AAPM QI Symposium – July 2014

Quantitative Imaging: Techniques, Applications, and Challenges

Introduction: Modality-Agnostic QI Goals & Challenges

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The Promise of Quantitative Imaging

•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

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Modality-Independent Issues

General quantitative imaging challenges

- Lack of detailed assessments of sources of bias and precision
- Lack of standards (acquisition, analysis, and reporting)
  - Varying measurement results across vendors and centers
- Little support from imaging equipment vendors
  - No apparent competitive advantage (reimbursement) or regulatory requirements
    - Varying measurement results across vendors
    - Varying measurement results across time for any particular vendor
- Highly variable quality control procedures
  - QC programs, if in place, are typically not specific for *quantitative* imaging
    - Varying measurement results across centers

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Modality-Independent Issues

General quantitative imaging challenges (continued)

- Cost of QIB studies (comparative effectiveness)
- Radiologist acceptance
  - QIBs are not a part of radiologist education & training.
  - The software and workstations needed to produce and interpret QIB results are typically not integrated into the radiologists' workflow.
  - Clinical demand on radiologists is high --- "time is money".
  - There are few guidelines for QIB reporting.
- Resource availability
  - Technologists trained in advanced, quantitative, protocols
  - Physicists and/or imaging scientists, data processing capabilities, *etc*.

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Single-vendor, single-site studies: *Key Challenges*

- Acquisition protocol optimization
  - Scan mode and acquisition parameter optimization for:
    - contrast response and CNR
    - temporal resolution (for dynamic imaging)
    - spatial resolution
    - anatomic coverage
  - Application specific phantoms needed for initial validation scans and ongoing quality control
    - phantom acquisition and data analysis protocols
    - established frequency of assessment and data reporting
- Mechanism for detecting and addressing changes in measured response due to system upgrades (Quality Control)
  - Vendors focused on competitive advantage in radiology, not on quantitative imaging applications and maintaining signal response characteristics over time

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Single- to multi-vendor studies: *Key Challenges*

- Acquisition protocol harmonization
  - Scan mode and acquisition parameter selection for matched:
    - contrast response and CNR
    - temporal resolution (for dynamic imaging)
    - spatial resolution
    - anatomic coverage
  - Application specific phantoms needed for initial validation scans and ongoing quality control
    - phantom acquisition and data analysis protocols
    - established frequency of assessment and data reporting
  - Can be achieved, but requires substantial effort at start up
- Mechanism for detecting and addressing changes in measured response due to system upgrades (Quality Control)
  - Vendors focused on competitive advantage in radiology, not on quantitative imaging applications and maintaining signal response characteristics over time

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Single- to multi-center studies: *Key Challenges*

- Acquisition protocol
  - Harmonization across centers and vendors
  - Distribution and activation of protocols
    - Distribute/load electronically
    - Provide expert training and initial protocol load/test
    - Develop / utilize local expertise
  - Compliance with protocol
    - Local radiologists, technologists
- Widely varying quality control
  - Ranging from specific for a given imaging biomarker, to ACR accreditation, to none
  - Even if QC program is in place, it may not test parameters relevant to the study
- "Scanner upgrade dilemma"
- Data management and reporting

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Data Analysis: *Key Challenges*

- Data analysis implementation strategies are often as variable as acquisition strategies
- Choice of model must match data acquisition strategy, *e.g.*, temporal resolution of the acquired data
- Analysis parameters must be standardized, *e.g.*, choice of model, ROI definition, *etc*.
- To facilitate testing/validation of various analysis packages, readily available, standardized test data and analysis results are needed:
  - Digital reference objects
  - Physical phantoms and standardized acquisition protocols and data analysis software
  - Publicly available test/retest human subject data and associated metadata

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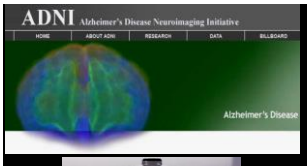

Sphere ID	Color	Number of Spheres	Grams of Copper Sulfate Penta Hydrate per liter	Target T1 (ms)
1.0cm	none	158	0.820	
1.5cm	none	2	0.820	
3.0cm	green	1	0.220	900
3.0cm	yellow	1	0.295	750
3.0cm	red	1	0.430	600
3.0cm	orange	1	0.590	450
6.0cm	none	1	0.820	

ADNI

- Multicenter, multivendor study
- Optimized pulse sequence / acquisition parameters for each platform
- MagPhan/ADNI phantom scan at each measurement point
- Access to vendor gradient correction parameters
- With corrections for gradient nonlinearities and optimized acquisition strategies, spatial accuracies of <0.3 mm can be obtained over a ~180 mm spherical volume

Quantitative MR Imaging Initiatives

- Consensus Group Guidelines
- NCI: RIDER and Academic Center Contracts
  Imaging Response Assessment Team (IRAT)
- RSNA: Quantitative Imaging Biomarkers Alliance (QIBA)
- ISMRM: *Ad Hoc* Committee on Standards for Quantitative MR
- NCI: U01-Funded Quantitative Imaging Network (QIN)
- ACRIN: NCI Centers of Quantitative Imaging Excellence (CQIE)
- Core Labs

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