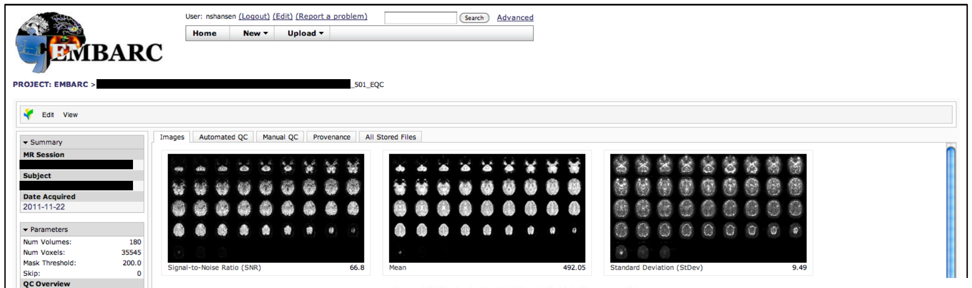
MRI Quality Control

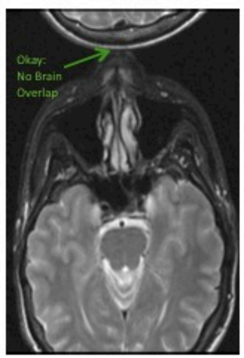


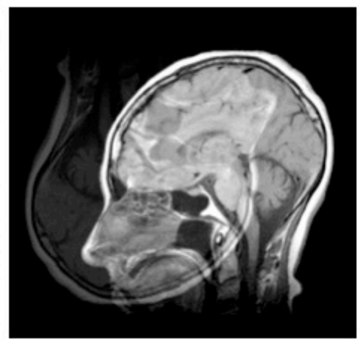
Center for Brain Science

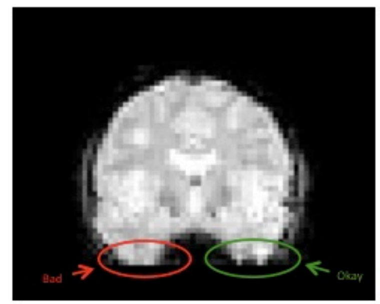
Presented by

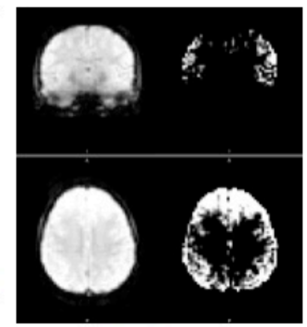
Natasha S. Hansen

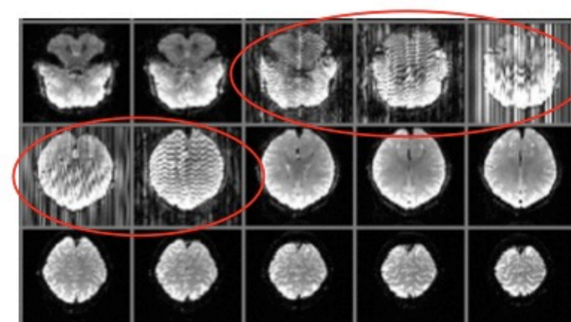
February 20, 2013











Workshop Road Map

Where we're headed….

- Why is Quality Control (QC) Important?
- Two Kinds of QC
- Quantitative QC
  - Quantitative QC in action: EMBARC Central XNAT
- Qualitative QC
  - MRI artifacts
  - Qualitative QC in action: EMBARC scans in FSL
- Acknowledgements
- Questions & Discussion

Why is Quality Control Important?

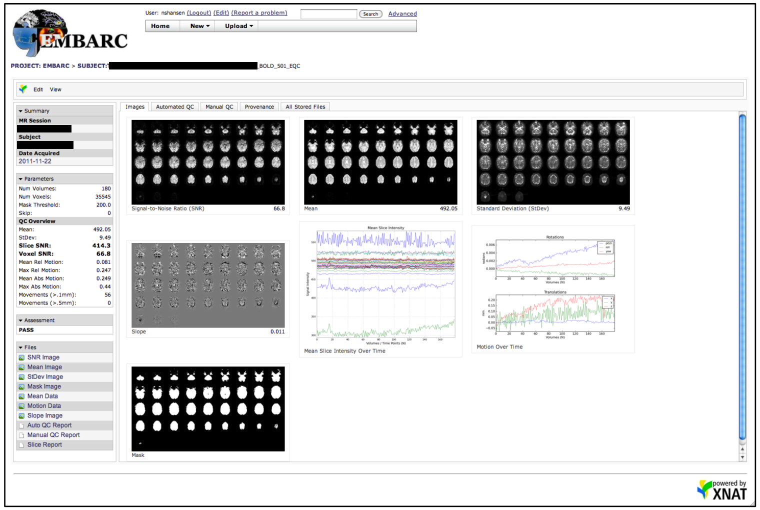
1. Quality data are <u>essential</u> for good science
2. Flawed data are surprisingly common
3. Even serious flaws in data can sometimes be very difficult to detect without carefully looking for them

Two Kinds of QC

1. Quantitative:

By the numbers…..

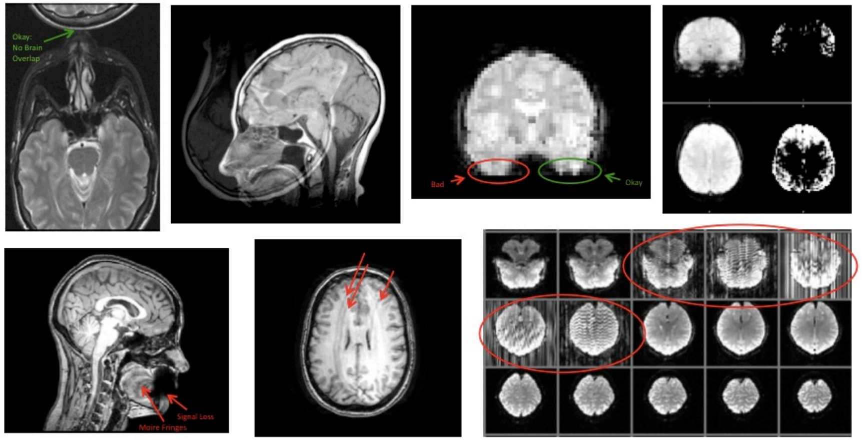
Evaluating automated system-calculated numerical values



2. Qualitative:

By the trained eye….

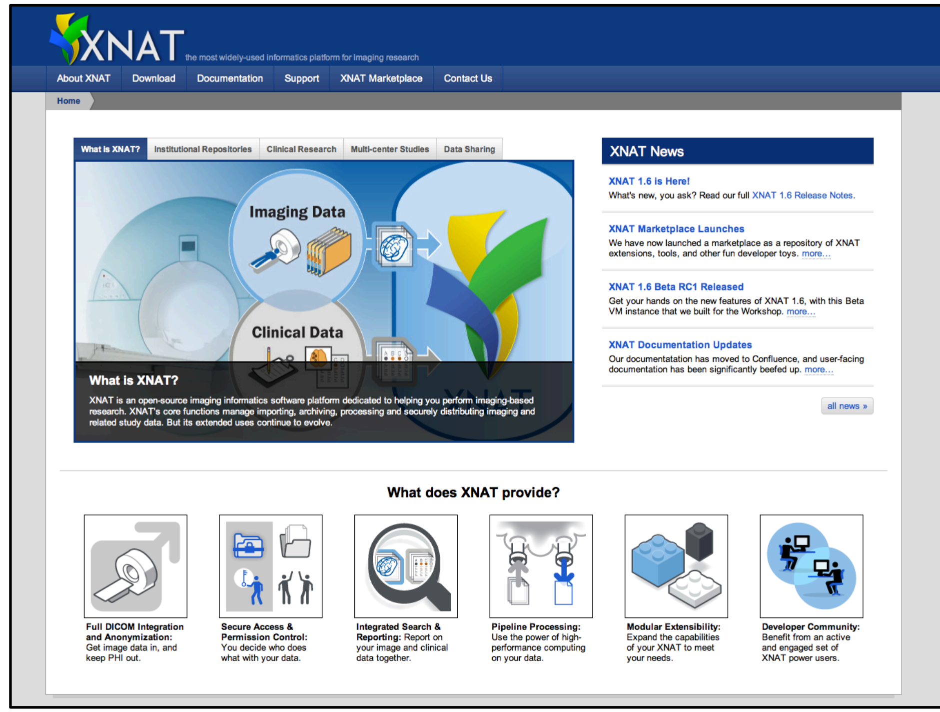
Manually scrolling through each slice of RAW data to look for artifacts



What is XNAT?

XNAT can calculate values used for Quantitative QC

- 3rd party neuroimaging database developed and maintained by Washington University in St. Louis
- Designed to help researchers capture, organize, and process neuroimaging data
- First developed by Dan Marcus under Randy Buckner at WUSTL (Marcus 2006)*
- Has large user community
- Visit: http://xnat.org/



*Marcus, D. S., Olsen, T., Ramaratnam, M., & Buckner, R. L. (2006). XNAT: a software framework for managing neuroimaging laboratory data. In *Proceedings of the 12th Annual Meeting of the Organization for Human Brain Mapping Held in Florence* (pp. 11-15).

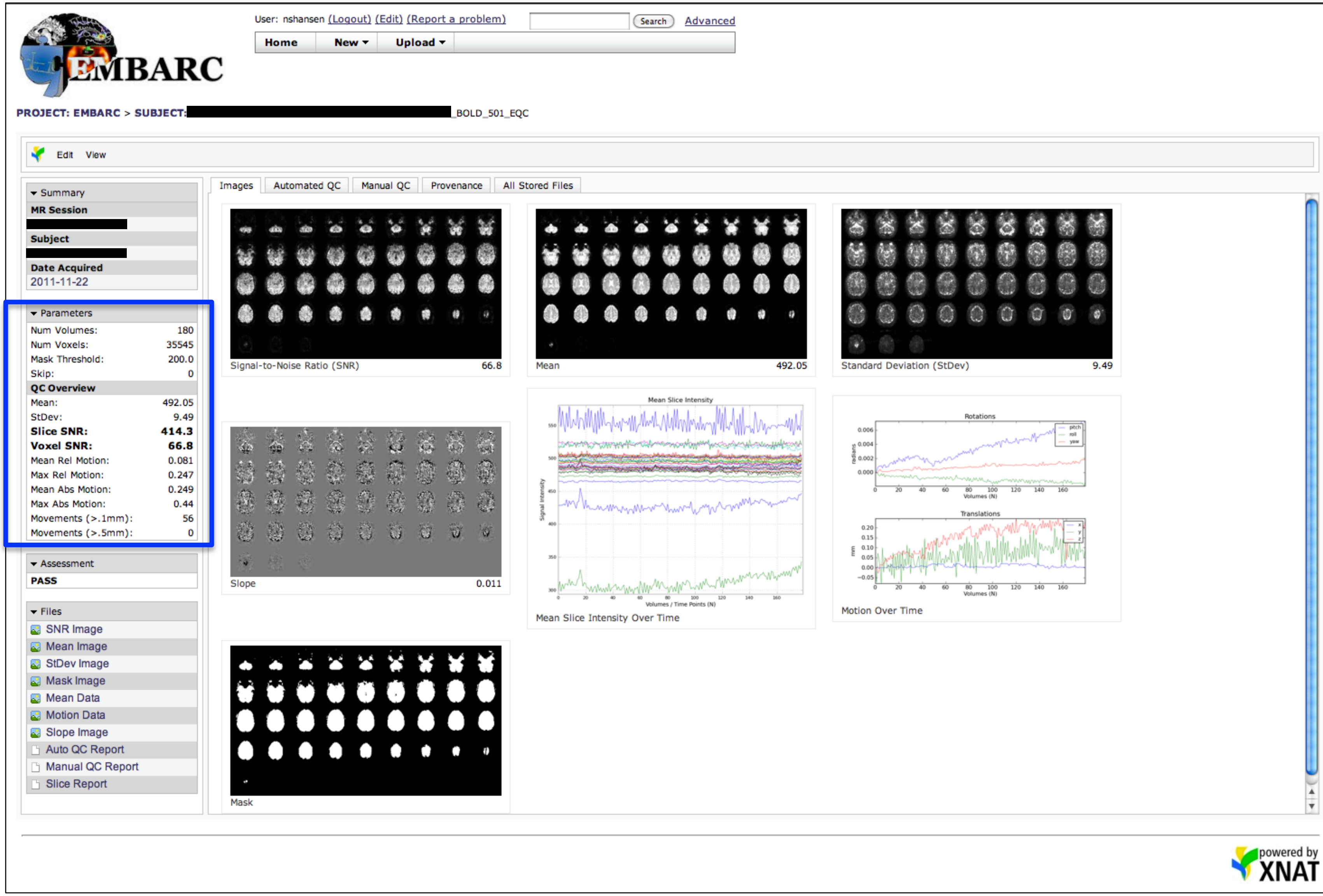
Quantitative QC

QC by the numbers.....

Examples of Quantitative QC values calculated in XNAT:

- Mean Signal Intensity
- Signal Intensity Standard Deviation
- Voxel-Based Signal to Noise Ratio (vSNR)
- Slice-based Signal to Noise Ratio (sSNR)
- Subject Motion:
  - ➢ Relative Motion & Absolute Motion
  - ➢ Mean Motion & Maximum Motion
  - ➢ # Movements >.1mm & # Movements >.5mm

Quantitative QC in XNAT



Quantitative QC in XNAT

For EMBARC* Quantitative QC, we focus on:

1. Slice-Based SNR
2. Maximum Absolute Motion
3. Movements ≥ 0.5mm

Parameter Evaluations:

Slice-Based SNR: Good = ≥150, Bad = <99
Maximum Absolute Motion: Good = <1.49, Bad = >2mm
Movements ≥.5mm: Good <5, Bad = ≥ 5

Parameters	
Num Volumes:	397
Num Voxels:	36772
Mask Threshold:	200.0
Skip:	0
QC Overview	
Mean:	548.13
StDev:	11.36
Slice SNR:	**341.8**
Voxel SNR:	**67.3**
Mean Rel Motion:	0.049
Max Rel Motion:	0.154
Mean Abs Motion:	0.411
Max Abs Motion:	0.79
Movements (>.1mm):	19
Movements (>.5mm):	0

NOTE: Remember these parameters are examples only. Consider your scanner (e.g. Siemens vs. Phillips) and head coil (e.g. 12 vs. 32 channel) to determine the right Quantitative QC parameters for your study.

* Establishing Moderators/Biosignatures of Antidepressant Response in Clinical Care (EMBARC) is a multi-site NIMH-funded study used in the creation of these QC standards

Why these Parameters?

The Quantitative QC parameters used for EMBARC are based on research done at Massachusetts General Hospital and Harvard Medical School

Learn more about:

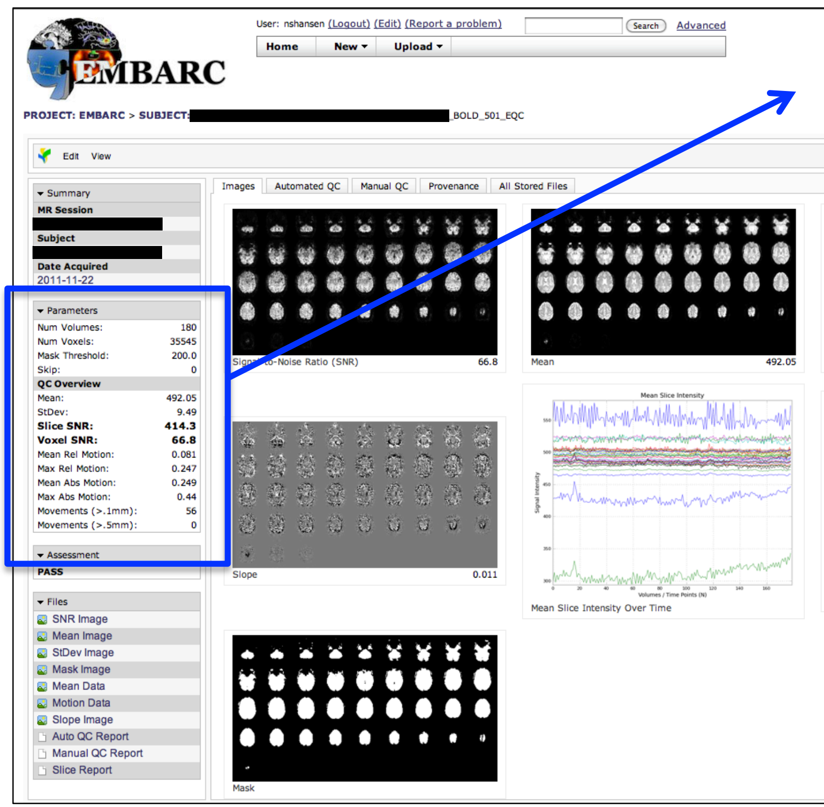
- How subject motion affects MRI data
- How motion values are calculated
- The relationship between Quantitative QC measures (e.g. mean vs. max motion values)
- How temporal SNR is calculated

Van Dijk KRA, Sabuncu MR, and Buckner RL. (2012) The Influence of Head Motion on Intrinsic Functional Connectivity MRI. NeuroImage. 59(1):431-8.

Quantitative QC in Action

For EMBARC Quantitative QC, we focus on:

1. Slice-Based SNR: Good = >150, Bad = <99
2. Maximum Absolute Motion: Good = <1.49, Bad = >2mm
3. Movements >.5mm: Good <5, Bad = >5



Parameters

Num Volumes:	180
Num Voxels:	35545
Mask Threshold:	200.0
Skip:	0
QC Overview	
Mean:	492.05
StDev:	9.49
Slice SNR:	**414.3**
Voxel SNR:	**66.8**
Mean Rel Motion:	0.081
Max Rel Motion:	0.247
Mean Abs Motion:	0.249
Max Abs Motion:	0.44
Movements (>.1mm):	56
Movements (>.5mm):	0

414.3 > 150 = Good

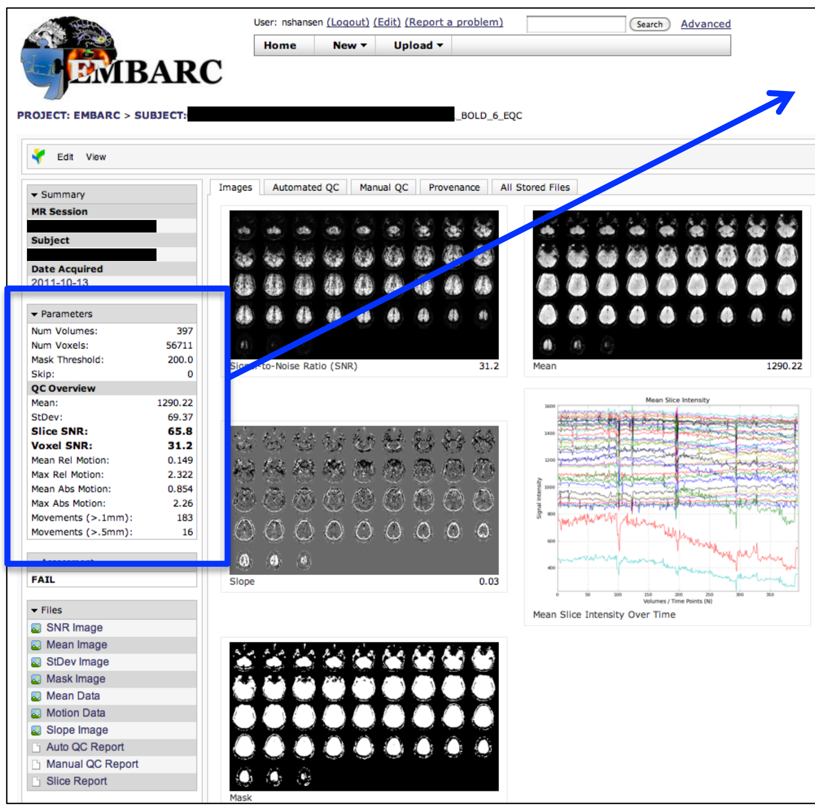
.44 < 1.49 = Good

0 < 5 = Good

Quantitative QC in Action

For EMBARC Quantitative QC, we focus on:

1. Slice-Based SNR: Good = >150, Bad = <99
2. Maximum Absolute Motion: Good = <1.49, Bad = >2mm
3. Movements >.5mm: Good <5, Bad = >5



▾ Parameters	
Num Volumes:	397
Num Voxels:	56711
Mask Threshold:	200.0
Skip:	0
QC Overview	
Mean:	1290.22
StDev:	69.37
Slice SNR:	**65.8**
Voxel SNR:	**31.2**
Mean Rel Motion:	0.149
Max Rel Motion:	2.322
Mean Abs Motion:	0.854
Max Abs Motion:	2.26
Movements (>.1mm):	183
Movements (>.5mm):	16

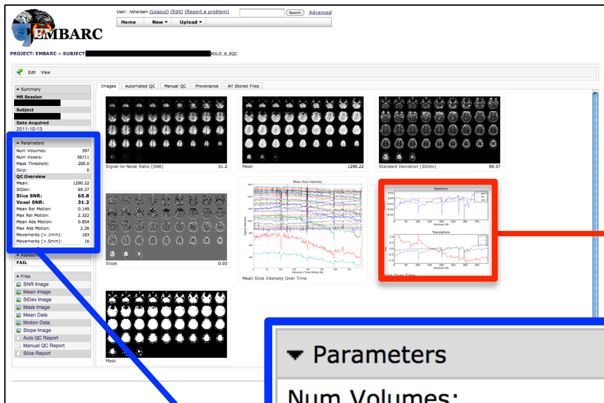
65.8 < 150 = Bad

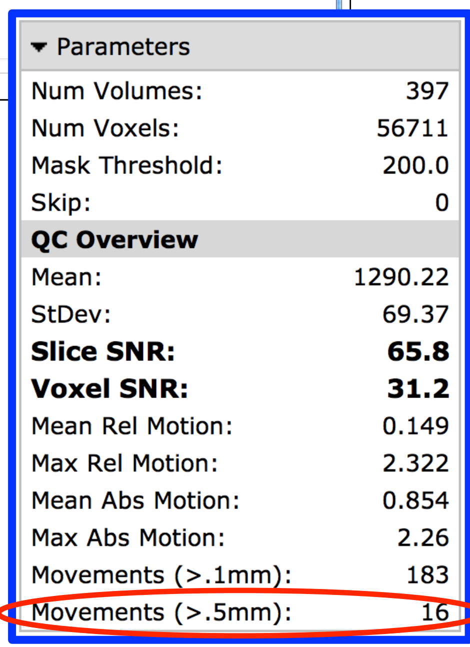
2.26 > 2 = Bad

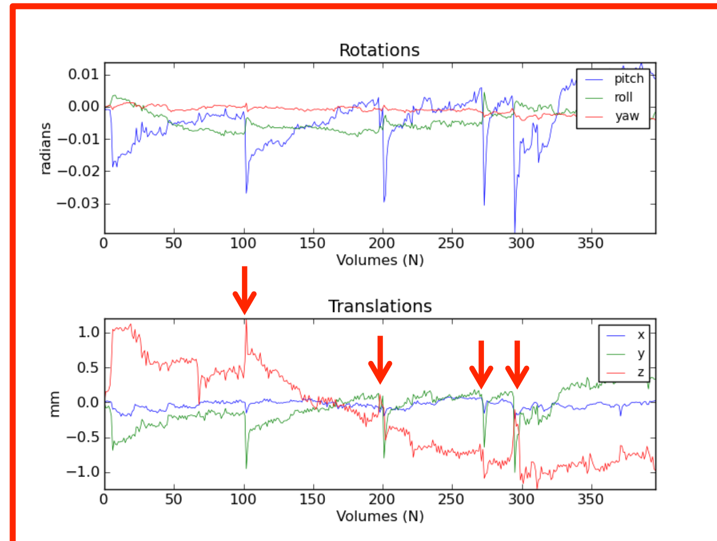
16 > 5 = Bad

Quantitative QC meets Qualitative QC

A scan's numerical values are often reflected in its visible artifacts…

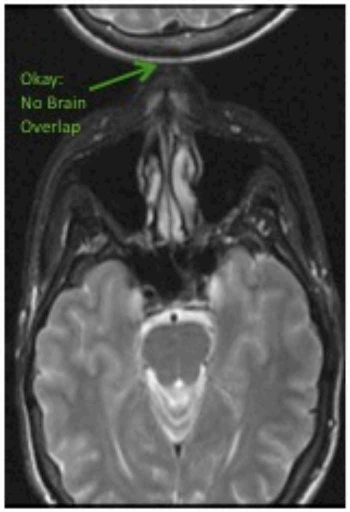


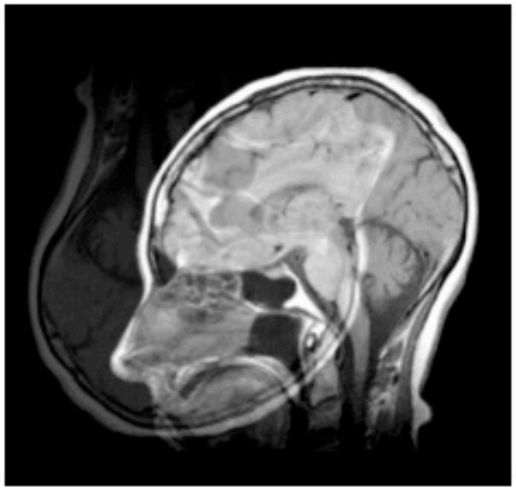


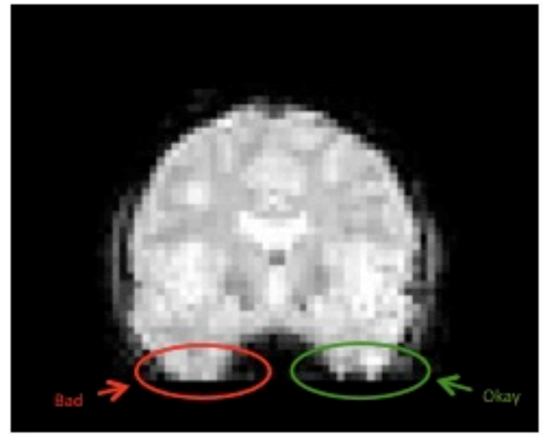


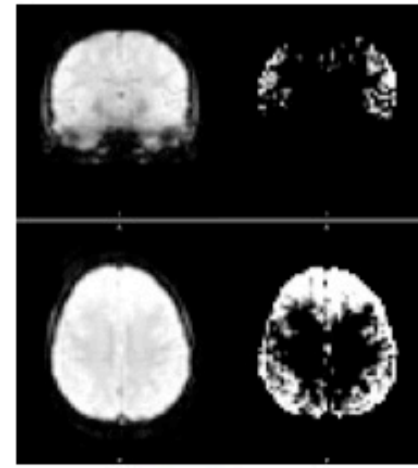
Qualitative Quality Control

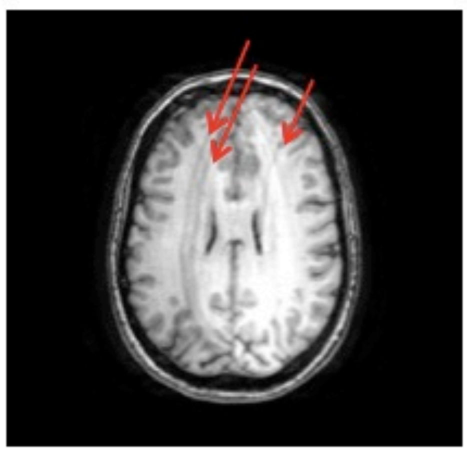
Artifacts in Structural and Functional MRI

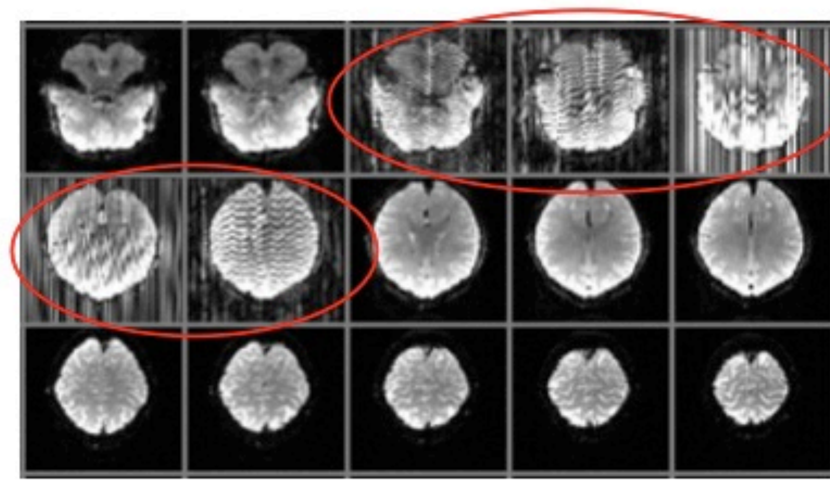












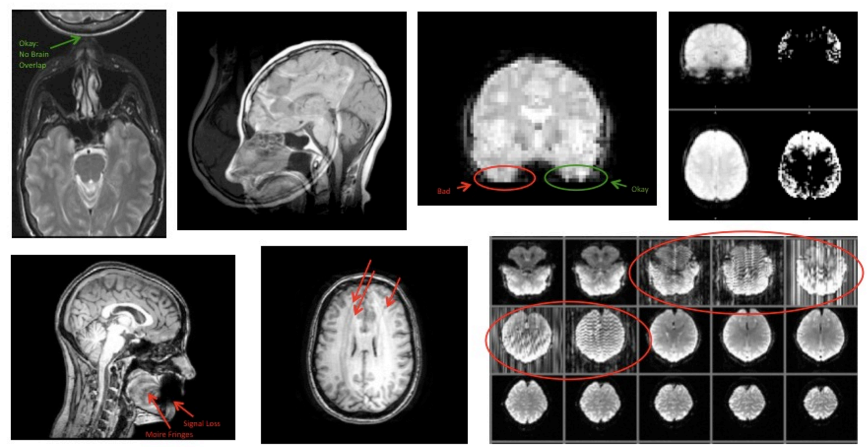
Qualitative QC

QC by the trained eye….

Some factors that can compromise data quality are so far only detectable by manually scrolling through each slice of RAW data to look for visible distortions called "**artifacts**".

Examples of MRI artifacts:

- Field of View (FOV) clipping anatomy
- Wrapping
- Signal Loss/Susceptibility Artifact
- Ringing, Striping, or Blurring (in ANAT)
- Ghosting
- Radio Frequency Noise/Spiking
- Signal Inhomogeneity
- Motion Slice Artifact (in BOLD)



What causes MRI artifacts?

Experimenter Error:

- Field of View (FOV) positioned wrong -> brain image clipped -> "Wrapping"
- Neglected to remove all ferromagnetic metal -> signal loss -> "Susceptibility Artifact"

Subject Motion:

- Ringing, Striping, or Blurring (in structural scans)
- "Motion Slice Artifact" (in functional scans)

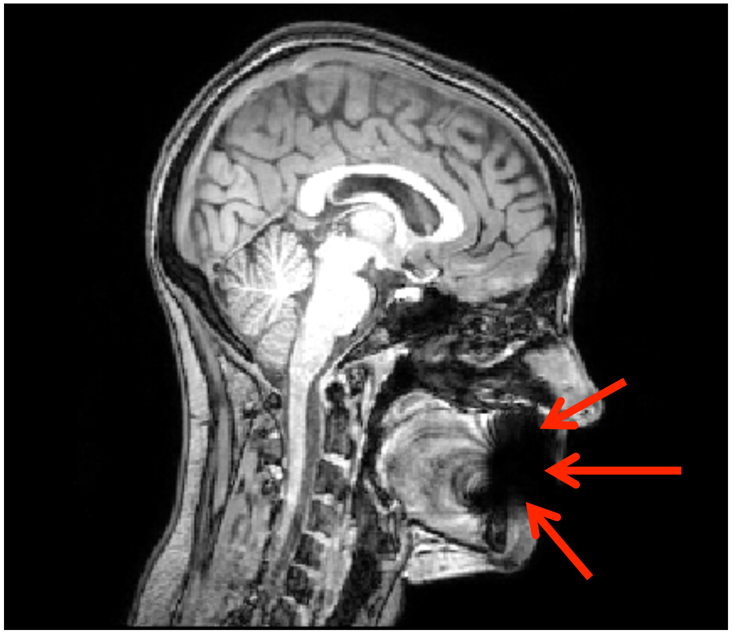
Problems with the Scanner/Head Coil:

- Radio Frequency Noise/Spiking
- Signal Inhomogeneity

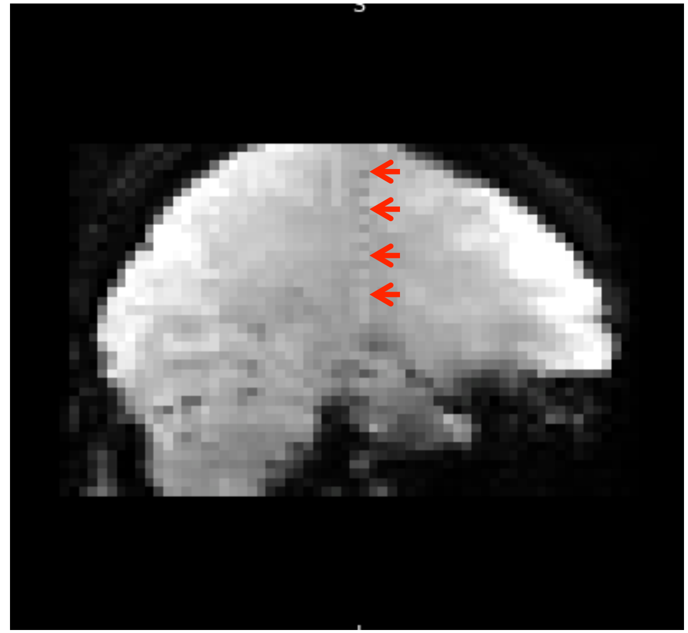
Artifacts from Image Reconstruction:

- Consistent low-level "Ghosting"
- Some types of "Ringing" (e.g. "Shadowed Arc Artifact" in structural scans)

How do you detect artifacts?

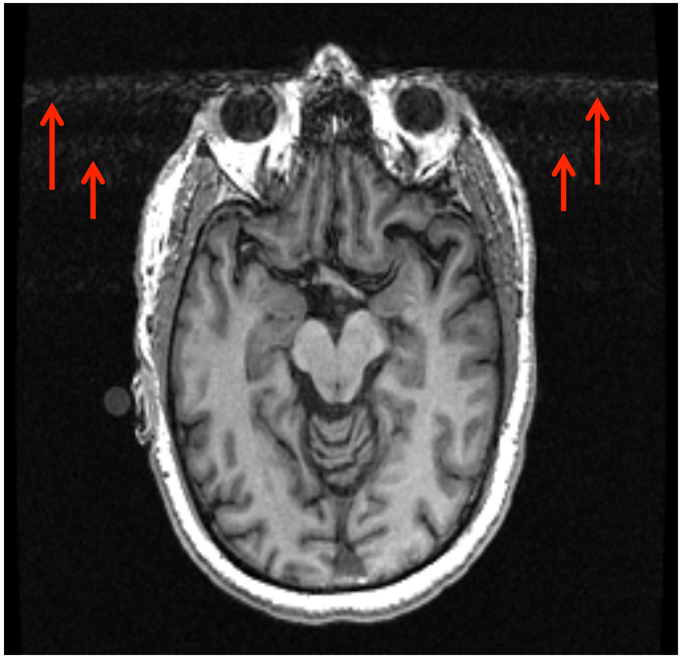


Some artifacts are hard to miss

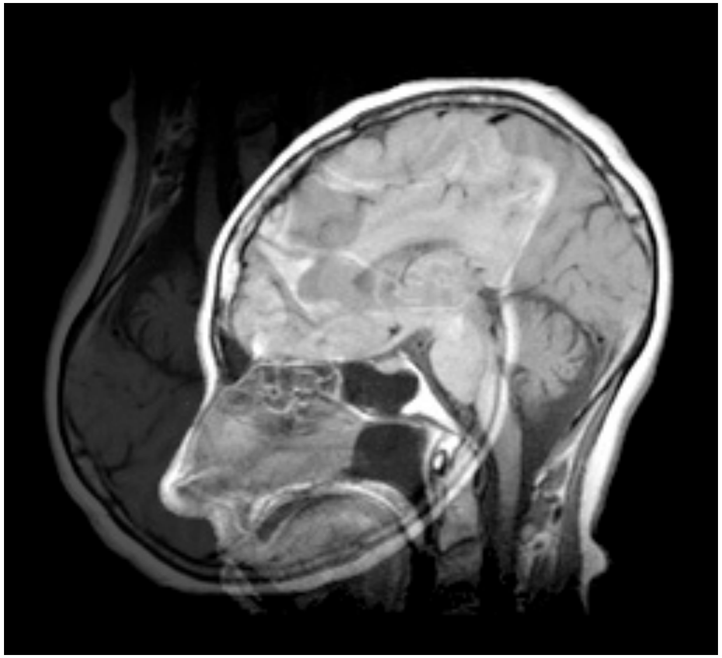


Others are incredibly subtle

When are artifacts a problem?



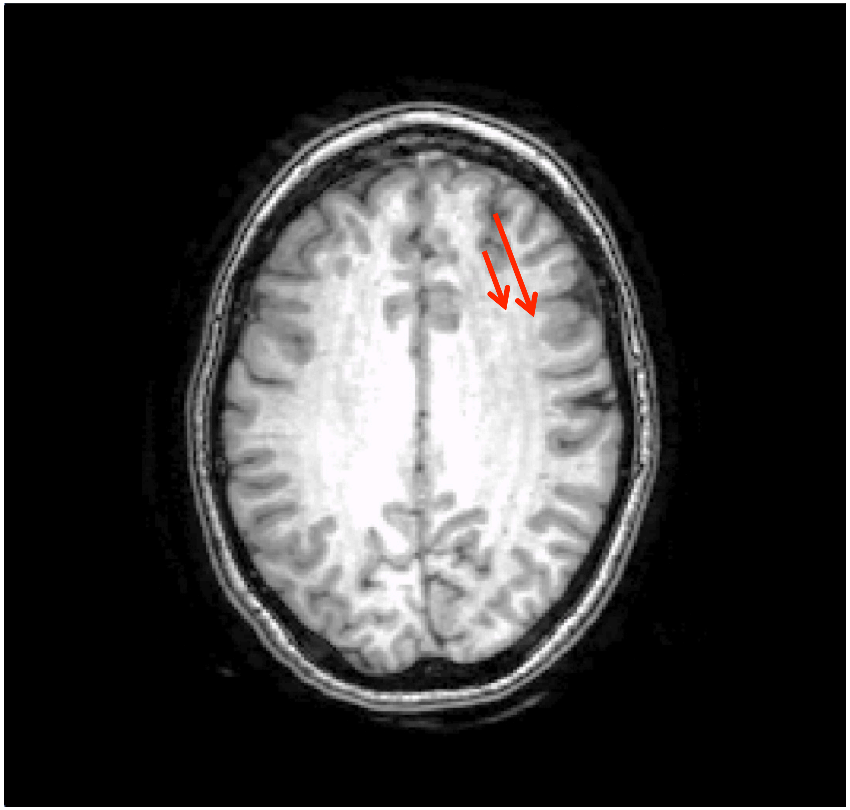
Some artifacts don't affect data quality



Others render it unusable

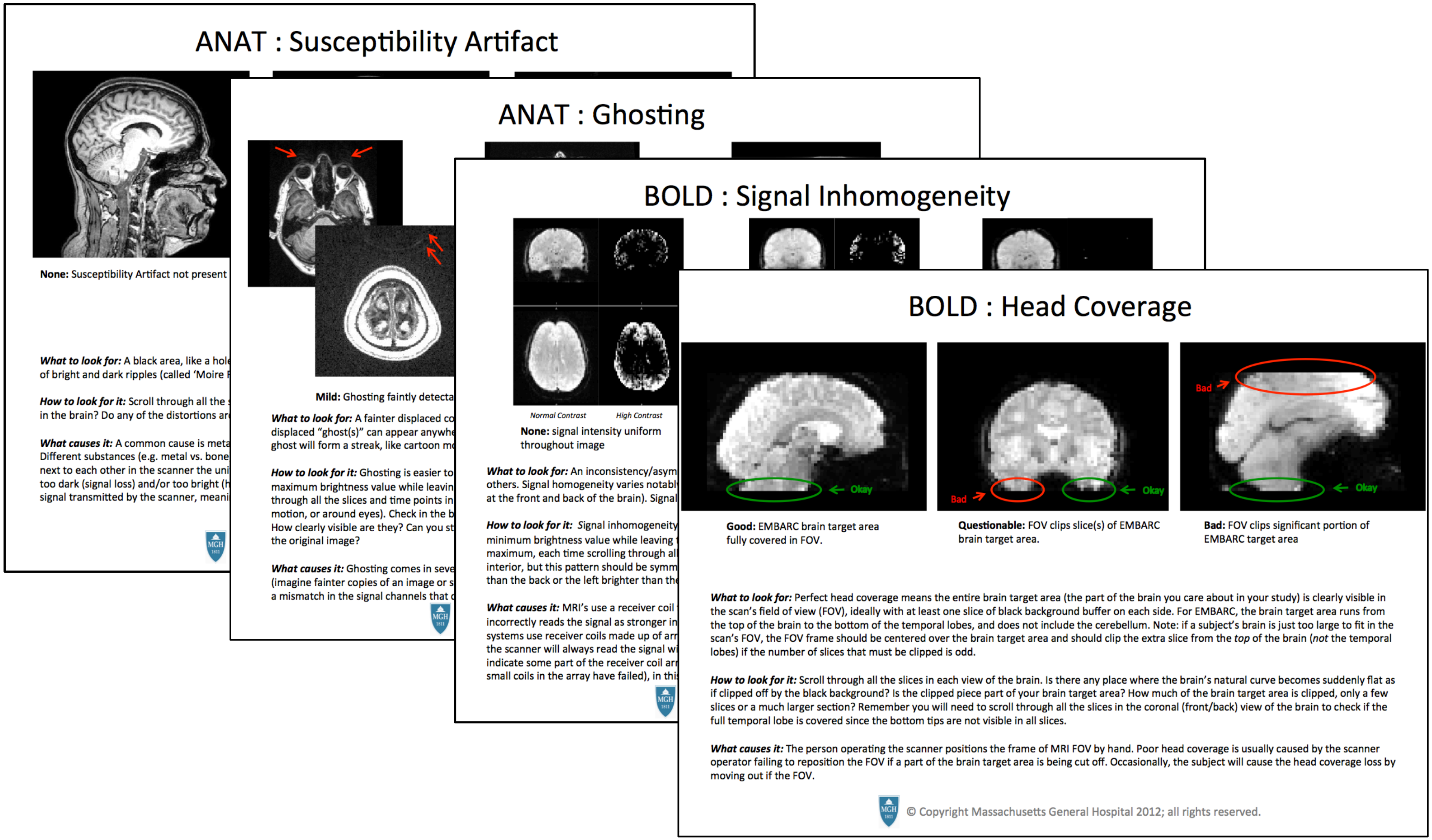
Training the Eye…

The intention is to familiarize you with the various types of artifacts and their levels of severity so you will be able to recognize them in your own data and make an informed decision for yourself about whether or not they affect your data quality.



MRI Qualitative Quality Control Manual

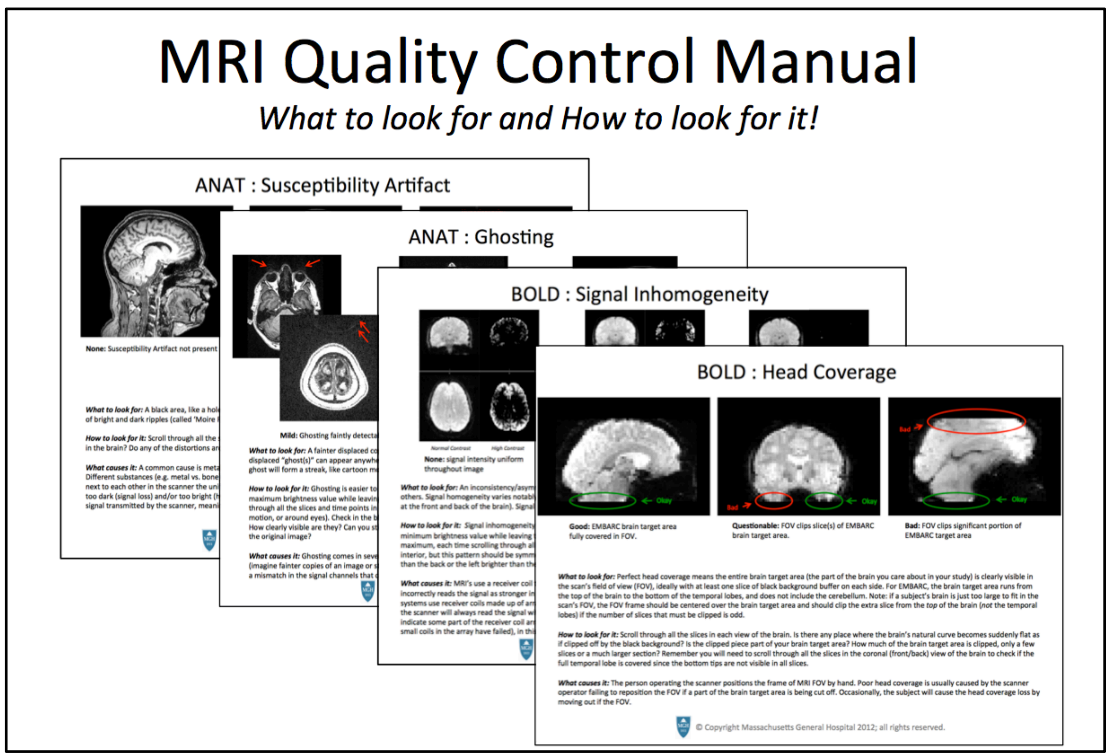
What to look for and How to look for it!



Want to Reference the Manual?

The full MRI Qualitative Quality Control Manual is available online!

Go to the Harvard Center for Brain Science Website: http://cbs.fas.harvard.edu/
Center for Brain Science > Neuroimaging > Information for Investigators > FAQ

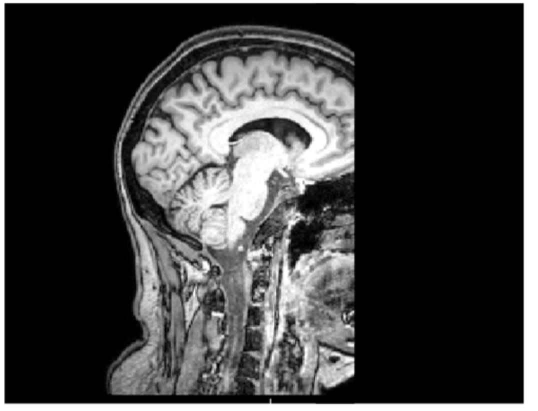


Manual Sample Page

Includes: *What to look for*, *How to look for it*, and *What causes it*

ANAT : Head Coverage

Good: brain fully covered in FOV.



Bad: FOV clips brain

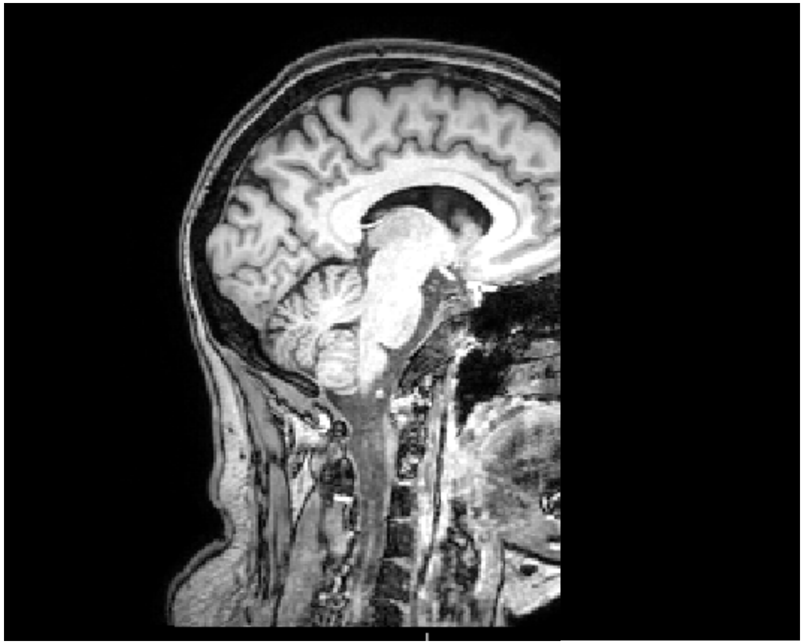
What to look for: Perfect head coverage means the entire brain target area (the part of the brain you care about in your study) is clearly visible in the scan's field of view (FOV), ideally with at least one slice of black background buffer on each side. For EMBARC, the brain target area runs from the top of the brain to the bottom of the temporal lobes, and does not include the cerebellum. Note: imperfect head coverage with no wrapping is almost never seen in anatomical scans.

How to look for it: Scroll through all the slices in each view of the brain. Is there any place where the head's natural curve becomes suddenly flat as if clipped off by the black background? Does the clipping cut off any portion of the brain?

What causes it: The person operating the scanner positions the frame of MRI FOV by hand. Poor head coverage is usually caused by the scanner operator failing to reposition the FOV if a part of the brain target area is being cut off. Occasionally, the subject will cause the head coverage loss by moving out if the FOV.

ANAT : Head Coverage*

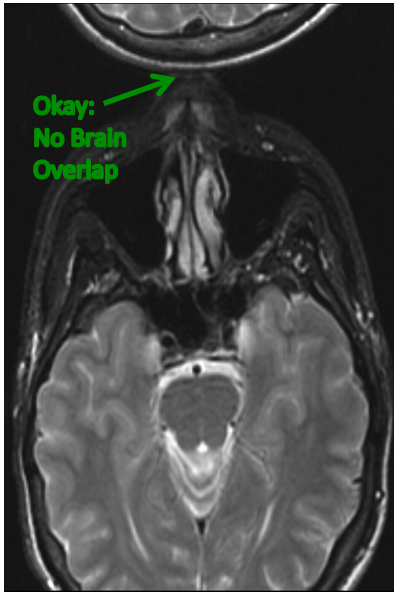
Good: brain fully covered in FOV

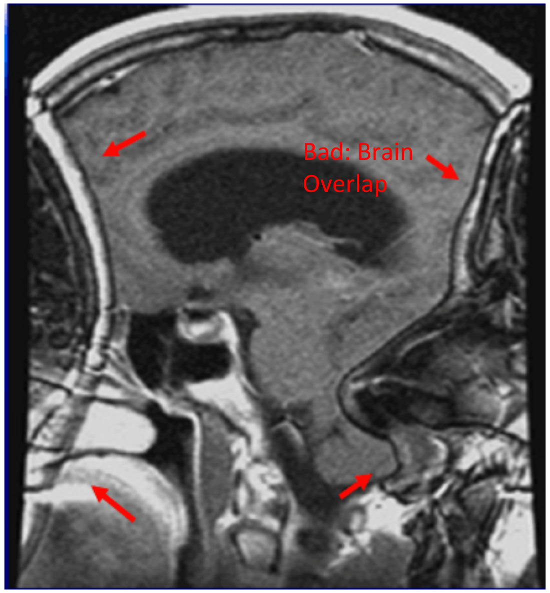


Bad: FOV clips brain

*Reference the MRI Qualitative Quality Control Manual for full text on each artifact

ANAT : Wrapping



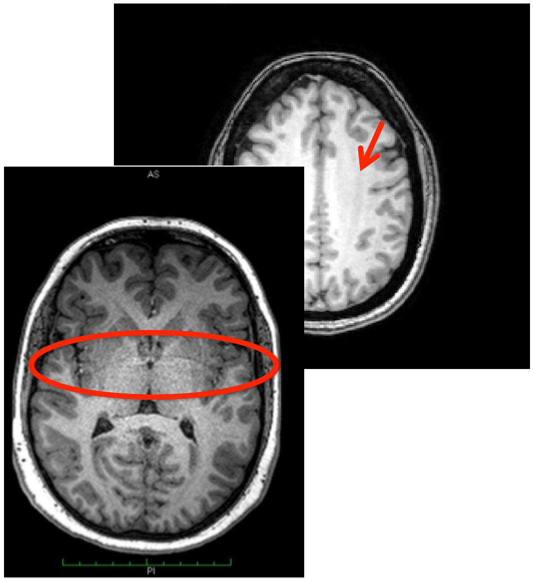


Mild: head wrapping, but does not affect brain

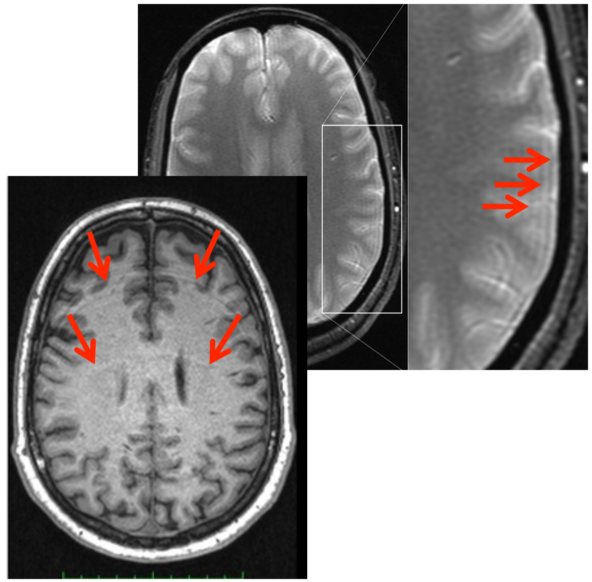
Moderate: brain wrapping but not overlapped by other anatomy

Severe: brain wrapping and overlapped by other anatomy

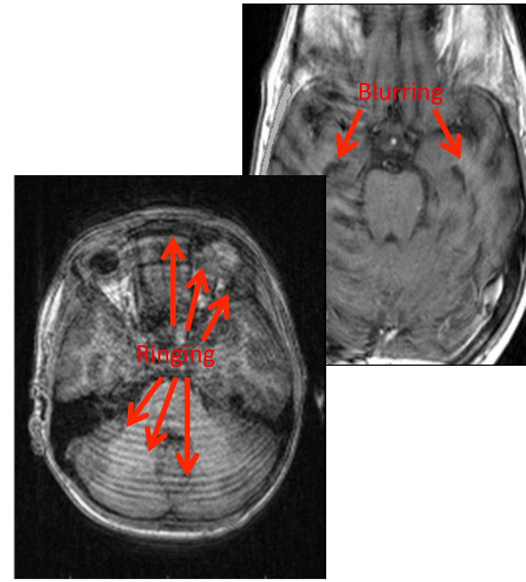
ANAT : Ringing, Striping, Blurring



Mild: Ringing, Striping, Blurring faintly detectable

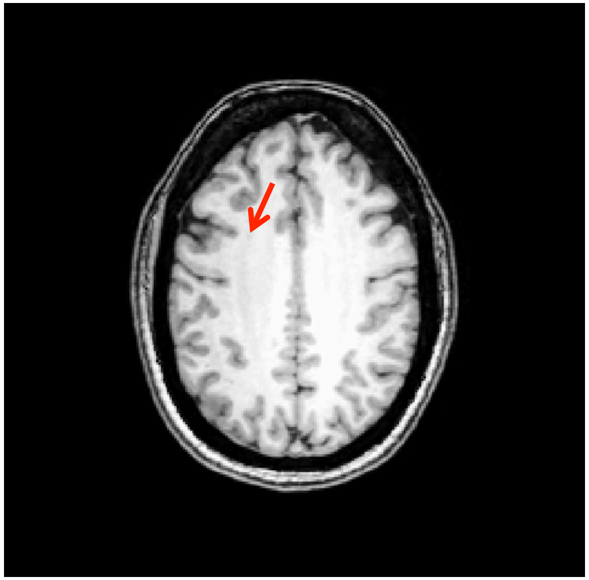


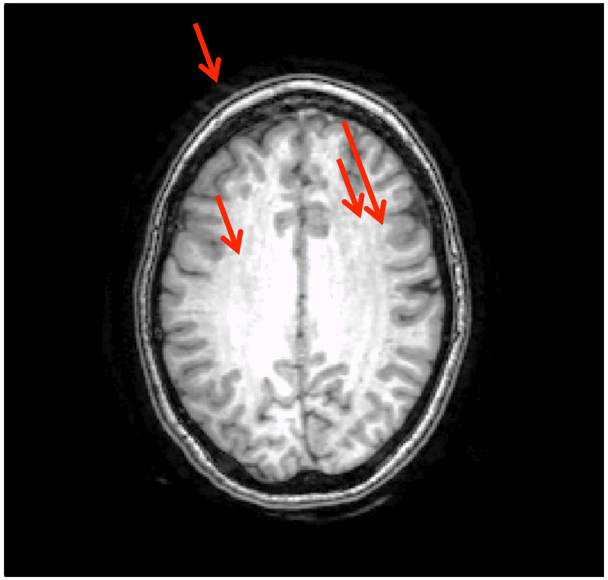
Moderate: Ringing, Striping, Blurring pronounced

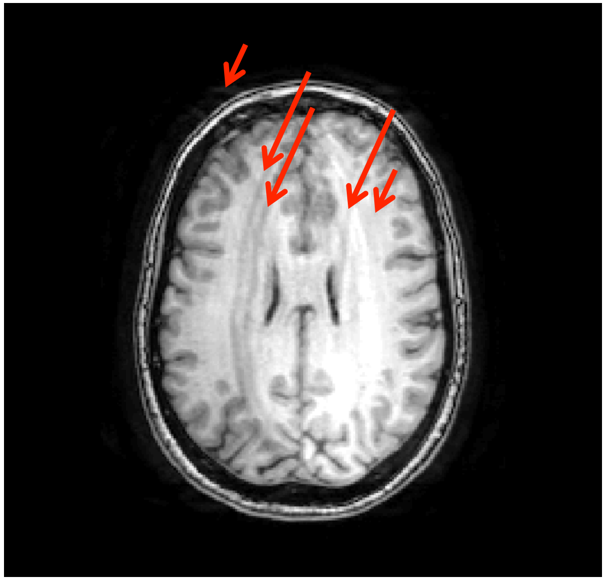


Severe: Ringing, Striping, Blurring extreme

ANAT : Shadowed Arc Artifact







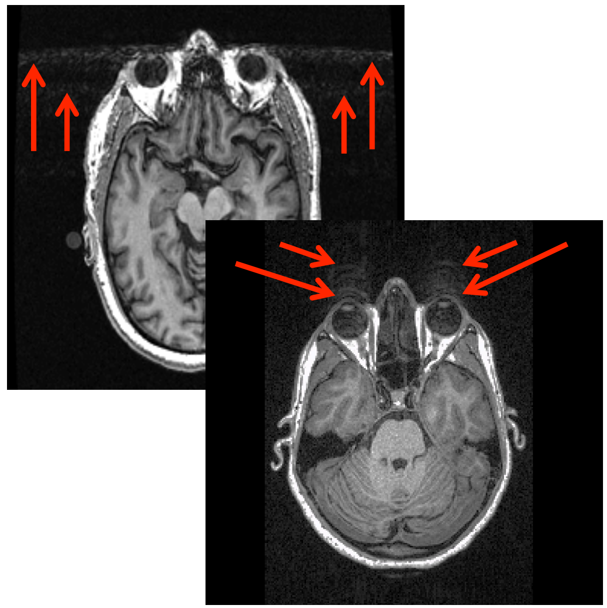
Mild: Shadowed Arc Artifact faintly detectable

Moderate: Shadowed Arc Artifact pronounced

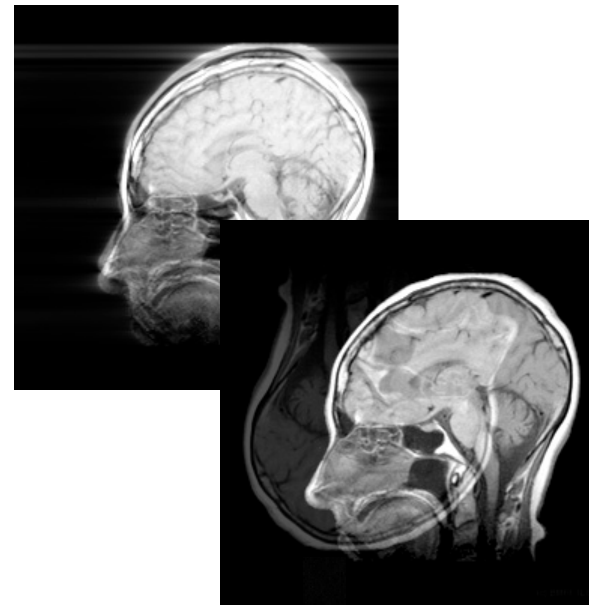
Severe: Shadowed Arc Artifact extreme

ANAT : Ghosting

Mild: Ghosting faintly detectable

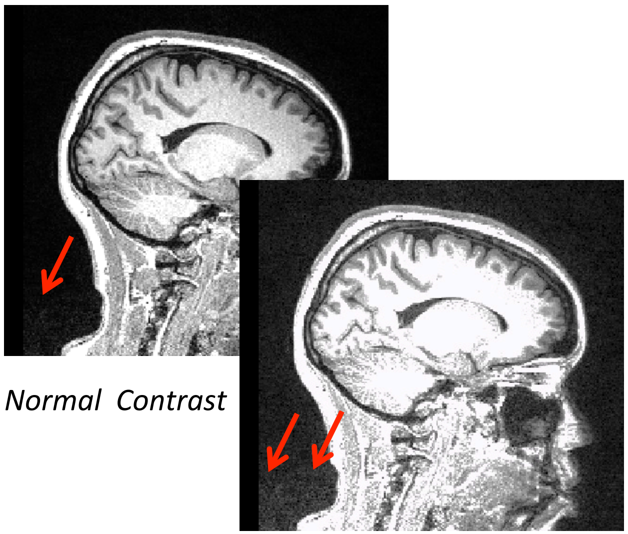


Moderate: Ghosting pronounced



Severe: Ghosting extreme

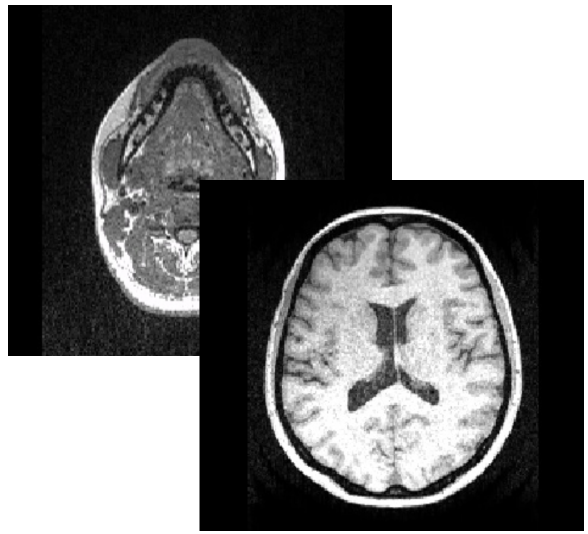
ANAT : Radio Frequency (RF) Noise (Severe = Spiking)



Normal Contrast

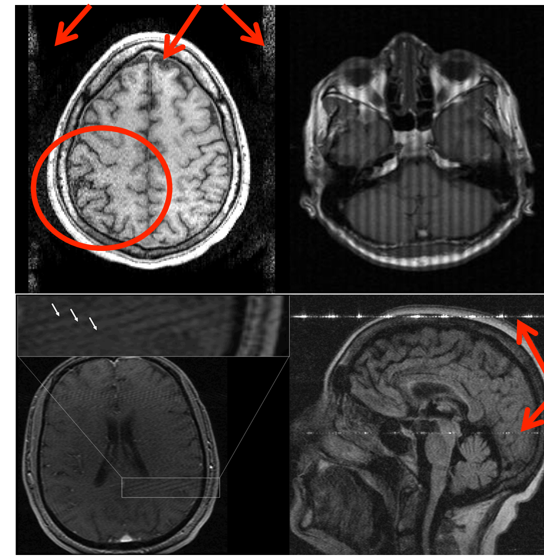
*High Contrast**

Mild: Low-level RF noise visible only after adjusting contrast



Normal Contrast

Moderate: RF noise prominently visible without adjusting contrast

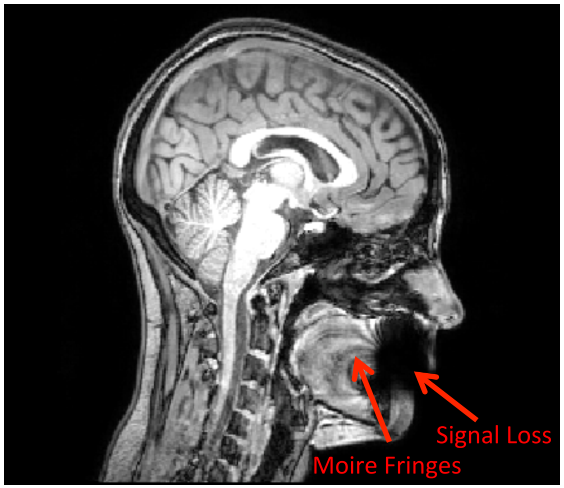


Severe: Spiking is present

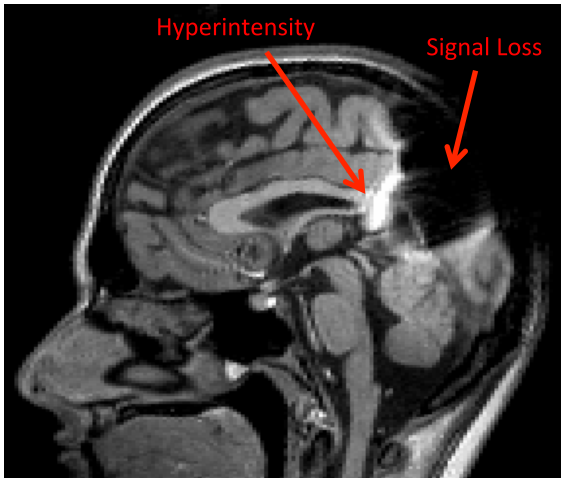
*RF Noise is most clearly visible at high contrast, adjusted by lowering the Maximum Brightness.

ANAT : Susceptibility Artifact

None: Susceptibility Artifact not present

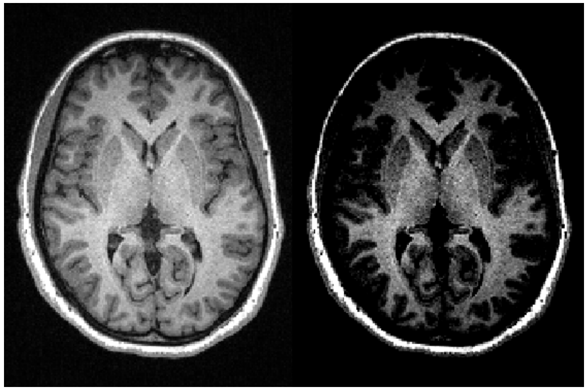


Outside Brain: Susceptibility Artifact present, but does not affect brain



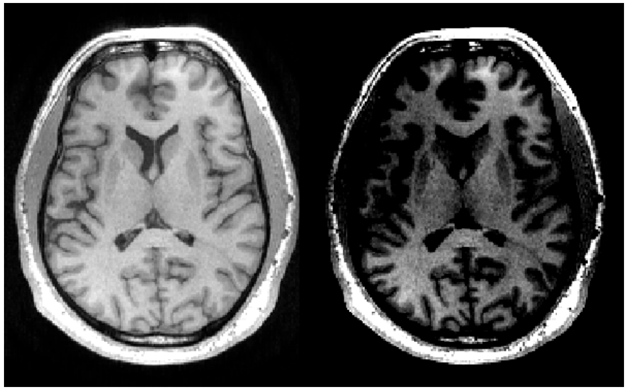
Affecting Brain: Susceptibility Artifact present and affects brain

ANAT : Unexpected Inhomogeneity



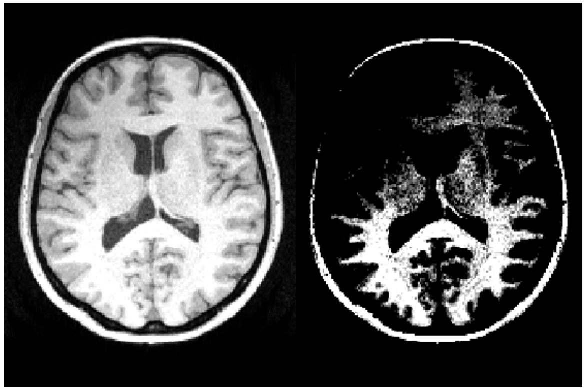
Normal Contrast *High Contrast**

None: signal intensity uniform throughout image



Normal Contrast *High Contrast**

Expected: inconsistent signal intensity fits coil profile

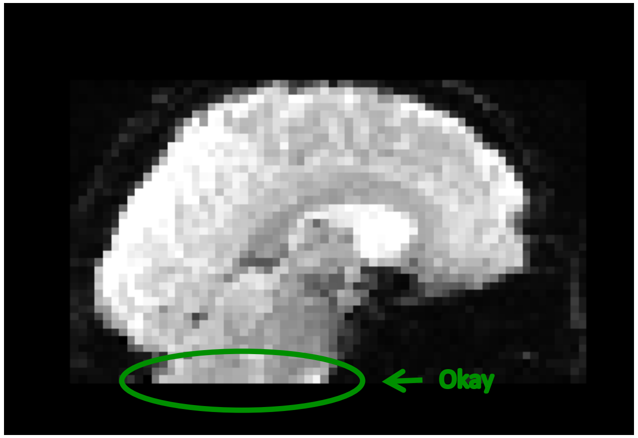


Normal Contrast *High Contrast**

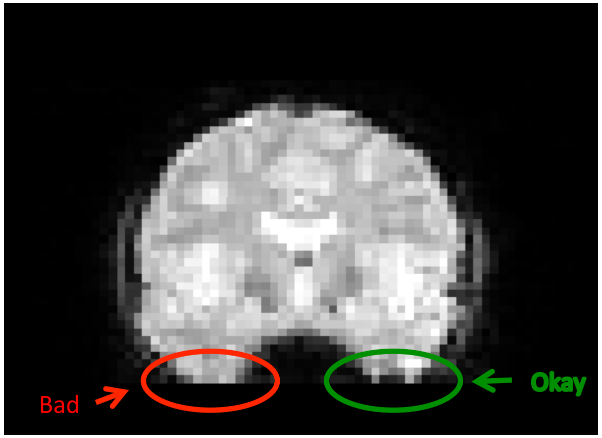
Unexpected: inconsistent signal intensity does not fit coil profile

*Signal inhomogeneity is most clearly visible at high contrast, adjusted by raising the Minimum Brightness.

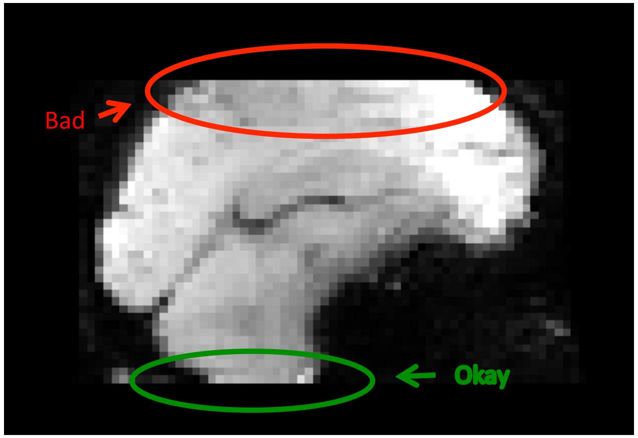
BOLD : Head Coverage



Good: EMBARC brain target area fully covered in FOV.

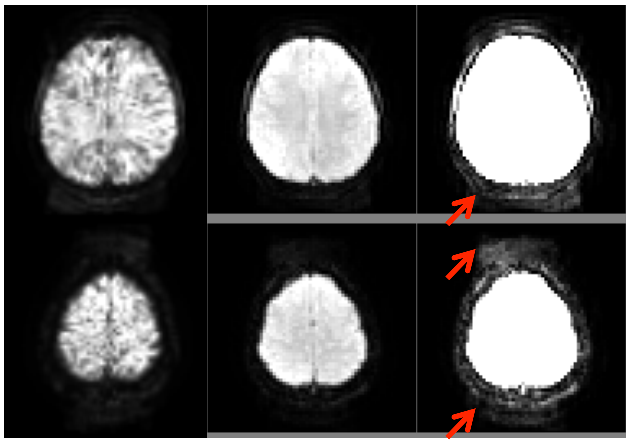


Questionable: FOV clips slice(s) of EMBARC brain target area.



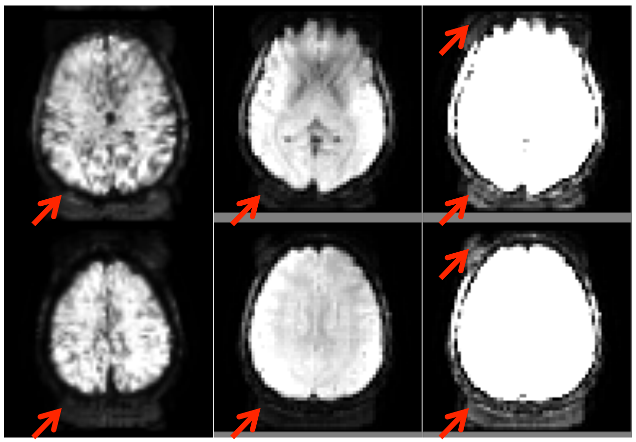
Bad: FOV clips significant portion of EMBARC target area

BOLD : Ghosting



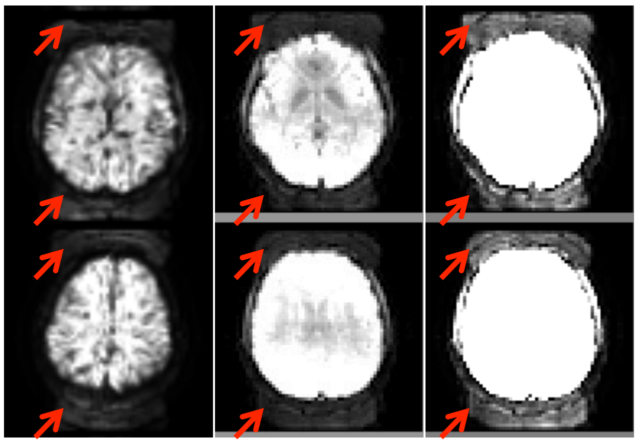
SNR Map *Mean Intensity Map* *Mean Intensity (lowered max. brightness)*

Mild: Ghosting faintly detectable only after adjusting contrast (decrease Maximum Brightness)



SNR Map *Mean Intensity Map* *Mean Intensity (lowered max. brightness)*

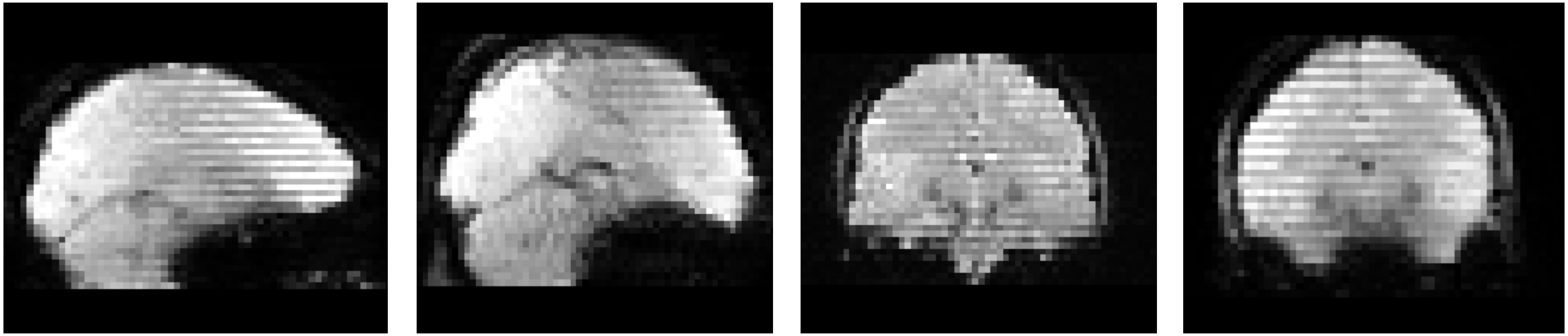
Moderate: Ghosting notably visible without adjusting contrast and prominently visible after adjusting contrast



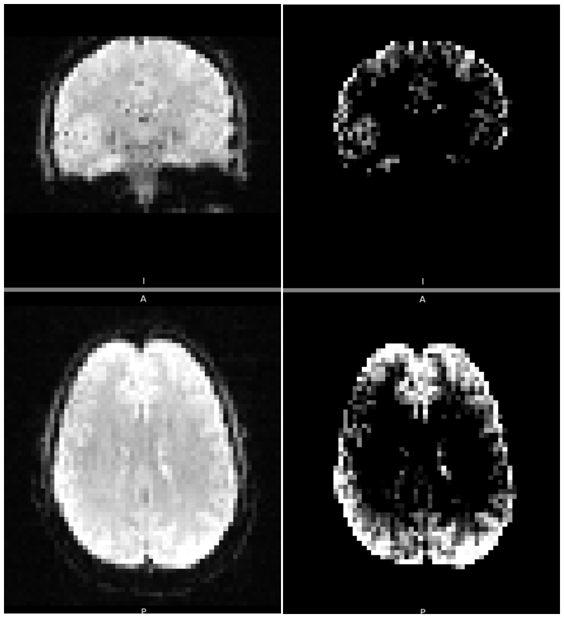
SNR Map *Mean Intensity Map* *Mean Intensity (lowered max. brightness)*

Severe: Ghosting prominently visible without adjusting contrast

BOLD : Motion Slice Artifact

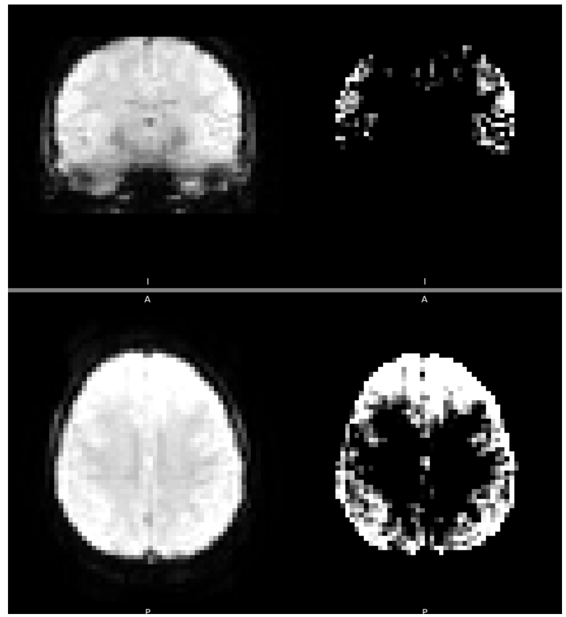


BOLD : Signal Inhomogeneity



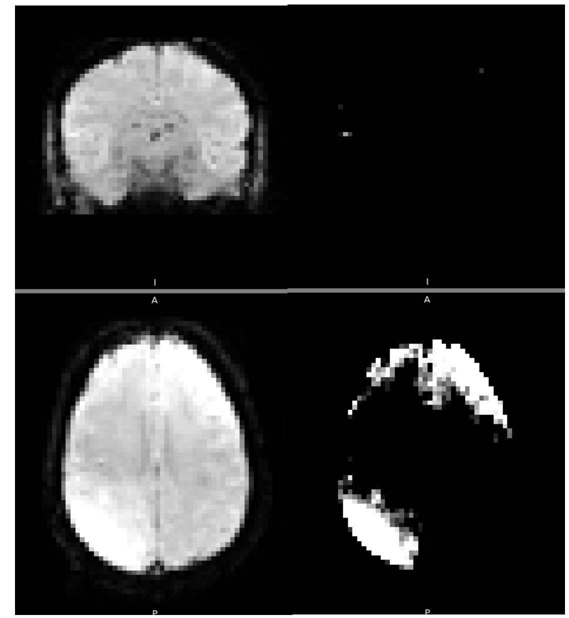
Normal Contrast *High Contrast**

None: signal intensity uniform throughout image.



Normal Contrast *High Contrast**

Expected: inconsistent signal intensity fits scanner/coil profile



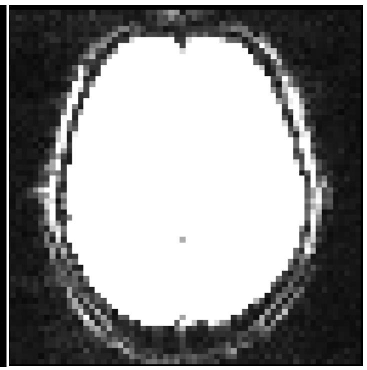
Normal Contrast *High Contrast**

Unexpected: inconsistent signal intensity does not fit scanner/coil profile

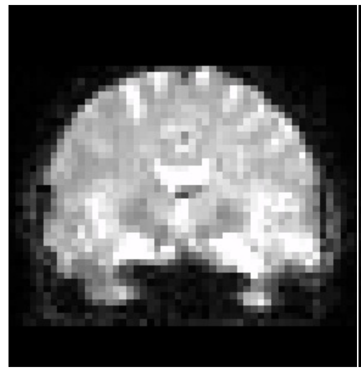
*Signal inhomogeneity is most clearly visible at high contrast, adjusted by raising the Minimum Brightness.

BOLD : Radio Frequency (RF) Noise (Severe = Spiking)

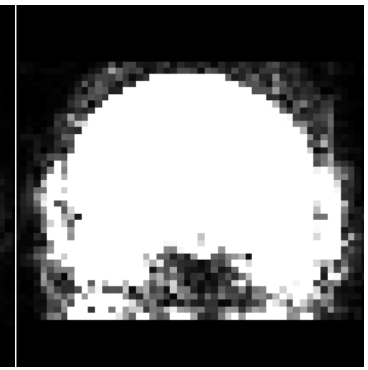
Normal Contrast



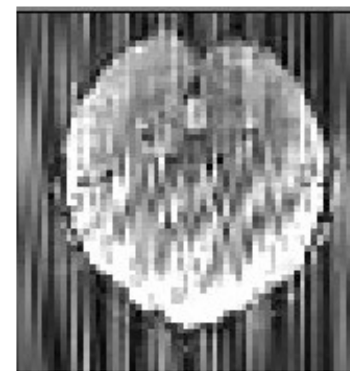
*High Contrast**



Normal Contrast



*High Contrast**



Normal Contrast

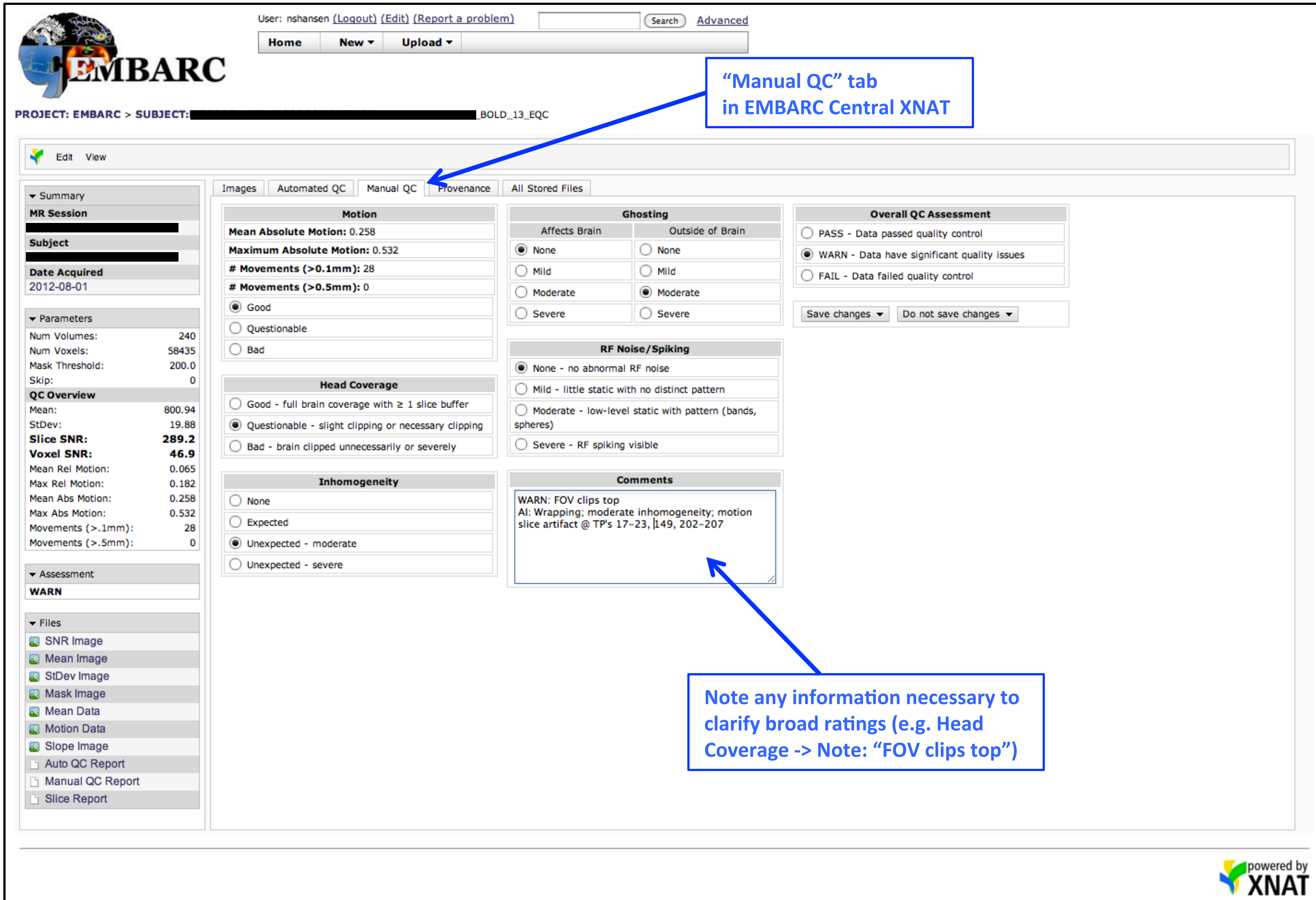
Mild: Low-level RF noise visible only after adjusting contrast

Moderate: RF noise prominently visible without adjusting contrast

Severe: Spiking is present

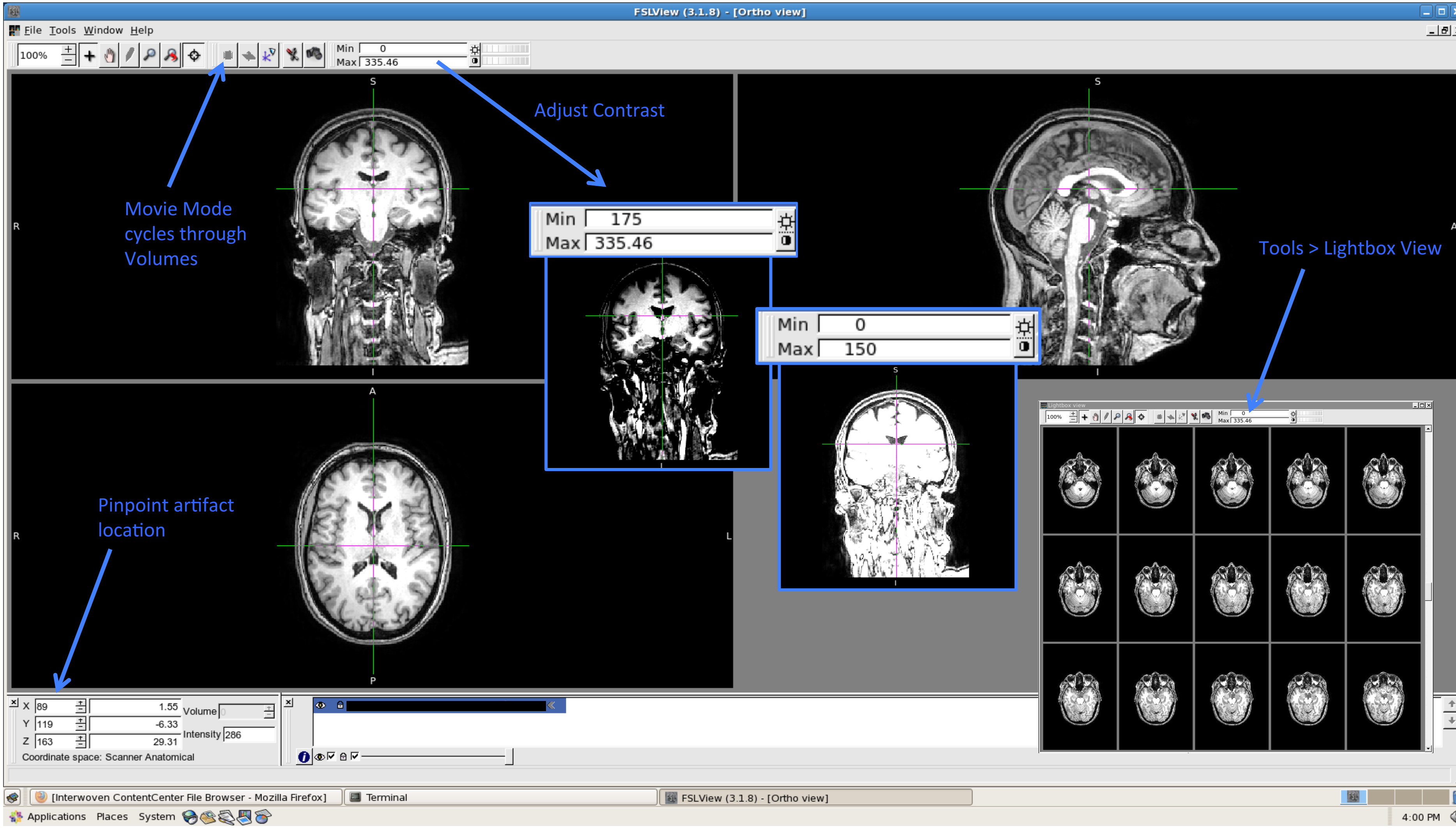
*RF Noise is most clearly visible at high contrast, adjusted by lowering the Maximum Brightness.

Make a Record



Qualitative QC in Action

Examples from EMBARC scans in FSL

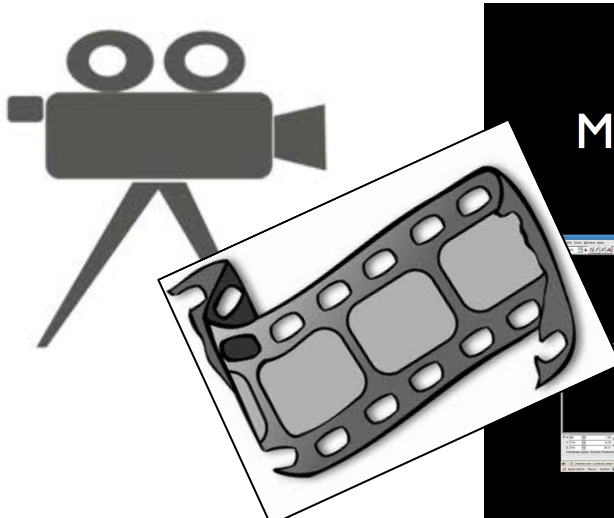


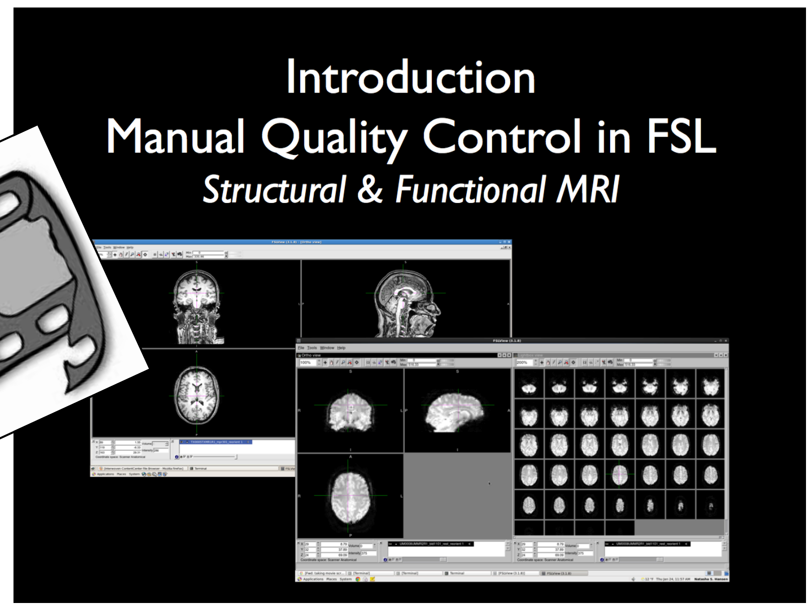
Video Tutorial

“Introduction to Quality Control Tools in FSL”

MRI quality control tutorial videos are available online!

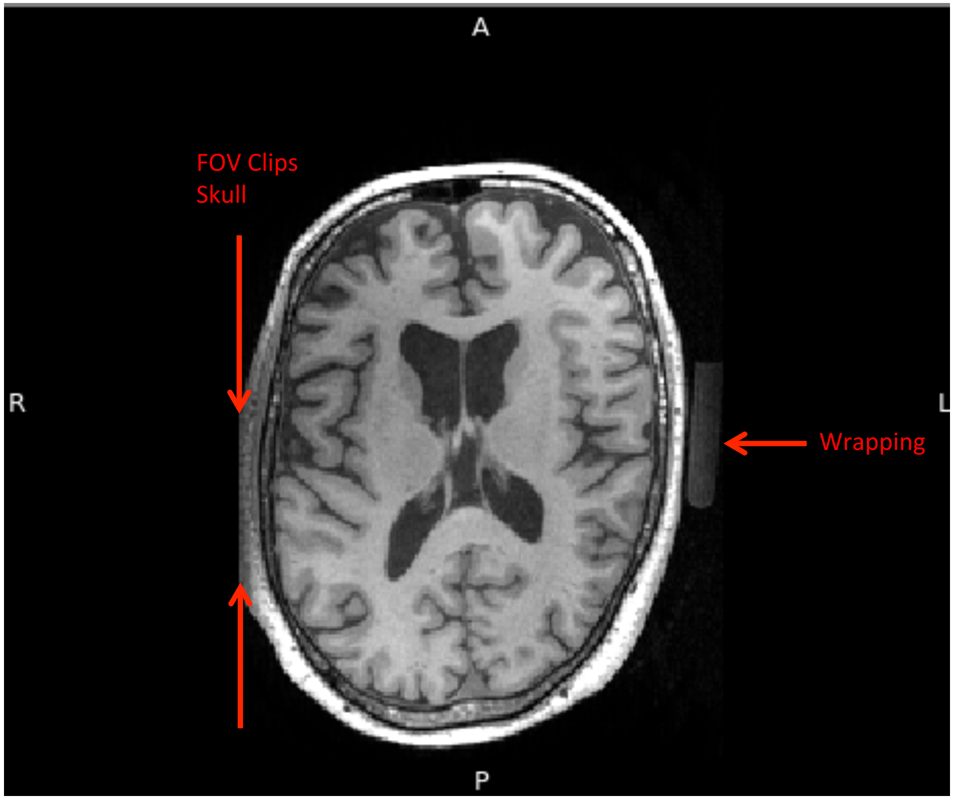
Go to the Harvard Center for Brain Science website: http://cbs.fas.harvard.edu/
Center for Brain Science > Neuroimaging > Information for Investigators > FAQ





Head Coverage & Wrapping

FOV clips skull causing Wrapping

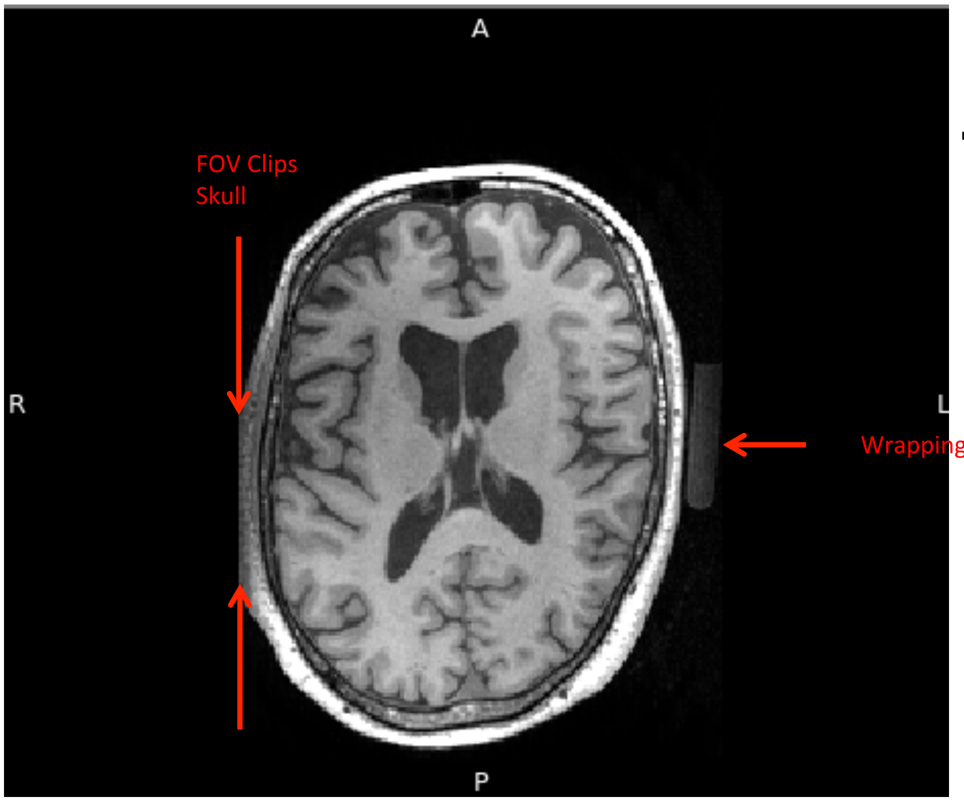


Normal Contrast

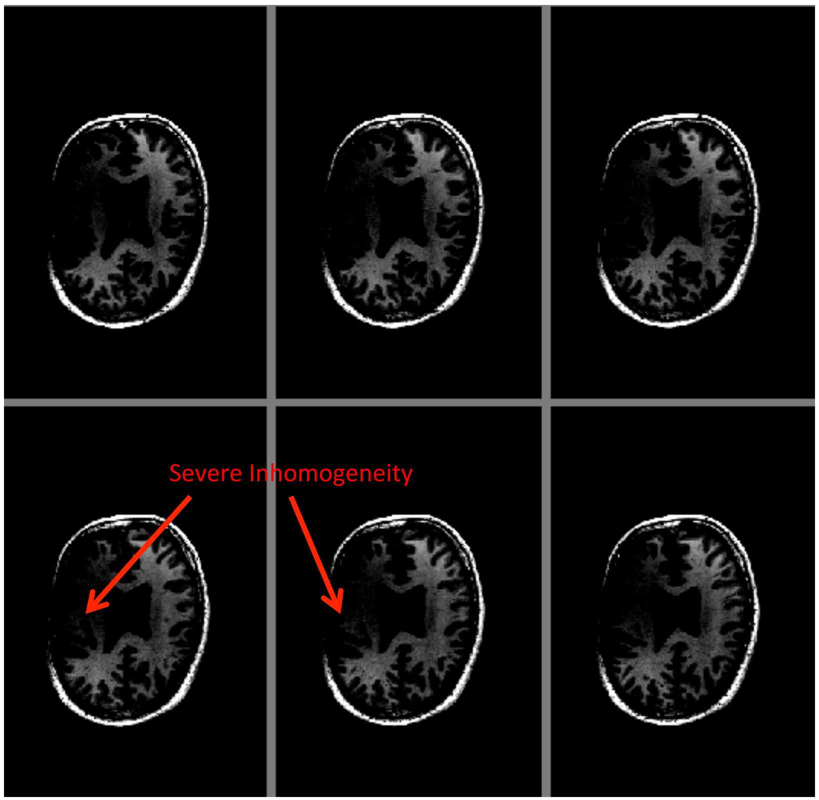
Head Coverage & Wrapping

FOV clips skull causing Wrapping

Inhomogeneity revealed at point of skull clip



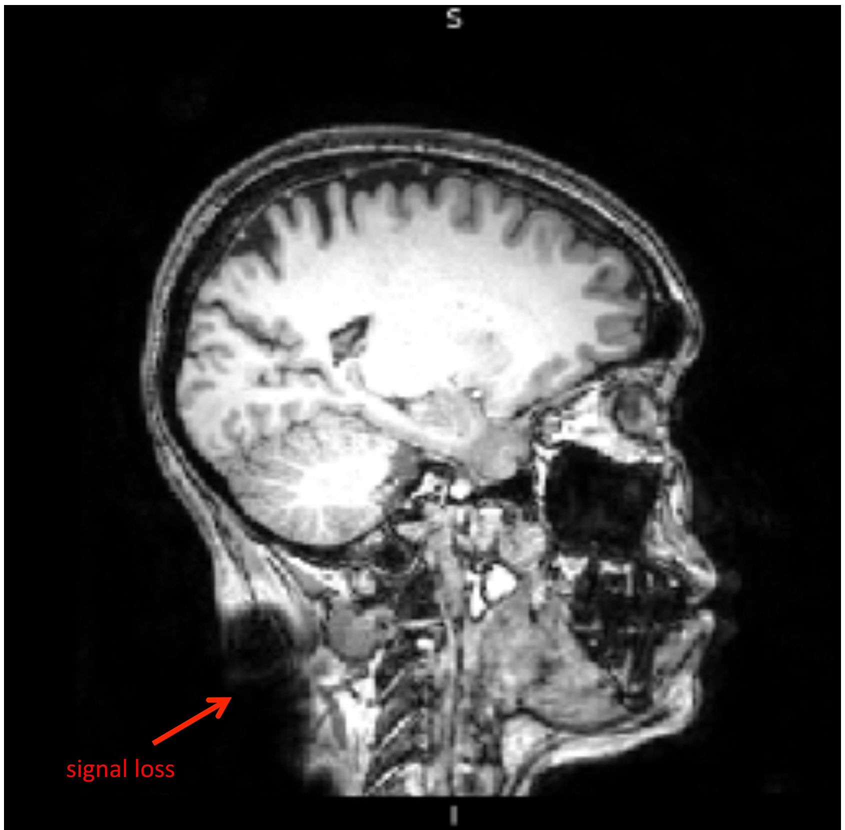
Normal Contrast

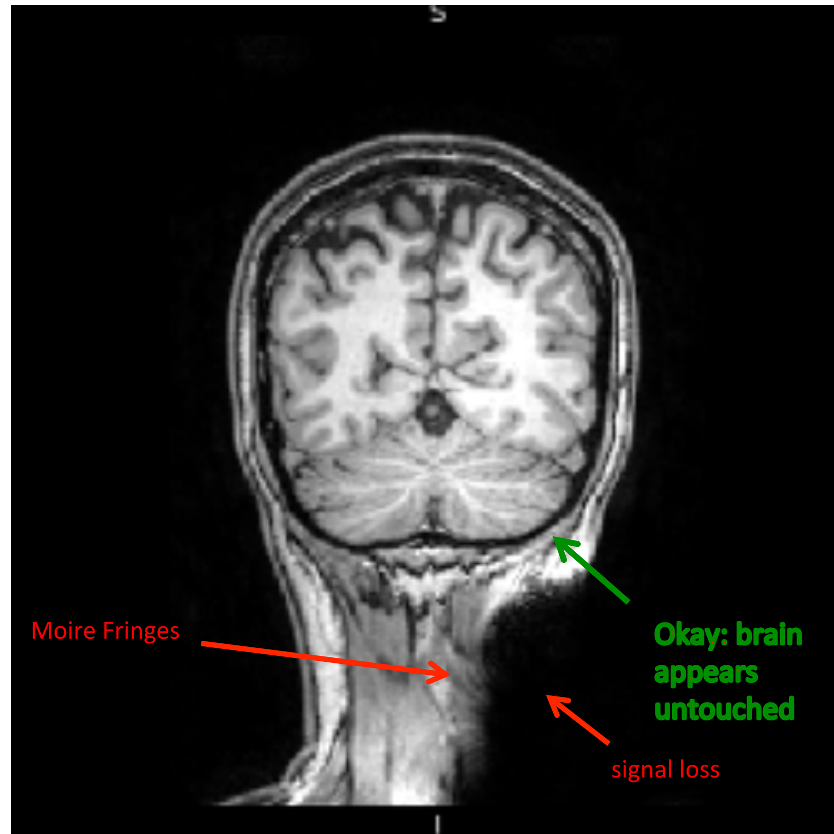


Adjusted Contrast

Susceptibility Artifact

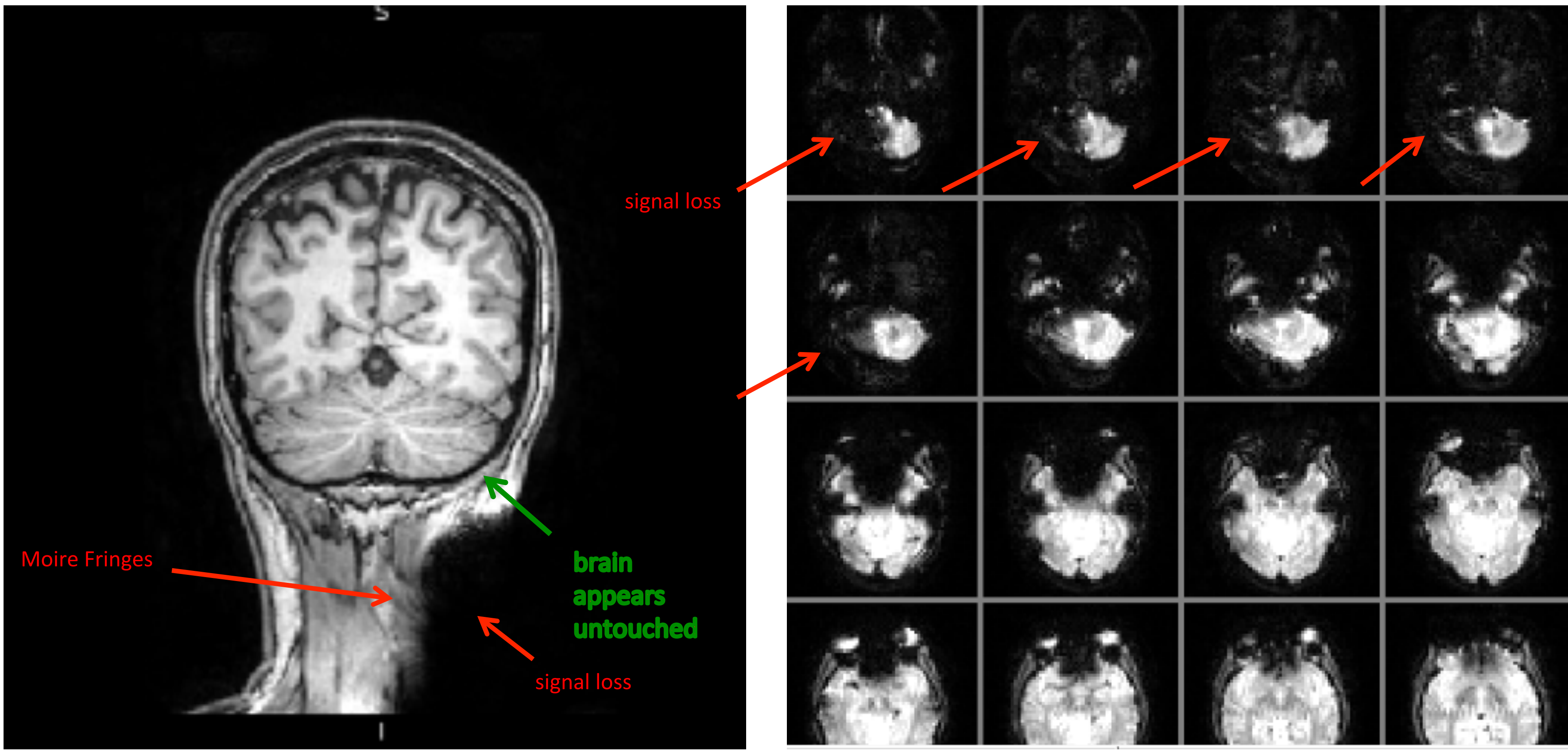
Massive signal loss accompanied by “Moire Fringes” – brain appears unaffected





Susceptibility Artifact

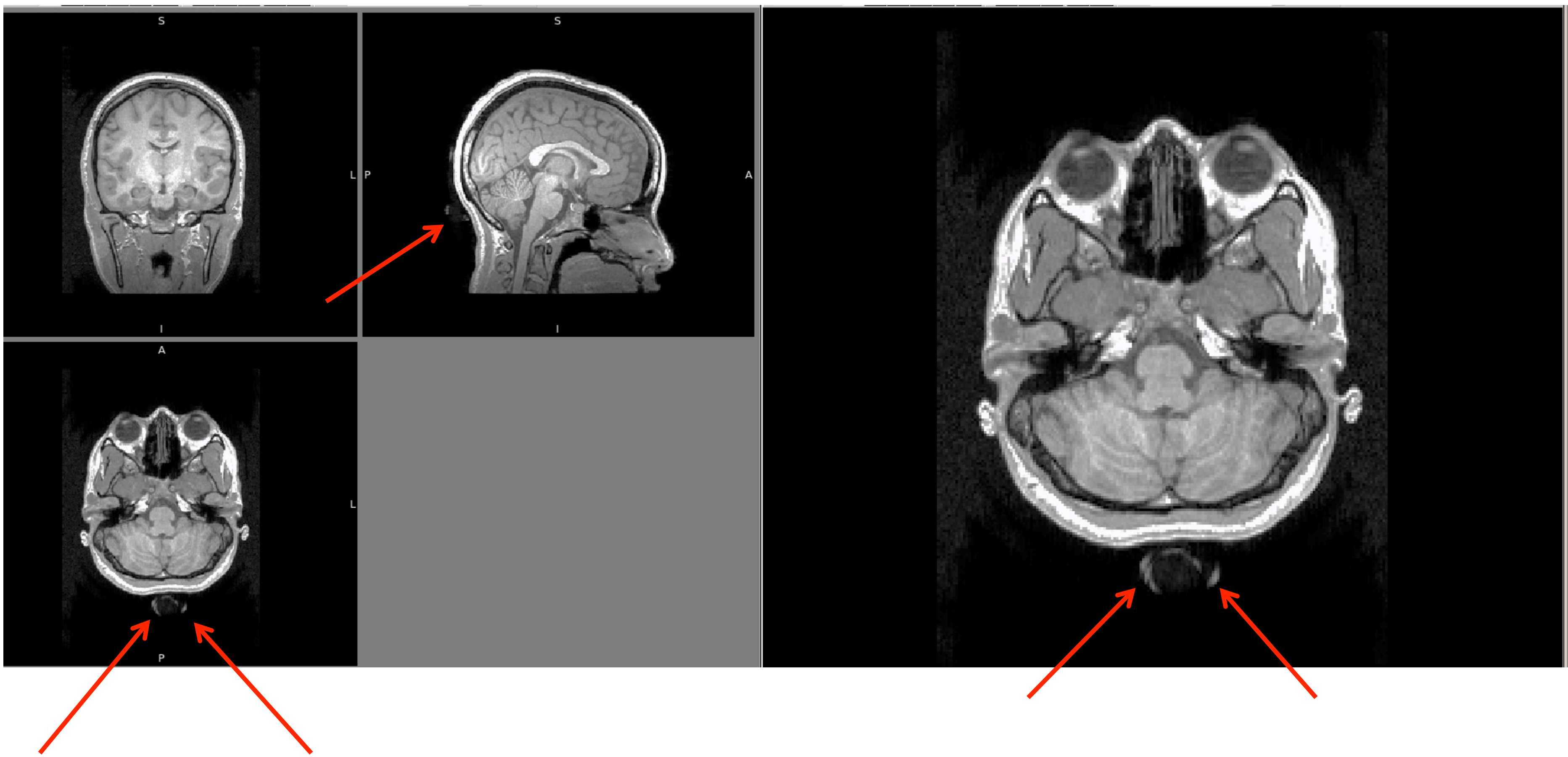
Brain appears unaffected in by Susceptibility Artifact in structural scans, but signal drop out is visible in BOLD scans



Normal Contrast

"Swirling Galaxy Artifact"!

This artifact is caused by the subject's hair tie or greasy bun – perspective and humor are key!



Want to Learn More?

The Harvard Center for Brain Science Website has more useful information for you!

Go to: http://cbs.fas.harvard.edu/

Center for Brain Science > Neuroimaging > Information for Investigators > FAQ

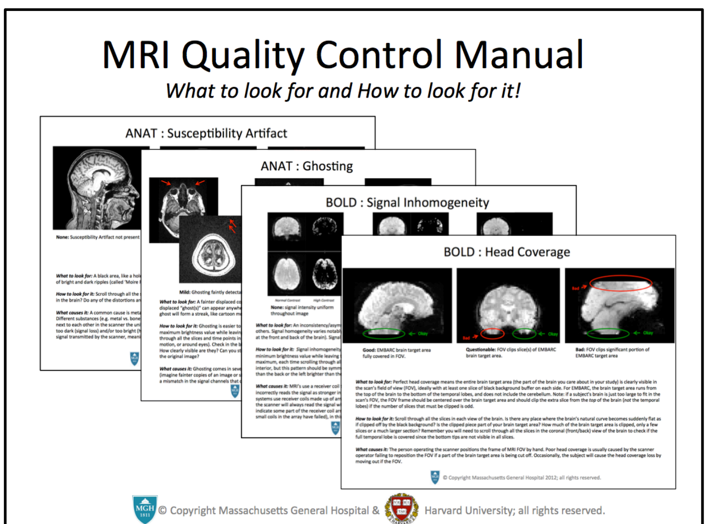
The Qualitative QC Manual

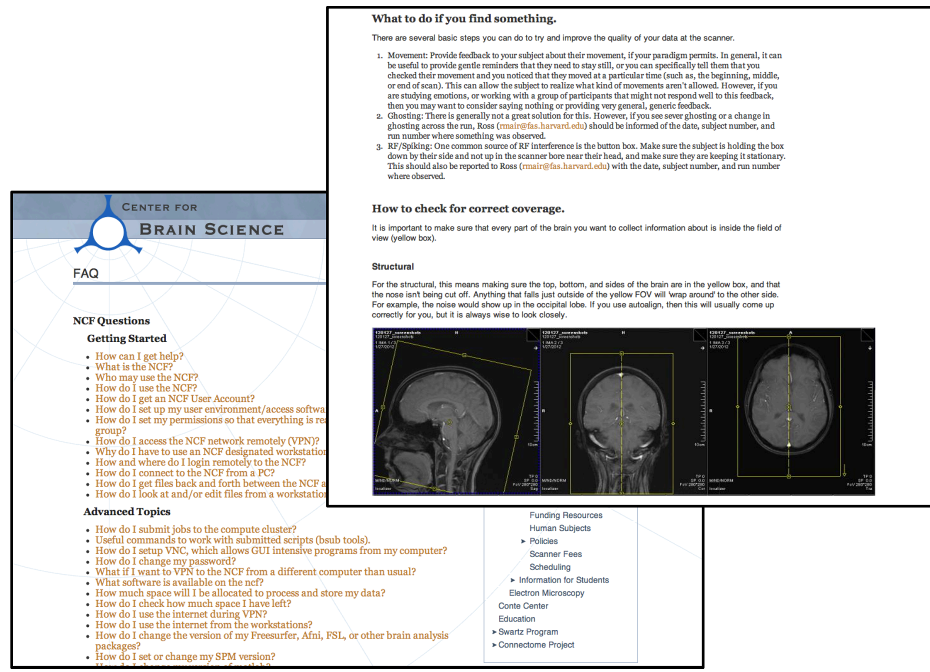
Detailed practical QC Tutorial Videos

How to create your own measures of goodness

Preventive QC: at the scanner

What to do when you discover artifacts





Acknowledgements

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Questions and Discussion…