and current developments in quantitative MR imaging.

Biomarkers

Biomarkers are characteristics that are *objectively measured* and evaluated as an indicator of normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention.[1]

Quantitative imaging biomarkers (QIBs) are objective characteristics derived from *in vivo* images as indicators of normal biological processes, pathogenic processes, or response to a therapeutic intervention.[2]

[1]NIH Biomarkers Definitions Working Group, *Clin Pharmacol Therap* 69(3):89-95, 2001
[2]Sullivan *et al.*, *Radiology* 277(3):813-825, 2015 (www.rsna.org/qiba)

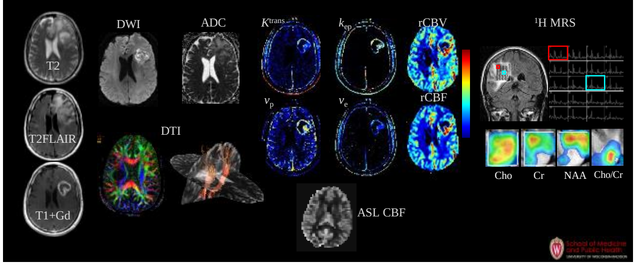
From Qualitative Findings to QIB Assay

- Validation: "assessing the assay and its measurement performance characteristics, and determining the range of conditions under which the assay will give reproducible and accurate data"
- Qualification: "'fit-for-purpose' evidentiary process linking a biomarker with biology and clinical endpoints"
- Surrogate: a biomarker that can substitute for a clinical endpoint in a regulatory approval process

Wagner JA, *et al.* Translational Medicine 81(1):104-7, 2007

Current MR QIB Applications

Existing MR QIBs in Glioma: Morphological to Functional



MR QIBs in Glioma

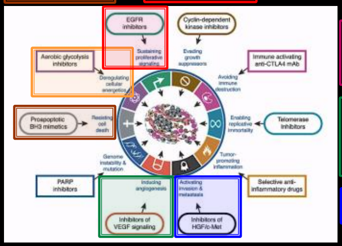
Biological Process	MR Technique	MR QIB Measurand
Tumor Cellularity / Proliferation	^{1}H MRS, DTI/DWI	↑Cho, ↑Cho/NAA, ↓ADC
Necrosis	^{1}H MRS, Gd-enhanced, T2W	↑lipids, No Gd uptake, ↑T2W signal
Edema	T2FLAIR, DTI/DWI	↑FLAIR signal, ↑ADC, ↓FA
Gliosis	^{1}H MRS (short TE)	↑myo-inositol
Hypoxia	^{1}H MRS, BOLD	↑lactate, ↓ΔR2*
Angiogenesis / Permeability	DCE-MRI, DSC-MRI	↑K^{trans} & v_p, ↑rCBV & rCBF
Invasion	DTI, ^{1}H MRS	↓FA, ↑ADC, ↓NAA
Radiation Effects	SWI, DTI	Micro-hemorrhages (late), ↓FA

Modified version of Table 1 of Nelson, *NMR Biomed* 24:734-739, 2011

Imaging Applications in Precision Medicine

^{18}F/^{99m}Tc-Annexin V
Diffusion MRI

^{18}F-FLT PET
Diffusion MRI
^{1}H MR Spectroscopy



^{18}F-FDG PET
^{18}F-MISO PET
^{1}H & ^{13}C MR Spectroscopy
BOLD MRI

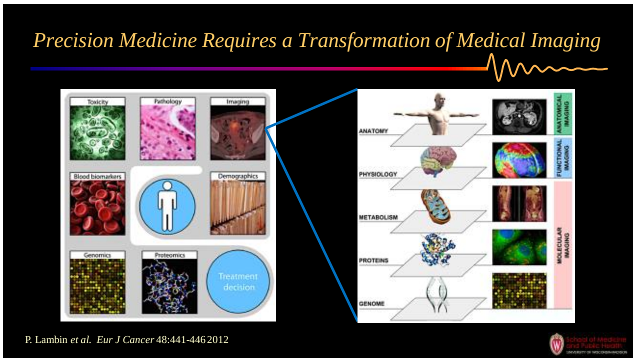
DCE-MRI / DCE-CT
DSC-MRI / ASL MRI
CE-US
^{68}Ga-/^{64}Cu-DOTA-cRGD PET
^{89}Zr-bevacizumab

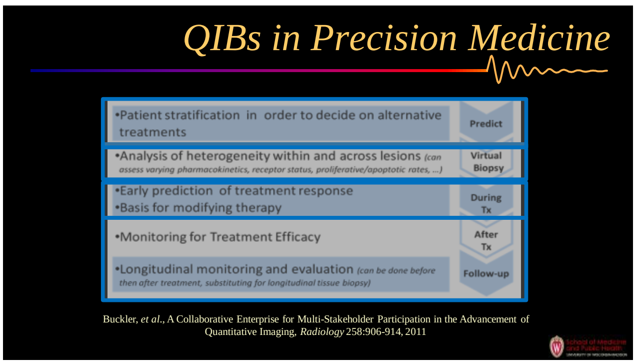
^{18}F-FDG PET
Diffusion MRI

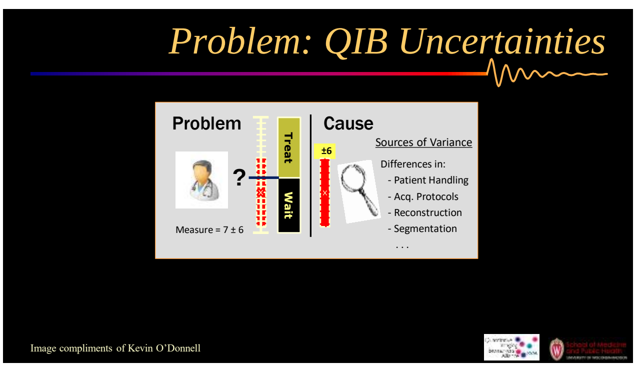
Hanahan & Weinberg, Hallmarks of Cancer: The Next Generation, *Cell* 144:646-674, 2011

Consumer Expectations for Quantification

- 94% of oncologists expect some or all tumors to be measured at the time of standard initial clinical imaging. (Jaffe T, *AJR* 2010)
- Pulmonologists desire CT-derived quantitative measures in COPD and asthma patients. (ATS/ERS Policy statement, *Am J Resp Crit Care Med* 2010)
- Hepatologists desire quantitative measures of liver fat infiltration (Fitzpatrick E, *World J Gastro* 2014)
- Rheumatologists desire quantitative measures of joint disease (Chu C, *JBJS:J Bone Joint Surg* 2014)
- Neurologists and psychiatrists desire quantitative measures of brain disorders (IOM Workshop, August 2013).
- Regulatory agencies desire more objectivity in interpretations.


Precision Medicine Requires a Transformation of Medical Imaging
Toxicity
Pathology
Imaging
Blood biomarkers
Demographics
Genomics
Proteomics
Treatment decision
ANATOMY
PHYSIOLOGY
METABOLISM
PROTEINS
GENOME
ANATOMICAL IMAGING
FUNCTIONAL IMAGING
MOLECULAR IMAGING
P. Lambin et al. Eur J Cancer 48:441-446 2012


QIBs in Precision Medicine
•Patient stratification in order to decide on alternative treatments
Predict
•Analysis of heterogeneity within and across lesions (can assess varying pharmacokinetics, receptor status, proliferative/apoptotic rates, …)
Virtual Biopsy
•Early prediction of treatment response
•Basis for modifying therapy
During Tx
•Monitoring for Treatment Efficacy
After Tx
•Longitudinal monitoring and evaluation (can be done before then after treatment, substituting for longitudinal tissue biopsy)
Follow-up
Buckler, et al., A Collaborative Enterprise for Multi-Stakeholder Participation in the Advancement of Quantitative Imaging, Radiology 258:906-914, 2011


Problem: QIB Uncertainties
Problem
?
Treat
Wait
Measure = 7 ± 6
Cause
±6
Sources of Variance
Differences in:
- Patient Handling
- Acq. Protocols
- Reconstruction
- Segmentation
. . .
Image compliments of Kevin O'Donnell

Poor Reproducibility has Clinical Implications

- Willemink MJ, *et al.* Coronary artery calcification scoring with state-of-the-art CT scanners from different vendors has substantial effect on risk classification. *Radiology* 173:695-702, 2014
  "Among individuals at intermediate cardiovascular risk, state-of the-art CT scanners made by different vendors produced substantially different Agatston scores, which can result in reclassification of patients to the high- or low-risk categories in up to 6.5% of cases."
- Oberoi S, *et al.* Reproducibility of noncalcified coronary artery plaque burden quantification from coronary CT angiography across different image analysis platforms. *AJR Am J Roentgenol* 202:W43-9, 2014
  "Currently available noncalcified plaque quantification software provides …poor interplatform reproducibility. Serial or comparative assessments require evaluation using the same software. Industry standards should be developed to enable reproducible assessments across manufacturers."

2017 Fleischner Society Guidelines for Management of CT Pulmonary Nodules

Nodule Type	Size			Comments
	<6 mm (<100 mm^3)	6–8 mm (100–250 mm^3)	>8 mm (>250 mm^3)	
Single				
Low risk†	No routine follow-up	CT at 6–12 months, then consider CT at 18–24 months	Consider CT at 3 months, PET/CT, or tissue sampling	Nodules <6 mm do not require routine follow-up, but certain patients at high risk with suspicious nodule morphology, upper lobe location, or both may warrant 12-month follow-up (recommendation 1A).

MacMahon H, *et al.*, Guidelines for Management of Incidental Pulmonary Nodules Detected on CT Images: From the Fleischner Society 2017.
Radiology 2017 Feb 23

QIB Challenges

Diagnostic Imaging System ≠ Measurement Device

- Measurement Device:
  - Specific measurand(s) with known bias and variance (confidence intervals)
  - Specific requirements for reproducible quantitative results
  - Example: a pulse oximeter
- Diagnostic Imaging Equipment:
  - Historically: best image quality in shortest time (*qualitative*)
  - No specific requirements for reproducible *quantitative* results (with few exceptions)

QIB Challenges

General QIB challenges:

- Lack of detailed assessment of sources of bias and variance
- Lack of standards (acquisition and analysis)
- Highly variable quality control procedures
  - QC programs / phantoms, if any, typically not specific for *quantitative* imaging
- Little support (historically) from imaging equipment vendors
  - No documented competitive advantage of QIB (regulatory or payer)

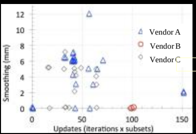
All lead to varying measurement results across vendors, centers, and/or time

QIB Challenges

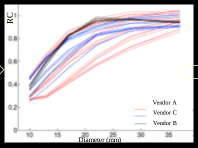
Other QIB challenges:

- Cost of QIB studies (comparative effectiveness) / reimbursement
- Radiologist acceptance
  - Limited number of use cases for QIBs *vs.* conventional practice
  - QIBs are not part of radiologist education & training
  - The software and workstations needed to calculate and interpret QIBs are often not integrated into the radiologist's workflow
  - Clinical demand on radiologists is high --- "time is money"

PET Reconstruction Harmonization

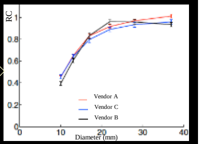


Sample of reconstruction settings from 68 academic imaging centers



Range of biases as a function of object size for different reconstruction settings

(1.0 = no bias)



Harmonized results

RC = Ratio of Observed Activity Concentration to Actual Activity Concentration

Source: Paul Kinahan, PhD

General Challenges in MR Quantification

Arbitrary (and spatially- / temporally-dependent) signal intensity units

- Magnitude and homogeneity of B_o
- Magnetic field gradient nonlinearities, eddy currents, concomitant fields, *etc.*
- RF coil dependency: RF coil type, B_1 sensitivity profiles, subject positioning within the coil
- Slice profile variations (with RF pulse shape, flip angle, *etc.*)
- Off resonance effects
- Parallel imaging, compressed sensing, and other acceleration techniques
- System stability issues (B_0, RF & gradient subsystems, RF coils, *etc.*)

Adopting Metrology Principles in Imaging

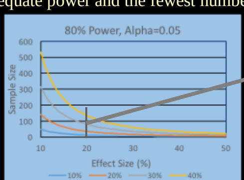
Sources of bias and variance in QIB measurands are identified and mitigated to the degree possible.

- Bias* (accuracy):
  - Often difficult to assess due to absence of reference standard ("ground truth") measures
  - Potential role for application-specific phantoms
- Precision* (variance):
  - Repeatability* – All conditions the same except short time separation ("test/retest") – Repeatability coefficient
  - Reproducibility* – Different operators, different days – Reproducibility coefficient

*Kessler, Barnhart, *et al.*, *Stat Meth Med Res* 24:9-26, 2015; Sullivan, Obuchowski, *et al. Radiology* 277:813-825, 2016
available at www.rsna.org/qiba

Adopting Metrology Principles in Imaging

- Levels of bias and variance remaining after mitigation are characterized => confidence intervals.
- Knowing these levels translates to statistically valid study designs with adequate power and the fewest number of patients.



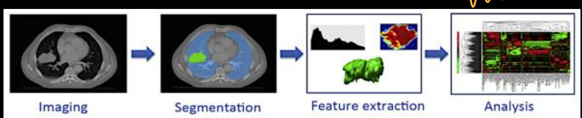
Number of patients:

10%	12
20%	35
30%	78
40%	133

Need for Data Sharing

- Clinical trials involving QIBs are expensive
  - Individual trials typically have small numbers of patients (Phase I / II)
- Standardization ➔ Pooled, quality data
  - Meta analysis studies
  - Algorithm development, validation, and comparison
  - Evidence-based medicine / comparative effectiveness studies
  - Radiomics / radiogenomics studies

Radiomics / Imaging Genomics



Imaging	Segmentation	Feature extraction	Analysis
Standardized protocols (acquisition, reconstruction, and post-processing)	Automated (or standardized if semi-automatic)	Automated (or standardized if semi-automatic)	Integrated clinical, imaging, genomics, proteomics data (disparate databases)
Quality control program	Reproducible	Feature-space based	Informatics analytics
Multiplatform longitudinal harmonization	Validated	Reproducible	Standardized reporting
		Low redundancy	

P. Lambin *et al.* *Eur J Cancer* 48:441-446 2012

Selected QIB Initiatives

NCI: Quantitative Imaging Network (QIN)

RSNA: Quantitative Imaging Biomarkers Alliance (QIBA) with support from NIBIB

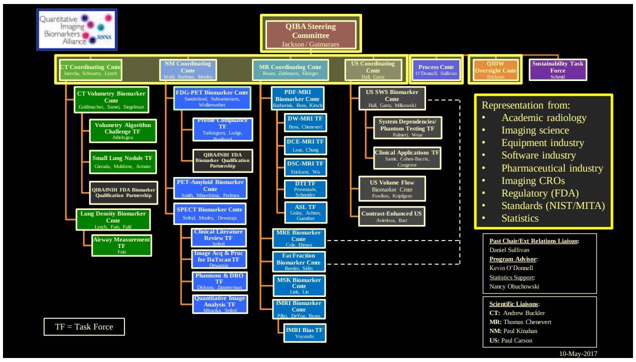
ISMRM: *Ad Hoc* Committee on Standards for Quantitative MR

NIST: Quantitative Imaging Physical Phantoms / Metrology

FDA: Quantitative Imaging Physical Phantoms & Regs

Quantitative Imaging Biomarkers Alliance

- QIBA was initiated in 2007
- RSNA Perspective: *One approach* to reducing variability in radiology is to extract objective, quantitative results from imaging studies.
- QIBA Mission
  - Improve the value and practicality of *quantitative imaging biomarkers* by reducing variability across devices, imaging centers, patients, and time.
  - "Industrialize imaging biomarkers"



Goal of QIBA

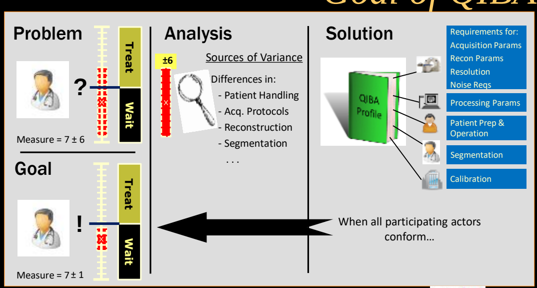
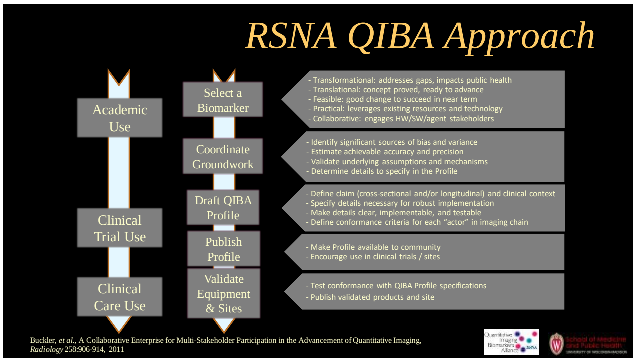
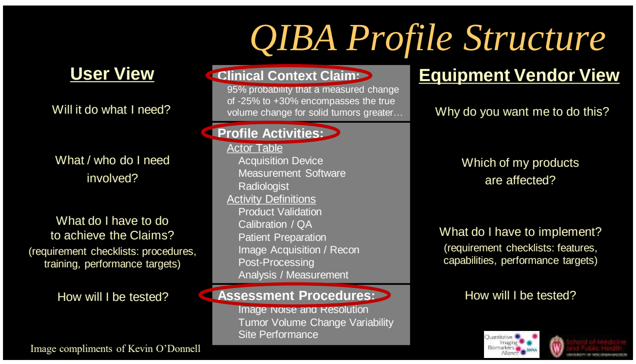
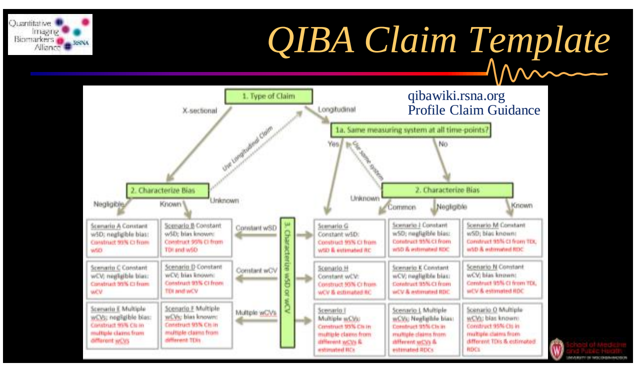


Image compliments of Kevin O'Donnell


RSNA QIBA Approach
Academic Use
Clinical Trial Use
Clinical Care Use
Select a Biomarker
Coordinate Groundwork
Draft QIBA Profile
Publish Profile
Validate Equipment & Sites
- Transformational: addresses gaps, impacts public health
- Translational: concept proved, ready to advance
- Feasible: good change to succeed in near term
- Practical: leverages existing resources and technology
- Collaborative: engages HW/SW/agent stakeholders
- Identify significant sources of bias and variance
- Estimate achievable accuracy and precision
- Validate underlying assumptions and mechanisms
- Determine details to specify in the Profile
- Define claim (cross-sectional and/or longitudinal) and clinical context
- Specify details necessary for robust implementation
- Make details clear, implementable, and testable
- Define conformance criteria for each "actor" in imaging chain
- Make Profile available to community
- Encourage use in clinical trials / sites
- Test conformance with QIBA Profile specifications
- Publish validated products and site
Buckler, et al., A Collaborative Enterprise for Multi-Stakeholder Participation in the Advancement of Quantitative Imaging, Radiology 258:906-914, 2011


QIBA Profile Structure
User View
Will it do what I need?
What / who do I need involved?
What do I have to do to achieve the Claims?
(requirement checklists: procedures, training, performance targets)
How will I be tested?
Clinical Context Claim:
95% probability that a measured change of -25% to +30% encompasses the true volume change for solid tumors greater…
Profile Activities:
Actor Table
Acquisition Device
Measurement Software
Radiologist
Activity Definitions
Product Validation
Calibration / QA
Patient Preparation
Image Acquisition / Recon
Post-Processing
Analysis / Measurement
Assessment Procedures:
Image Noise and Resolution
Tumor Volume Change Variability
Site Performance
Equipment Vendor View
Why do you want me to do this?
Which of my products are affected?
What do I have to implement?
(requirement checklists: features, capabilities, performance targets)
How will I be tested?
Image compliments of Kevin O'Donnell


QIBA Claim Template
qibawiki.rsna.org
Profile Claim Guidance
1. Type of Claim
X-sectional
Longitudinal
1a. Same measuring system at all time-points?
Yes
No
Use Longitudinal Claim
Use same system
2. Characterize Bias
Negligible
Known
Unknown
Common
3. Characterize wSD or wCV
Constant wSD
Constant wCV
Multiple wCVs

QIBA Metrology Working Group

Working Group Publications

Sullivan DC, Obuchowski NA, Kessler LG, et al. **Metrology Standards for Quantitative Imaging Biomarkers.** *Radiology*. 2015 Aug 12. Epub ahead of print. doi: 10.1148/radiol.2015142202.

Kessler, LG, et. al., **The Emerging Science of Quantitative Imaging Biomarkers Terminology and Definitions for Scientific Studies and Regulatory Submissions,** *Stat Methods Med Res 0962280214537333, first published on June 11, 2014 as doi:10.1177/0962280214537333*

Raunig, DL, et. al., **Quantitative Imaging Biomarkers: A Review of Statistical Methods for Technical Performance Assessment,** *Stat Methods Med Res 0962280214537344, first published on June 11, 2014 as doi:10.1177/0962280214537344*

Obuchowski, NA, et. al., **Quantitative Imaging Biomarkers: A Review of Statistical Methods for Computer Algorithm Comparisons,** *Stat Methods Med Res 0962280214537390, first published on June 11, 2014 as doi:10.1177/0962280214537390*

Obuchowski, NA, et. al., **Statistical Issues in the Comparison of Quantitative Imaging Biomarker Algorithms Using Pulmonary Nodule Volume as an Example,** *Stat Methods Med Res 0962280214537392, first published on June 11, 2014 as doi:10.1177/0962280214537392*

Huang, EP, et. al., **Meta-analysis of the Technical Performance of an Imaging Procedure: Guidelines and Statistical Methodology,** *Stat Methods Med Res 0962280214537394, first published on May 28, 2014 as doi:10.1177/0962280214537394*

Available at www.rsna.org/qiba

FDG-PET/CT SUV Profile

Table of Contents

Conformance to this Profile by all relevant staff and equipment supports the following claims:

Claim 1: Tumor glycolytic activity as reflected by the maximum standardized uptake value (SUVmax) is measureable from FDG-PET/CT with a within-subject coefficient of variation of 10-12%.

Claim 2: A measured increase in SUVmax of 39% or more, or a decrease of -28% or more, indicates that a true change has occurred with 95% confidence.

Current Profile Status *(As of 7/15/2017)*

- 20 Profiles (4 CT, 3 NM, 10 MR, 3 US)
- Technically Confirmed Stage:
  - *FDG-PET/CT SUV as an Imaging Biomarker for Measuring Response to Cancer Therapy* (v1.05)*
- Publicly Reviewed (Consensus) Stage and Posted:
  - *CT Tumor Volume Change* (v2.2) for tumor response (expected to be Technically Confirmed Spr 2017)*
  - *DCE-MRI Quantification* (v1.0) for tumor response
- In Public Comment Stage:
  - CT: *Lung Nodule Volume Assessment and Monitoring in Low Dose CT Screening Quantification*
  - SPECT: *Quantifying Dopamine Transporters with 123-Iodine labeled Ioflupane in Neurodegenerative Disease*
  - DW-MRI for tumor response

*Highlighted on Cancer Moonshot website

qibawiki.rsna.org

Current Profile Status *(As of 7/15/2017)*

- In Final Stage of Development for Public Comment Stage:
  - CT lung densitometry for COPD
  - PET amyloid for Alzheimer's Disease
  - fMRI for pre-surgical planning
  - Ultrasound shear wave speed for liver fibrosis
- In Development:
  - CT tumor volume change for liver lesions
  - MR elastography for liver fibrosis
  - Dynamic susceptibility contrast (DSC)-MRI for perfusion assessment in brain
  - MR proton density fat fraction (PDFF) for liver disease
  - MR diffusion tensor imaging (DTI) for traumatic brain injury
  - Revised DCE-MRI to address 3T and parallel imaging
  - Arterial spin labeling (ASL) MR – collaboration with EIBALL
  - T_2 and $T1_\rho$ MSK MR for degenerative joint disease
  - Ultrasound volume flow for perfusion studies – collaboration with AIUM
  - Contrast-enhanced ultrasound (CEUS) for perfusion studies

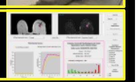
qibawiki.rsna.org

QIBA Groundwork Projects

QIB Implementation and Qualification

- Data acquisition => Physical phantoms & datasets
  - Application specific phantoms
  - Clinical trial datasets

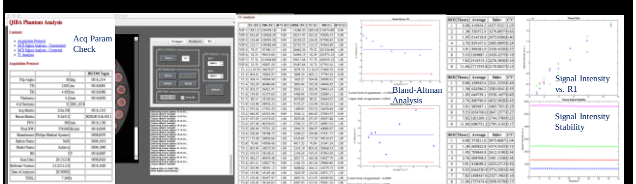
- Data analysis => Synthetic phantoms & datasets
  - Application specific "digital reference objects" or DROs
  - Clinical trial datasets



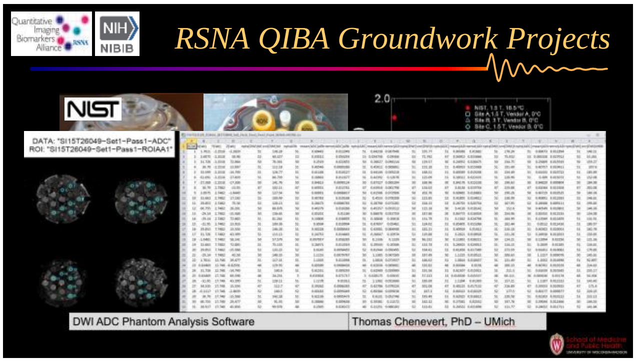
- Qualification => "Fit for purpose" <= clinical trials

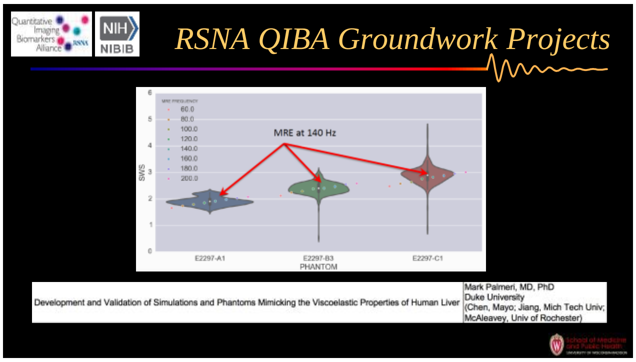
QIBA groundwork projects funded by 3 contracts from NIH National Institute of Biomedical Imaging and Bioengineering

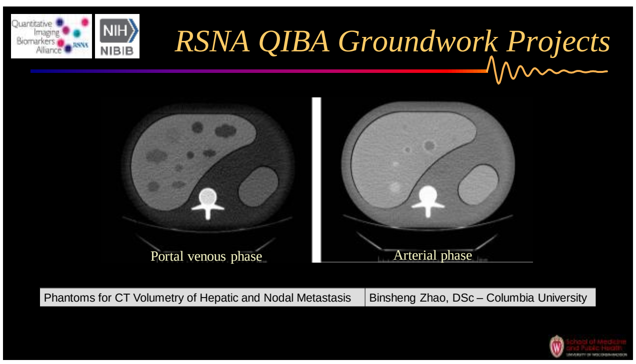
RSNA QIBA Groundwork Projects

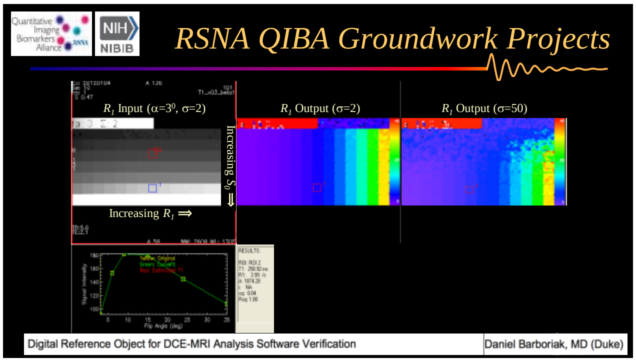


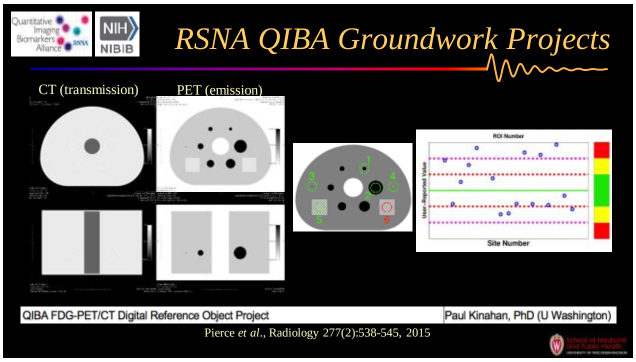
DCE-MRI Phantom Fabrication, Data Acquisition and Analysis, and Data Distribution | Edward Jackson, PhD (UW-Madison)

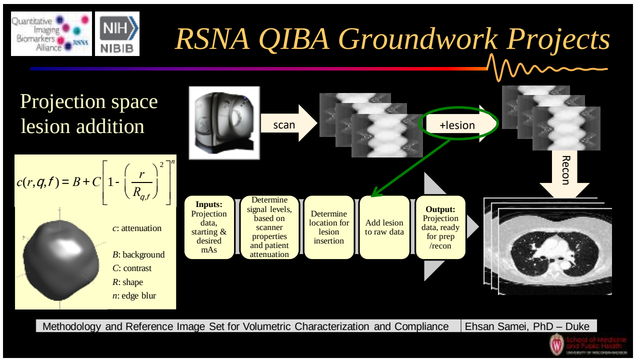

RSNA QIBA Groundwork Projects
NIST
DATA: "SI15T26049-Set1-Pass1-ADC"
ROI: "SI15T26049-Set1-Pass1-ROIAA1"
DWI ADC Phantom Analysis Software
Thomas Chenevert, PhD – UMich


RSNA QIBA Groundwork Projects
MRE at 140 Hz
SWS
E2297-A1
E2297-B3
E2297-C1
PHANTOM
Development and Validation of Simulations and Phantoms Mimicking the Viscoelastic Properties of Human Liver
Mark Palmeri, MD, PhD
Duke University
(Chen, Mayo; Jiang, Mich Tech Univ; McAleavey, Univ of Rochester)


RSNA QIBA Groundwork Projects
Portal venous phase
Arterial phase
Phantoms for CT Volumetry of Hepatic and Nodal Metastasis
Binsheng Zhao, DSc – Columbia University

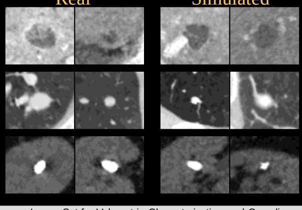

RSNA QIBA Groundwork Projects
R_1 Input (α=3^0, σ=2)
R_1 Output (σ=2)
R_1 Output (σ=50)
Increasing S_0 ⇒
Increasing R_1 ⇒
Digital Reference Object for DCE-MRI Analysis Software Verification
Daniel Barboriak, MD (Duke)


RSNA QIBA Groundwork Projects
CT (transmission)
PET (emission)
ROI Number
Site Number
QIBA FDG-PET/CT Digital Reference Object Project
Paul Kinahan, PhD (U Washington)
Pierce et al., Radiology 277(2):538-545, 2015


RSNA QIBA Groundwork Projects
Projection space lesion addition
scan
+lesion
Recon
$c(r,q,f) = B + C\left[1 - \left(\frac{r}{R_{q,f}}\right)^2\right]^n$
c: attenuation
B: background
C: contrast
R: shape
n: edge blur
Inputs: Projection data, starting & desired mAs
Determine signal levels, based on scanner properties and patient attenuation
Determine location for lesion insertion
Add lesion to raw data
Output: Projection data, ready for prep /recon
Methodology and Reference Image Set for Volumetric Characterization and Compliance
Ehsan Samei, PhD – Duke

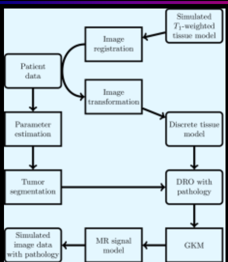
RSNA QIBA Groundwork Projects

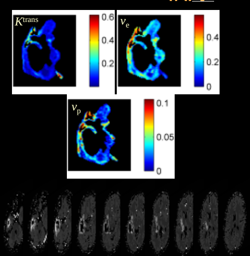
Which lesions are real?



Methodology and Reference Image Set for Volumetric Characterization and Compliance | Ehsan Samei, PhD – Duke

Anthropomorphic DCE-MRI DRO



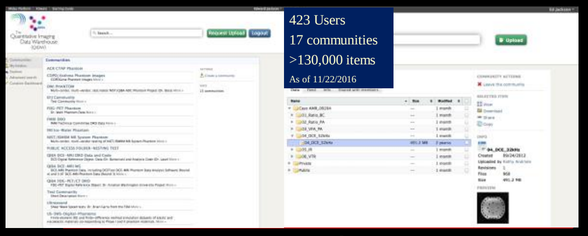


R Bosca, E Jackson. *Phys Med Biol* 61(2):974-982, 2016

QIBA Phantoms & Datasets

- Physical Phantoms
  - Volumetric CT Liver Phantom (arterial/portal venous phase)
  - DCE-MRI Phantom and analysis software
  - DWI ADC Phantom and analysis software
  - DSC-MRI Phantom (in development; target release Q2/2017)
  - Shear Wave Speed Phantoms (varying viscoelastic properties) – for both US SWS and MRE
- Digital Reference Objects (Synthetic Phantoms) – Publicly Available
  - Volumetric CT DRO (Liver, Lung, Kidney)
  - DCE-MRI DRO (T_1 mapping and K^{trans}, v_e) and analysis software
  - DWI ADC DRO
  - DSC-MRI DRO (in development; target release Q3/2017)
  - fMRI DROs (motor and language mapping)
  - PET SUV DRO
  - SPECT DRO (^{123}I dopamine transporter, DaTscan; in development; Q3/2017)

Quantitative Imaging Data Warehouse (QIDW)



www.rsna.org/qidw/

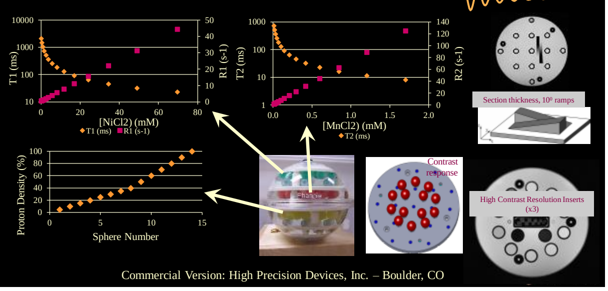
ISMRM MR QIB Efforts

Ad Hoc Committee on Standards for Quantitative MR (SQMR)

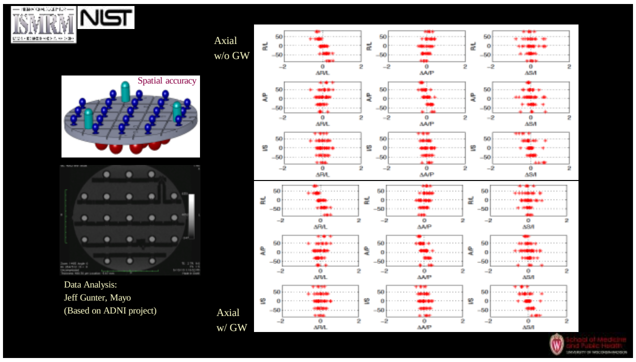
- Membership has included MR physicists, technologists, radiologists, NIST representatives, NIH representatives, vendors, pharma. Expertise in research trials using quantitative MR.
- Current status:
  - White paper on quantitative MR
  - Defined the specifications for and development of a MR System Phantom (collaboration with and funding by NIST)
  - Multicenter/multivendor phantom pilot studies

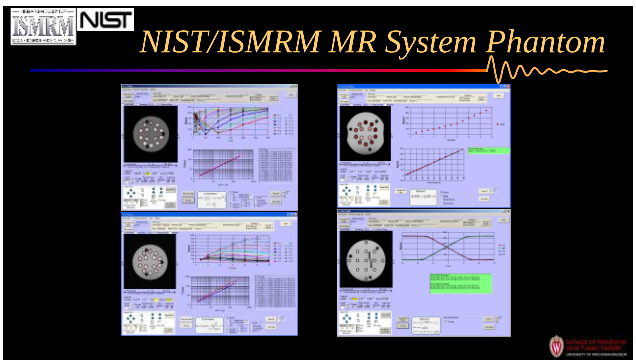
SQMR now a part of the new Quantitative MR Study Group

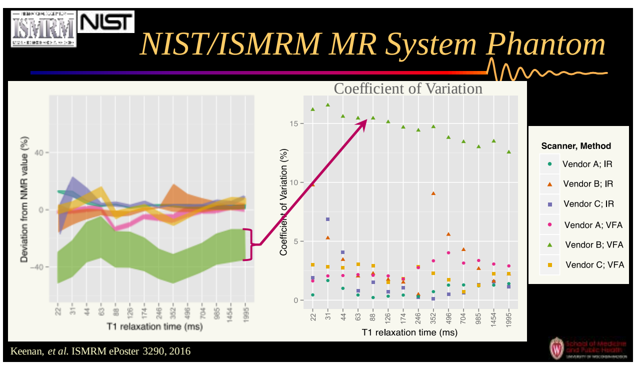
NIST/ISMRM MR System Phantom



Commercial Version: High Precision Devices, Inc. – Boulder, CO


Axial
w/o GW
Spatial accuracy
Data Analysis:
Jeff Gunter, Mayo
(Based on ADNI project)
Axial
w/ GW


NIST/ISMRM MR System Phantom


NIST/ISMRM MR System Phantom
Deviation from NMR value (%)
T1 relaxation time (ms)
Coefficient of Variation
Coefficient of Variation (%)
T1 relaxation time (ms)
Scanner, Method
Vendor A; IR
Vendor B; IR
Vendor C; IR
Vendor A; VFA
Vendor B; VFA
Vendor C; VFA
Keenan, et al. ISMRM ePoster 3290, 2016

Quantitative Imaging Network (QIN)

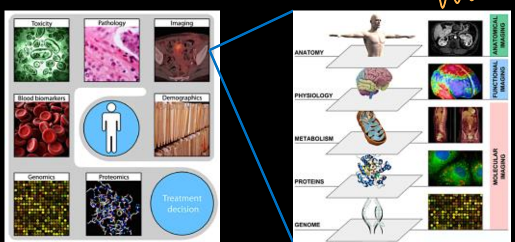
- NCI-funded (CIP)
  - PAR-17-128 & PAR-17-129
    Quantitative Imaging Tools & Methods for Evaluation for Cancer Response Assessment
- Goal: Translate quantitative imaging methods and algorithms as clinical decision support tools into clinical utility
- 21 current teams with additional associates (Per Robert Nordstrom, 7/17/2017)
- Working groups:
  - Image Analysis & Performance Metrics
  - Data Acquisition
  - Bioinformatics/IT and Data Sharing
  - Clinical Trial Design and Development

- Involved in development of a wide range of image analysis tools (N=46*) and a variety of algorithm comparison "challenges"

* As of 7/17/2017, per Robert Nordstrom

https://imaging.cancer.gov/informatics/qin.htm Accessed 7/17/2017

Precision Medicine Requires a Transformation of Medical Imaging

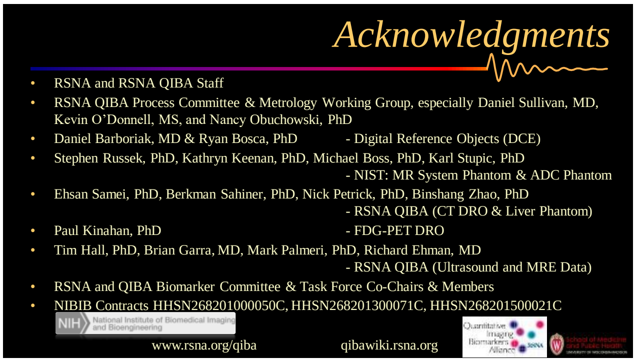


P. Lambin *et al. Eur J Cancer* 48:441-446 2012

Non-invasive QIBs should be critical enablers of the practice of precision medicine

Summary

- Non-invasive QIBs should be critical enablers of the practice of precision medicine.
- Translation of QIBs to clinical practice requires metrological approaches to characterizing the sources of bias and variance, mitigation of such sources to the degree possible, and harmonization of QIB measurements across vendor platforms and time.
- Standardization of QIBs (acquisition, data analysis, reporting) are critical for translation to clinical practice.


Acknowledgments
• RSNA and RSNA QIBA Staff
• RSNA QIBA Process Committee & Metrology Working Group, especially Daniel Sullivan, MD, Kevin O'Donnell, MS, and Nancy Obuchowski, PhD
• Daniel Barboriak, MD & Ryan Bosca, PhD - Digital Reference Objects (DCE)
• Stephen Russek, PhD, Kathryn Keenan, PhD, Michael Boss, PhD, Karl Stupic, PhD - NIST: MR System Phantom & ADC Phantom
• Ehsan Samei, PhD, Berkman Sahiner, PhD, Nick Petrick, PhD, Binshang Zhao, PhD - RSNA QIBA (CT DRO & Liver Phantom)
• Paul Kinahan, PhD - FDG-PET DRO
• Tim Hall, PhD, Brian Garra, MD, Mark Palmeri, PhD, Richard Ehman, MD - RSNA QIBA (Ultrasound and MRE Data)
• RSNA and QIBA Biomarker Committee & Task Force Co-Chairs & Members
• NIBIB Contracts HHSN268201000050C, HHSN268201300071C, HHSN268201500021C
NIH National Institute of Biomedical Imaging and Bioengineering
www.rsna.org/qiba
qibawiki.rsna.org
Quantitative Imaging Biomarkers Alliance