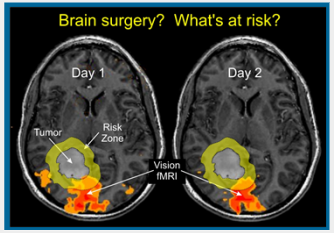
Reproducibility of Functional MRI – Progress Towards Profile Development

Edgar DeYoe[1], PhD, James Voyvodic[2], PhD, Cathy Elsinger, PhD (co-chair)[3], Jeffrey Petrella, MD (co-chair)[2], Harris Ahmad, MD[4], Andrew Buckler, MS[5], Feroze Mohamed, PhD[6], Jay Pillai, MD[7], James Reuss, PhD[8], Domenico Zaca, PhD[7]

[1]Medical College of Wisconsin, [2]Duke University, [3]NordicNeuroLab, [4]BioClinica, Inc, [5]Buckler Biomedical, [6]Temple University, [7]John's Hopkins University Medical School, [8]Prism Clinical Imaging

Quantitative Imaging Biomarkers Alliance RSNA

Use Case: fMRI as a biomarker of functionally eloquent brain cortex for guiding tumor surgery



- fMRI is a technology used routinely at a growing number of hospitals to identify and map functionally eloquent brain tissue near a planned site of tumor resection.
- Proximity of healthy brain tissue to the margin of a resection is a risk factor for post-operative neurological deficits.
- Proximities less than 0.5-1.0 cm increase the risk of permanent deficit. ("Risk zone" in figure is 1cm around tumor margin)
- But fMRI brain maps measured in the same patient can vary across days (illustrated in vision fMRI data at left).

Profile Development – claims for quantifiability of fMRI as a clinical biomarker

1) Location of centroid of activation for motor, language, and vision areas is reproducible and quantifiable – define quantitative limits
2) Spatial extent of activation for motor and language areas is reproducible and quantifiable – define quantitative limits
3) Language laterality is reproducible and quantifiable – define quantitative limits
Successful implementation of the fMRI biomarker will help promote successful brain surgery while minimizing neurological side-effects.
Improved standardization will facilitate adoption as standard of care and promote industry-wide acceptance.

Preliminary results of ongoing RSNA-funded reproducibility studies

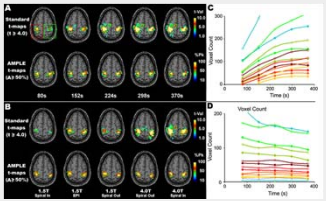
Test-retest comparisons of fMRI maps in repeated scans of the same subject show similar activation patterns but significant quantitative variability using standard analysis methods.

For localization of motor or language areas, normalization of fMRI activation signals relative to local peak BOLD amplitude significantly improves quantitative reproducibility[1,2].

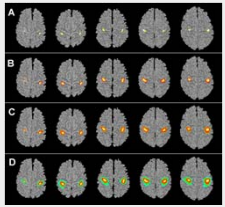
fMRI functional specificity is more reproducible within than across sessions

Hand motor mapping

Standard activation maps vary with scan duration
AMPLE normalized maps are stable over scan time

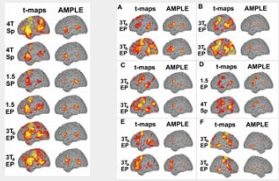


Normalized extent of activation is consistent within and across subjects



Language mapping

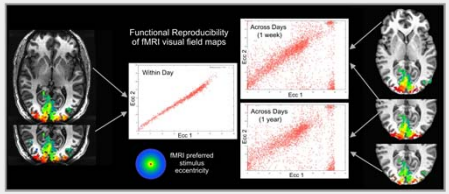
Standard t-maps vary across scans
Normalized maps have more consistent locations and extents of activations



6 scans of one subject — 2 scans for each of 6 subjects

Vision mapping

Voxels in visual cortex respond best to a visual stimulus at a specific distance (eccentricity) from the center of gaze. Here we compare the best eccentricity from repeated scans within and across days.



Qualification – Identify components required to successfully implement the biomarker

Ordering
- Indication
- Ability Assessment
- Paradigm Selection

Patient Preparation
- Task Training
- Positioning
- Peripherals Adjustment

Data Acquisition
- MR Scanner Q/A
- Stimulus Presentation
- Anatomical Images
- fMRI images
- Task Performance
- Physiologic monitoring

Data Analysis and Post Processing
- Image reconstruction
- Artifact detection/removal
- Smoothing
- Compute statistics
- Activation map generation

Visualization / Interpretation
- Composite image overlay
- Statistical thresholding
- Region of interest exploration
- Color assignment
- Overlay transparency
- Generate clinical report

Storage and Distribution
- Archiving
- Export to intraoperative navigation system

References
1. J.T. Voyvodic (2006) Mag. Res. Imag., 24:1249-1261.
2. J.T. Voyvodic, J.R. Petrella, and A.H. Friedman (2009) J. Mag. Res. Imag. 29:751-759.
3. http://qibawiki.rsna.org
4. http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM230597.pdf

Acknowledgements
The members of the QIBA fMRI Technical Committee would like to acknowledge the continued support of the RSNA and staff devoted to support of the QIBA activities.