ACR MRI Accreditation Update: The Role of the Medical Physicist

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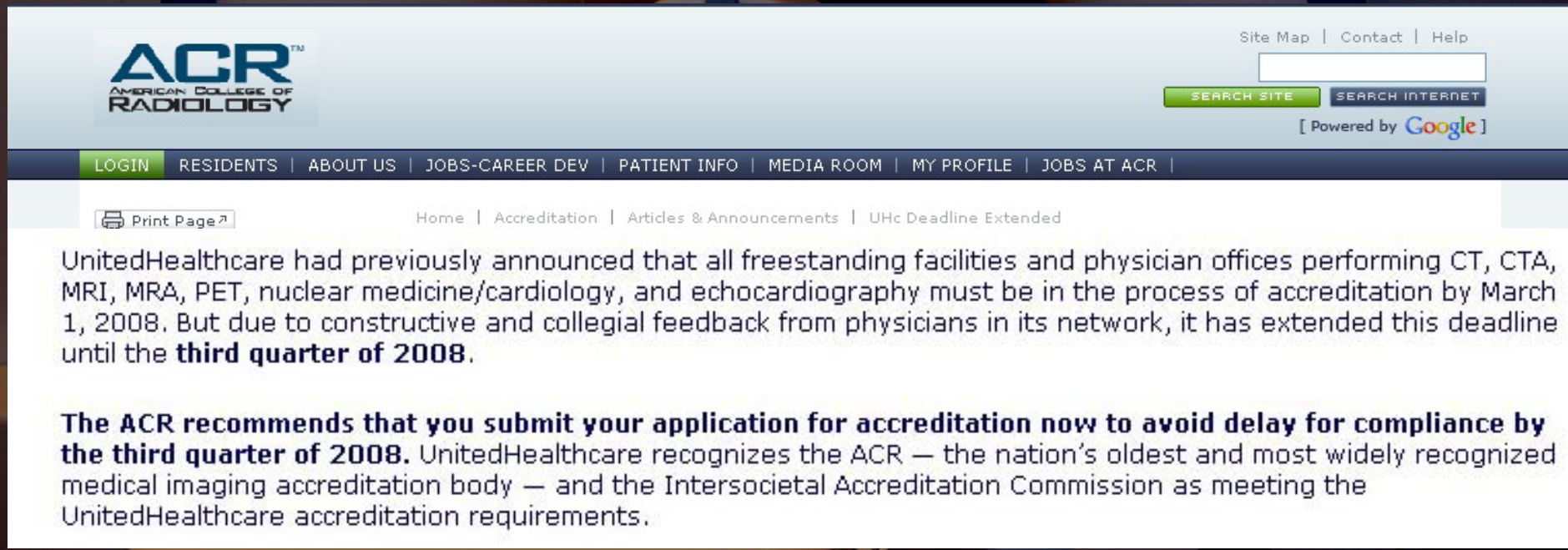
Nashville, TN

Please note that a number of slides have been provided compliments of Ed Jackson, Ph.D., Karl Keener, Ph.D. and Geoff Clarke, Ph.D.

Deadline Extended for UnitedHealthcare Mandatory Accreditation Program



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UnitedHealthcare had previously announced that all freestanding facilities and physician offices performing CT, CTA, MRI, MRA, PET, nuclear medicine/cardiology, and echocardiography must be in the process of accreditation by March 1, 2008. But due to constructive and collegial feedback from physicians in its network, it has extended this deadline until the **third quarter of 2008**.

The ACR recommends that you submit your application for accreditation now to avoid delay for compliance by the third quarter of 2008. UnitedHealthcare recognizes the ACR — the nation's oldest and most widely recognized medical imaging accreditation body — and the Intersocietal Accreditation Commission as meeting the UnitedHealthcare accreditation requirements.

The Purpose of ACR Accreditation

- *To set quality **standards*** for practices and to help continuously improve the quality patient care*

- *To be **educational** in nature. The ACR Accreditation Programs evaluate qualifications of personnel, equipment performance, effectiveness of quality control measures, and quality of clinical images*

** Standards Documents are available from the ACR (www.acr.org)*

*ACR Specifications for Qualified Medical Physicist/MR Scientist**

"The American College of Radiology (ACR) considers certification and continuing education in the appropriate subfield(s) … to be a Qualified Medical Physicist." The standard specifically identifies certification by ABR and ABMP.

"A Qualified MR Scientist is an individual who has obtained a graduate degree in a physical science involving nuclear MR or MRI. He or she should have 3 years of documented experience in a clinical MRI environment."

"The continuing education of a Qualified Medical Physicist/MR Scientist should be in accordance with the ACR Practice Guideline for Continuing Medical Education (CME). (2006-ACR Resolution 16g)"
(At least 15 CME hours in MRI in the prior 36-month period)

* ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment (effective 10/01/04)

*Responsibilities of the Qualified Medical Physicist/MR Scientist**

1. Acceptance Testing that is to be performed upon installation.

2. Assist in establishing a Quality Control Program that is continuous and implemented on all units. Determine frequency and who performs tests.

3. Perform an MRI Equipment Performance Evaluation at least annually and after major repair or system upgrade)

4. Provide Written Reports and Follow-up Procedures that are submitted to the responsible physician/personnel in a timely manner.

** ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment (Effective 10/01/04, Amended 2006) (www.acr.org)*

Medical Physicist/MR Scientist Responsibility

1. Acceptance Testing:

- *Performed on ew systems before the first patient scan*
- *Following any major hardware or software upgrade*
- *Performed on existing systems not previously accredited*

2. Quality Control Program:

Assistance the QC Technologist to establish a weekly QC program by acquiring baseline QC data and defining action limits and appropriate corrective actions (response to out-of-range values) for:

- *Central frequency*
- *Transmitter gain/attenuation*
- *Geometric accuracy*
- *High-contrast spatial resolution*
- *Low-contrast detectability*
- *Laser camera operating levels and SMPTE analysis (in consultation with laser camera service engineer)*
- *and in general to assist in the development and performance of an ongoing "Continuous QC Program"*

Technologist's Continuous Quality Control Program

Technologist's Weekly QC Tests Includes:

- *Center Frequency and RF gain/attn. (phantom prescan)*
- *Table Positioning (phantom)*
- *Setup and Scanning (phantom)*
- *Geometric Accuracy (phantom image)*
- *High-Contrast Resolution (phantom image)*
- *Low-Contrast Resolution (phantom image)*
- *Artifact Analysis (phantom image)*
- *Film Quality Control (SMTE)*
- *Visual Checklist*

3. *MRI Equipment Performance Evaluation*

Standard specifies at least annual checks of :

1. *Physical and mechanical stability*
2. *Phase stability (ghosting)*
3. *Magnetic field homogeneity*
4. *Magnetic field gradient calibration*
5. *Radiofrequency (RF) calibration for all coils*
6. *Image signal-to-noise ratio (SNR) for all coils*
7. *Intensity uniformity for all volume coils*
8. *Slice thickness and location accuracy*
9. *Interslice RF Interference**
10. *Spatial resolution and low contrast object detectability*
10. *Artifact evaluation*
11. *Film processor quality control (QC)*
12. *Hardcopy fidelity (SMTE)*
13. *Softcopy fidelity (monitor luminance)*
14. *Evaluation of MRI safety – environment and posting*

* *Scheduled for removal in 2009*

Additional ACR MRI Accreditation Documents
(www.acr.org)

- *MRI Accreditation Program Requirements (revised 9/25/07)*

- *MRI Accreditation Program TESTING INSTRUCTIONS (revised 12/19/07)*

- *Site Scanning Instructions for Use of the MR Phantom for the ACR MRI Accreditation Program (12/02)*

- *Phantom Test Guidance (2005)*

- *Clinical Test Image Data Forms (one for each type of clinical exam)*

- *ACR Guidance Document for Safe MR Practices: 2007*
  Kanal et al, American Journal of Radiology;188:1-27

Currently Active ACR MRI Accreditation Modules

- Whole Body
- Cardiac

Coming Soon: ACR Modular MRI Accreditation Program

- *Anticipated in 2008-2009*
- *Will be similar to CT program and will closely reflect the clinical use of each machine*
- *Proposed modules:*

1) Head/Neck	*4) Body*	*7) Orthopedic**
2) Spine	*5) MRA*	*8) Breast***
3) MSK	*6) Cardiac*	

*Specialty magnets

- *Each unit must undergo testing in the appropriate module(s)*

** *Note: Breast MRI Accreditation will be through the ACR Mammography Program*

ACR Accreditation Process Overview:

The accreditation process consists of two phases:

Phase 1: "Entry Application" (available online)

Essentially to request a Testing Material Packet for the Full Application

Entry Application requires:

- *Contact information (supervising physician and contact technologist)*
- *Information regarding the installed magnet(s) and clinical practice*
- *Credentials for physicians, technologists, medical physicist/MR scientist*
- *Date of last physics performance survey and evidence of a peer review program*
- *Payment information ($2400 for first magnet, $2300 for each subsequent magnet)*

Phase 2: "Full Application"

You will then receive a Testing Material Packet for the Full Application

The Full Application requires:

- *Phantom and Clinical Images*
- *Performance report for each magnet (< 1 year) and last quarter QC documents*

Who makes the measurements?

Does the ACR require that a physicist/MR scientist perform testing services for a facility to apply for accreditation?

***No**, however, sites usually appreciate the help of the medical physicist in both phases of the application process and ...*

"Starting July 1, 2005, sites applying for MRI accreditation must submit an annual MRI system performance evaluation performed by a medical physicist/MR scientist. A technologist may still perform the ACR phantom portion of the accreditation submission, although the ACR strongly recommends the services of a medical physicist or MR scientist for this also."

The Full Application Testing Materials Packet Contains:

1. The *Testing Instuctions* Document
2. Quality Assurance Questionnaire
3. Phantom order form ($730)
4. *Site Scanning Instructions for the MR Phantom* (how to make measurements)
5. *Phantom Test Guidance* booklet (how to check the measurements)
6. Clinical Test Image Data Forms* (one for each clinical exam)
7. Identification labels for images** (CD and film), forms and QC data
8. MRI Quality Control Manual
9. Laser Printer Attestation form (sites that indicated no filming on application)

** Clinical and Phantom images should be taken within a 2 week window*

*** Labels will have due dates for all forms and images (~90 days)*

ACR MR Accreditation Phantom

J. M. Specialty Parts

11689-Q Sorrento Valley Road

San Diego, CA 92121

Phone: (858) 794-7200

$730

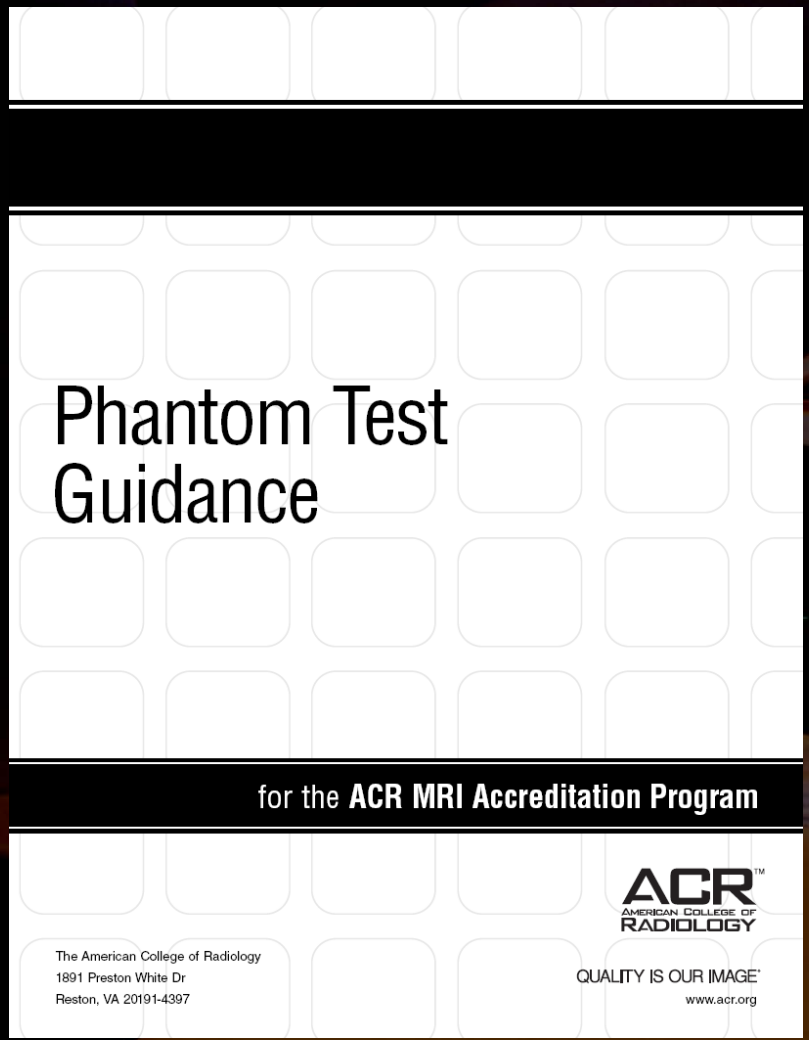
At this time, the phantom can be purchased by MRI facilities that apply for accreditation, MRI equipment manufacturers, and consulting physicists or MR scientists only. The order form for the phantom comes with the testing materials packet when a facility applies for, or renews accreditation. For your convenience, you can download the whole-body MR phantom order form. MRI manufacturers interested in purchasing a phantom should contact the MRI Accreditation Program at (800) 770-0145 or e-mail to MRI@acr.org.

ACR Phantom Scanning Instructions

Contains information on:

- *Phantom positioning*
- *Pulse sequences to be used*
- *Filming and data preparation instructions*
- *Sent to site with Full Application*
- *Also available at ACR website*

ACR Phantom Scan Documentation



Contains information on:

- *How to perform your own phantom evaluation using the same DICOM viewer used by the ACR reviewer (OSIRIS)*

  (http://www.sim.hcuge.ch/osiris/01_Osiris_Presentation_EN.htm)

- *Performance criteria that must be met by each unit*
- *Common reasons for failure*
- *Sent to site with Full Application*
- *Also available at ACR website*

Laser Printer Attestation: If the facility is completely filmless and does not have a laser printer.

MRAP ID No._____

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Place Laser Printer QC label here.

This Laser Printer Attestation must be signed by the facility's supervising radiologist (lead interpreting physician). Original signatures are required. Please maintain a copy for your files. Submit this form with your testing materials.

ACR™ AMERICAN COLLEGE OF RADIOLOGY

Magnetic Resonance Accreditation Program
1891 Preston White Drive
Reston, VA 20191

LASER PRINTER ATTESTATION

ACR Unit # _____

Manufacturer: _____

Model: _____

Check one:

This facility does not, nor will it, have laser printer capabilities.

Please sign the statement below, and return this attestation to the ACR along with your testing materials **only if your facility does not have the capability of producing film.** Please reference the MR Program Overview. You may also fax it to (703) 295-6776.

Having laser printer capability and not performing laser printer QC may jeopardize accreditation status.

If you have any questions, please call Theresa Branham at (800) 770-0145.

_____ _____
Lead Interpreting Physician's Signature Date

_____
Printed Name

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Phantom Image Submission:

- *Facility must scan the ACR MR Accreditation Phantom on each MR unit using five specified pulse sequences:*

  1) ACR specified sagittal localizer

  (SE 20/200 ms, FOV = 25 cm, 256X256, slice = 20 mm, NEX = 1, Time = 0.56 s)

  2) ACR T1-weighted sequence

  (SE 20/500 ms, FOV = 25 cm, 256X256, multi-slice (11 at 5 mm), 1 NEX, Time = 2:16 min)

  3) ACR T2-weighted sequence

  (SE 20-80/2000 ms, 25 cm, 256X256, multi-slice (11 at 5mm), 1 NEX, Time = 8:56 min)

  4) Site specific T1-weighted brain sequence (multi-slice with 11 at 5mm @ 5 gap)

  5) Site specific T2-weighted brain sequence (multi-slice with 11 at 5mm @ 5 gap)

- *Images must be submitted on film (if you use film) and in uncompressed DICOM format on CD-ROM* (no embedded viewer)*

- *Images will be evaluated by ACR reviewers to assess: 1) high-contrast resolution, 2) slice thickness accuracy, 3) distance measurement accuracy, 4) signal uniformity, 5) image ghosting ratio, 6) low-contrast detectability, 7) slice position accuracy and 8) image artifacts*

* *If the site does not produce DICOM CDs the site must have phantom images translated at extra cost.*

(Service available from DESACC @ $200/disk + $25 shipping)

Scanning the ACR Phantom

Alignment of the ACR Phantom

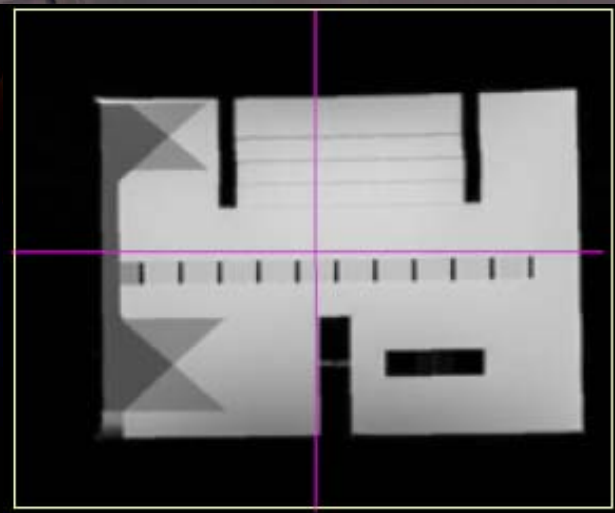
Alignment is very important!

- *Center the phantom in the head coil (3D)*

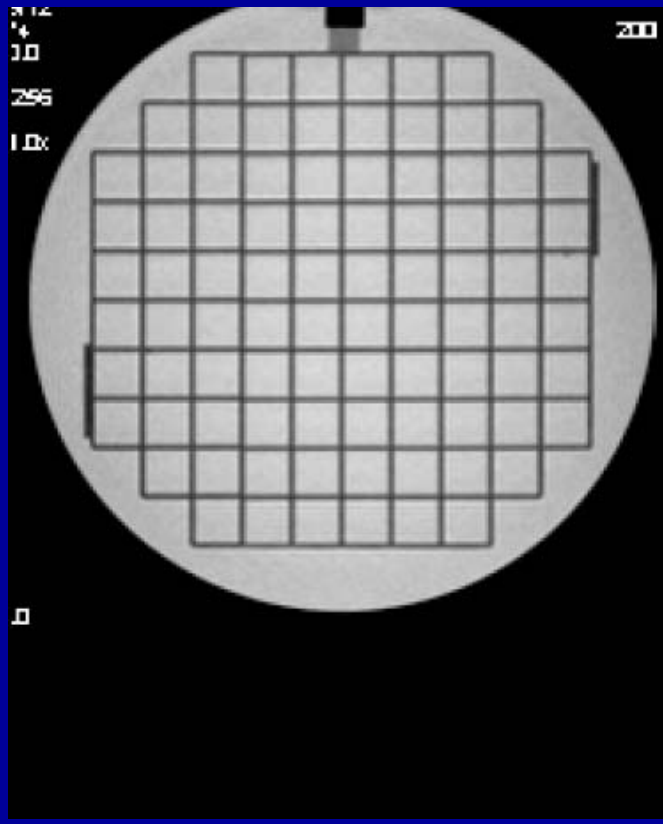
  (use foam, special frame, stack of paper, etc)
- *Make sure the phantom is straight*

  (be sure to use the bubble level provided)
- *Be sure the phantom is centered SI, L-R and AP*

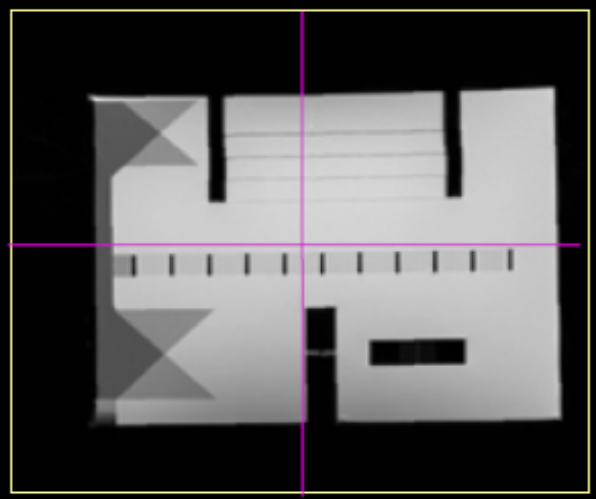
  (use 3-plane localizer and check with grid
- *Record position and save paper/cardboard shims for future use*

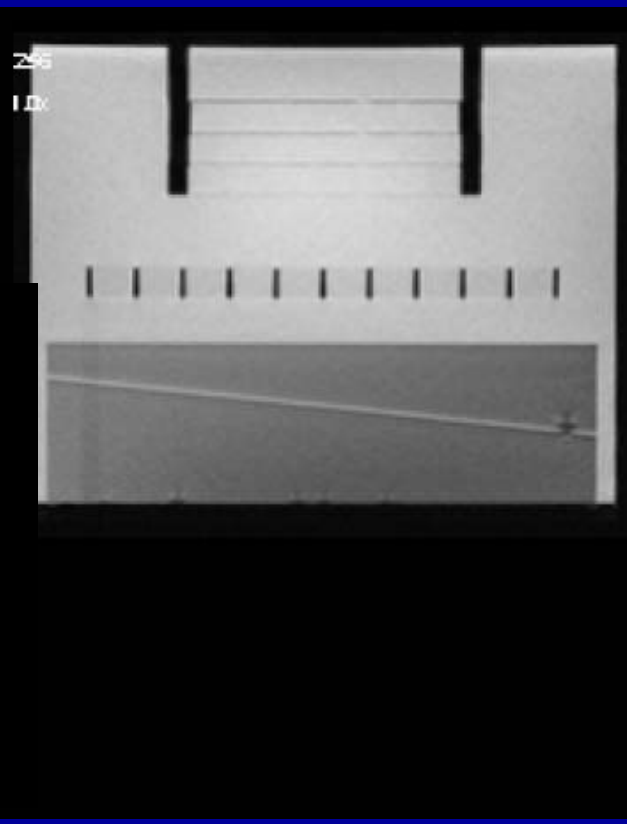


Confirm Proper Positioning Using Grid Overlays



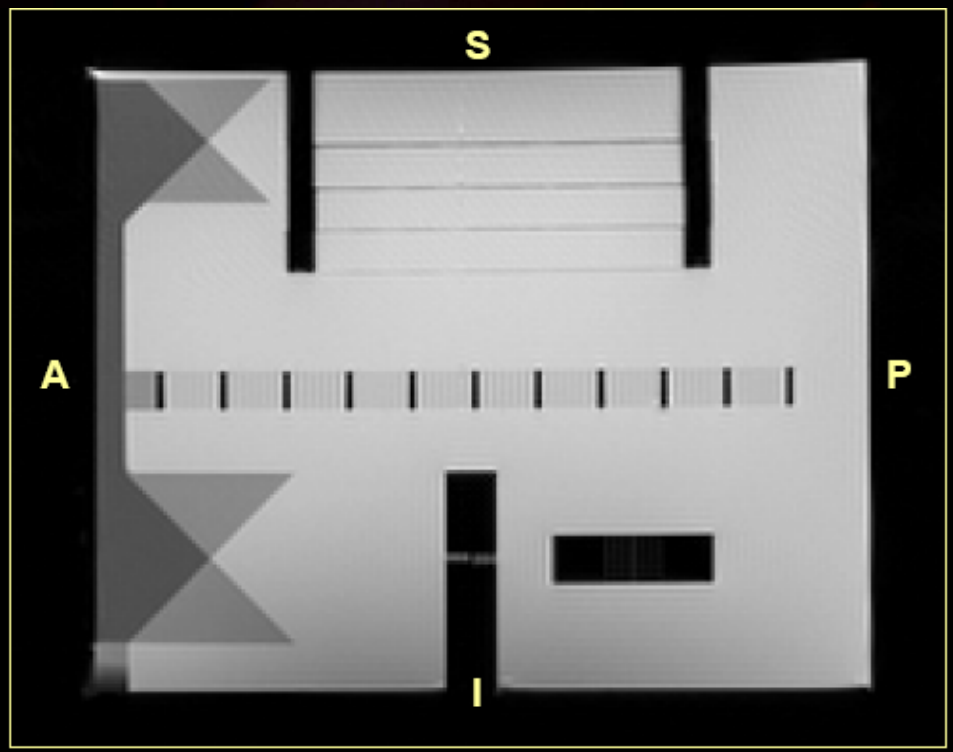
Use 3-plane localizer!

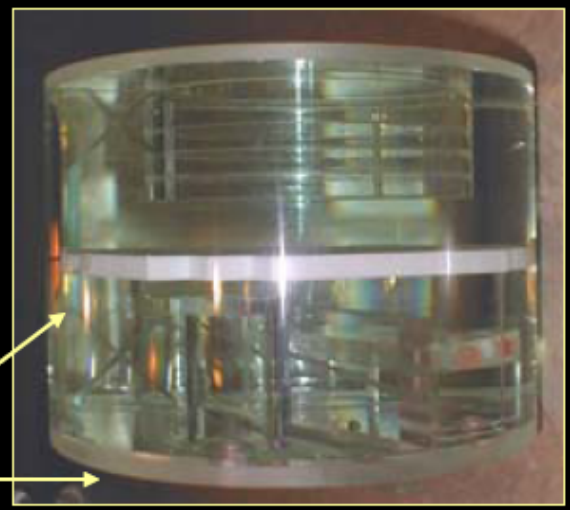




Scan #1: ACR Sagittal Localizer

(SE 20/200 ms, FOV = 25 cm, 256X256, slice = 20 mm, NEX = 1, Time = 0.56 s)

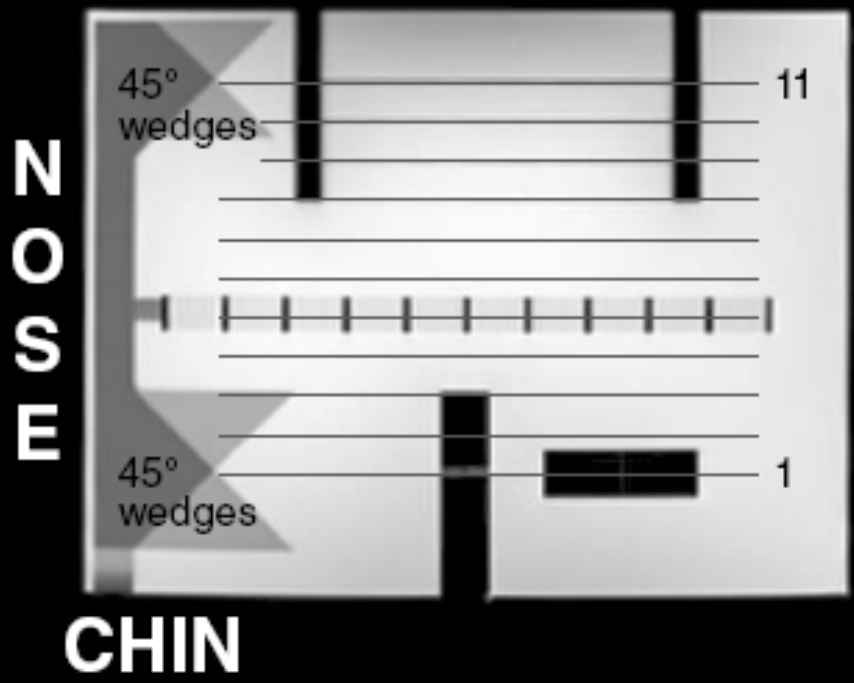




Images Compliments of Carl Keener, PhD

Scan #2: ACR Axial T1

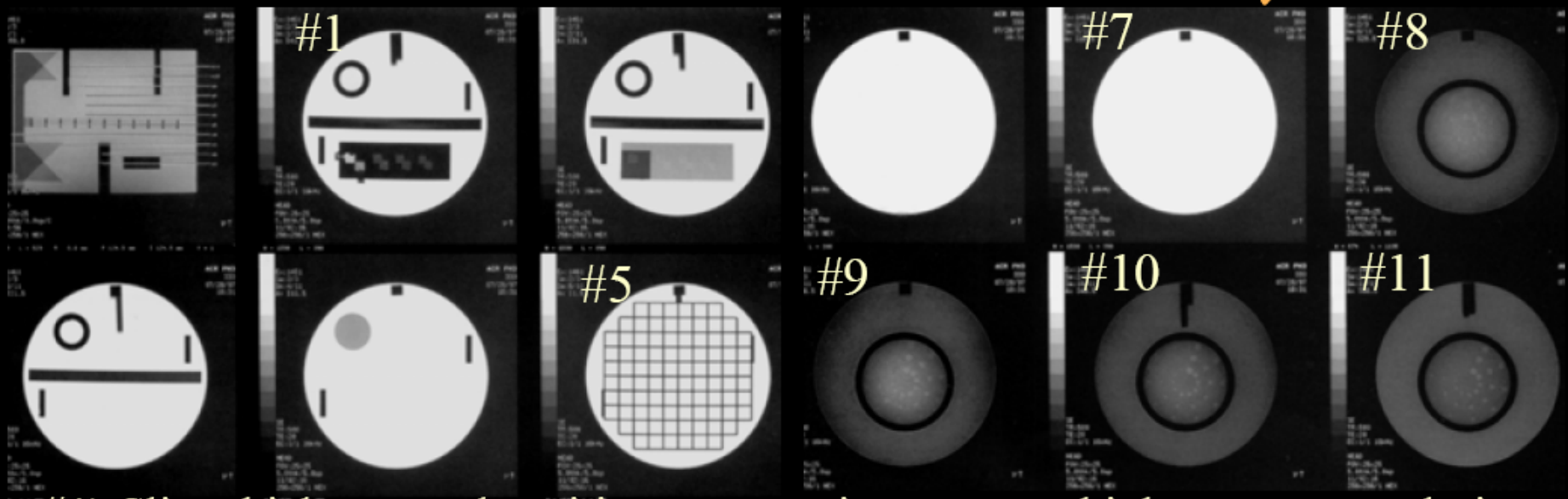
- Spin-echo sequence
- TE/TR=20/500ms
- Slice thickness / gap = 5/5 mm
- 11 slices graphically prescribed from sagittal localizer
- FOV = 25 cm
- Matrix: 256x256
- 1 average (NEX, NSA, *etc*.)
- Scan time: 2:16 min



Compliments of Ed Jackson, PH.D.

Scan #3: ACR Axial Dual Echo T2

(SE 20-80/2000 ms, 25 cm, 256X256, multi-slice (11 at 5mm), 1 NEX, Time = 8:56 min)



#1) Slice thickness and position, geometric accuracy, high contrast resolution

#5) Geometric accuracy

#7) Percent image uniformity, ghosting

#8-11) Low contrast object detectability, and slice position (in #11)

Compliments of Ed Jackson, PH.D.

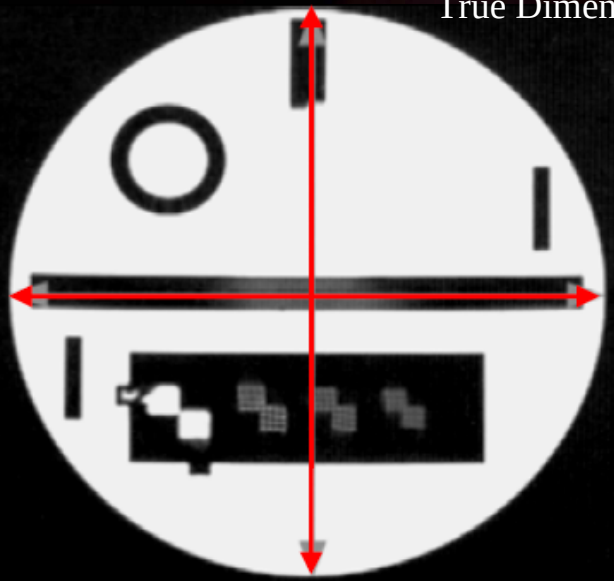
Assessment of Geometric Accuracy

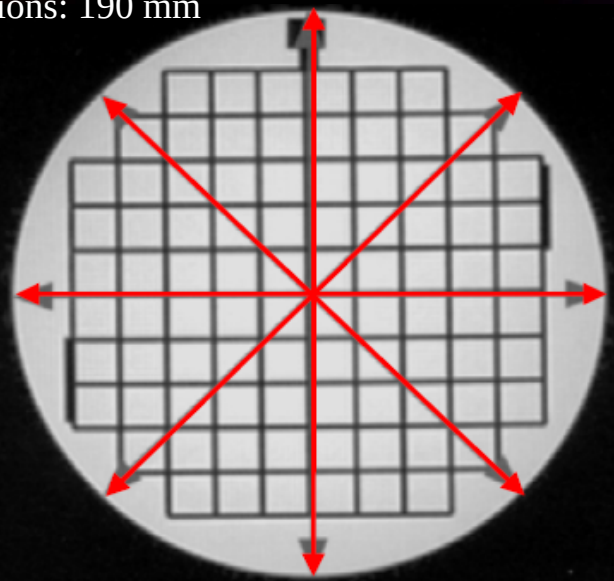
ACR T1

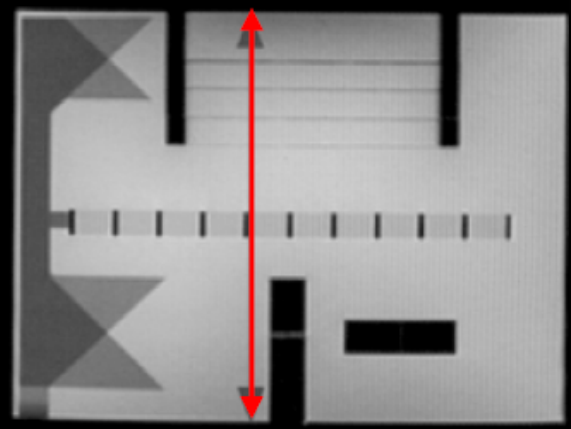
ACR T2

True Dimensions: 190 mm

True Dimension: 148 mm







Slice 1

Slice 5

Sag Loc

Set WW & WL to min, then raise WL until 1/2 water is dark (*mean*)
Set WW to *mean* and WL to 1/2(*mean*)

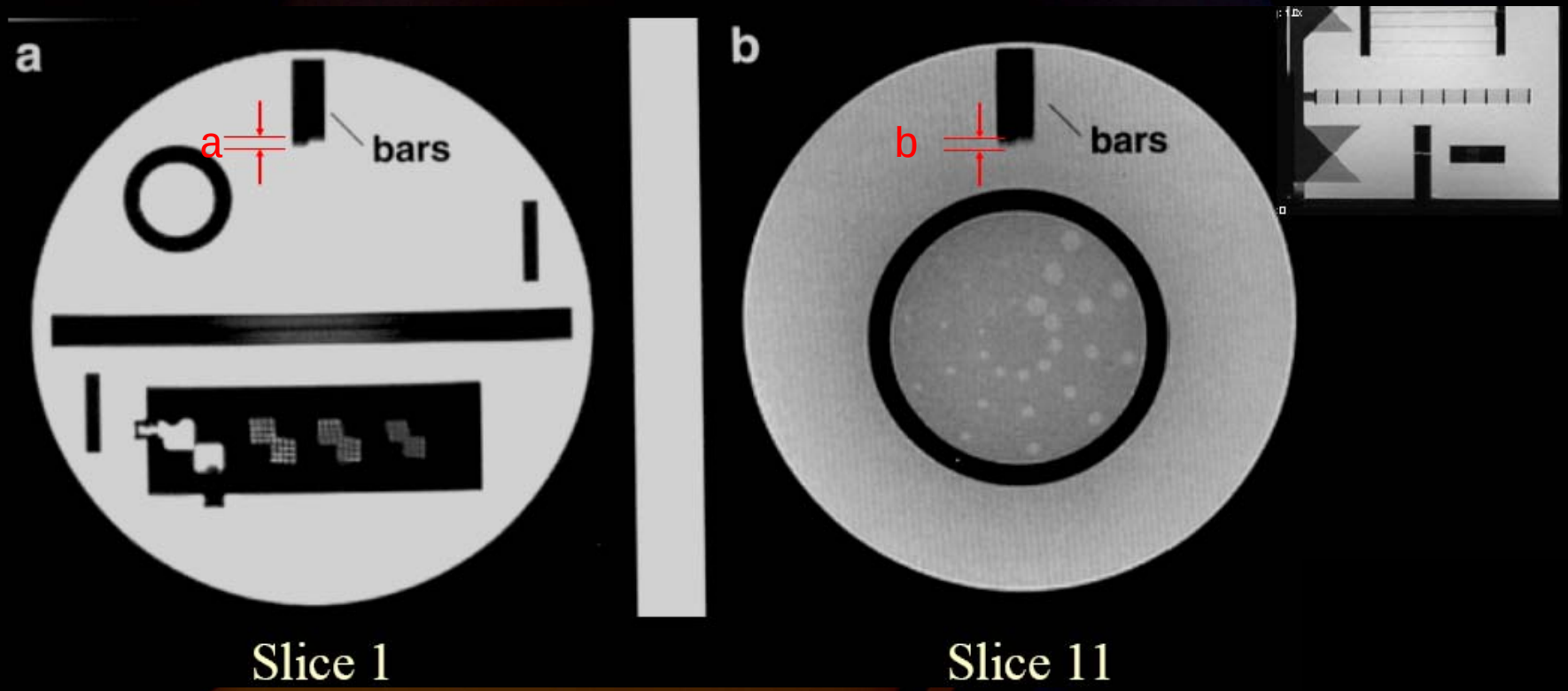
Criteria: ± 2 mm

Compliments of Ed Jackson, PH.D.

Assessment of Slice Position Accuracy

ACR T1 and T2

Use at least 2X magnification for measurements



slice position error (mm) = ½(a-b)

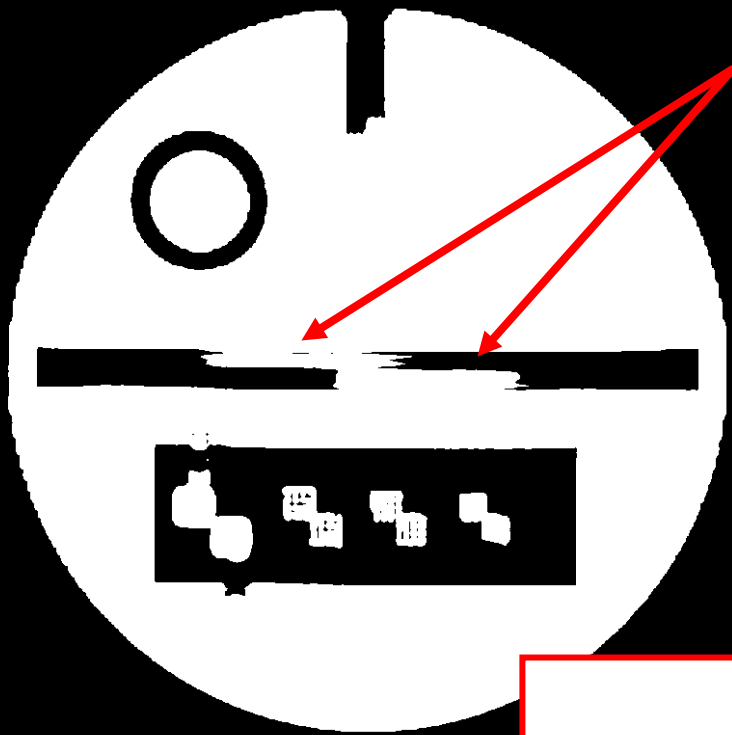
Where, a and b are signed distances:

(left longer + and right longer -)

Criteria: Position error < 5mm

Compliments of Ed Jackson, PH.D.

Assessment Slice Thickness Accuracy

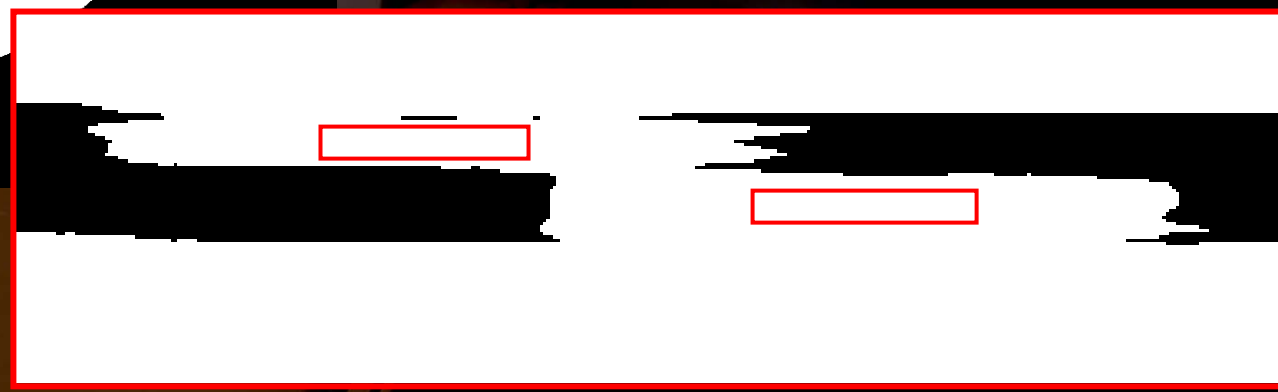


ACR T1 and T2 Sequences

Two 10:1 thin signal-producing ramps

To measure:

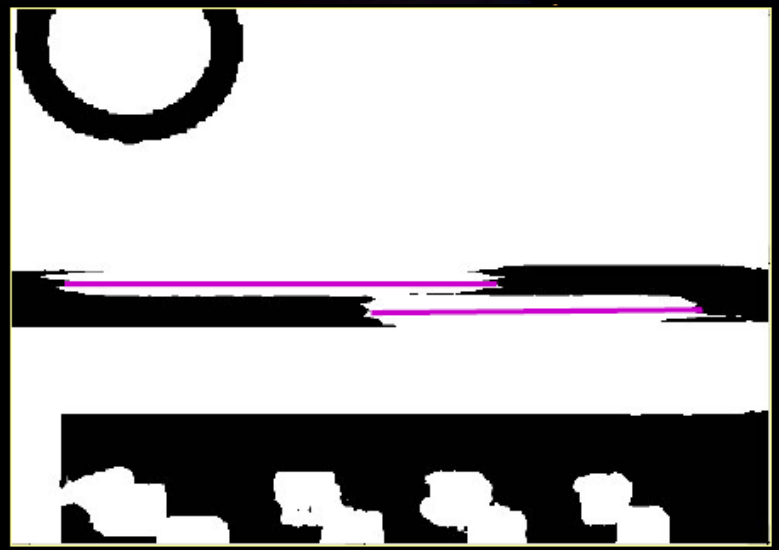
1. *Magnify image by 2-4X*
2. *Define two ROIs (typically rectangular), one on each ramp*
3. *Obtain average intensity from each*



ACR Slice Thickness Accuracy

Measurements:

- lower level to ½ *average*
- set window width to <u>minimum</u>
- measure lengths of top and bottom ramps
- calculate slice thickness



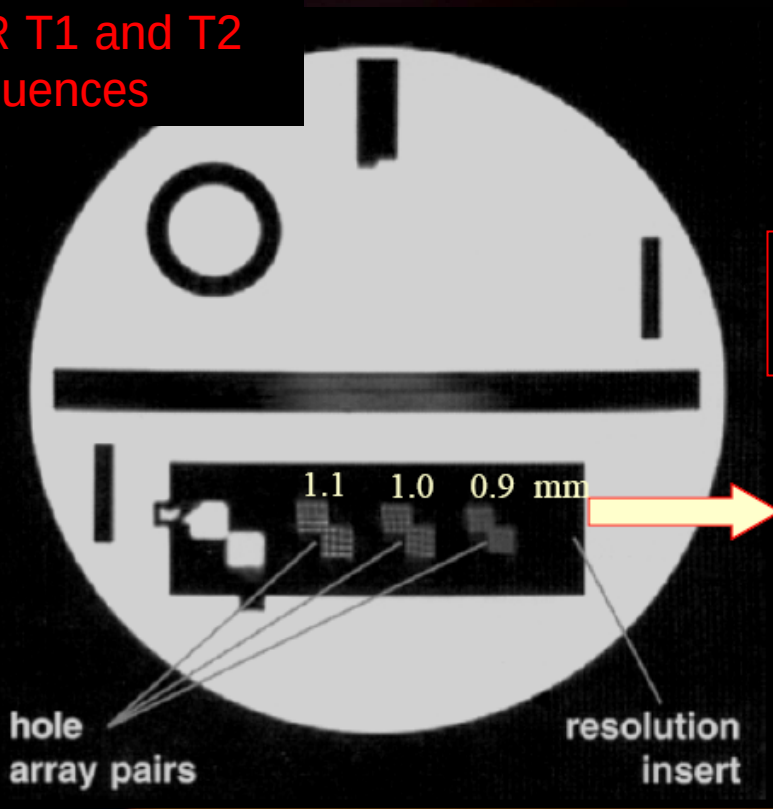
$$slice\ thickness = 0.2 \times \frac{(top \times bottom)}{(top + bottom)}$$

Criteria:
5.0 ±0.7 mm

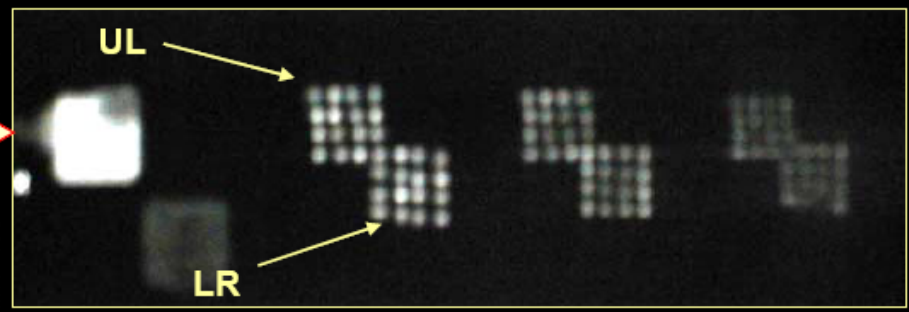
Compliments of Ed Jackson, PH.D.

Assessment of High Contrast Spatial Resolution

ACR T1 and T2 Sequences



- Magnify by 2-4x.
- Use UL for horizontal resolution and LR for vertical resolution.
- Must be able to resolve 1.0 mm holes vertically and horizontally.



Compliments of Ed Jackson, PH.D.

Spatial Resolution Matrix:

Registration with Phantom

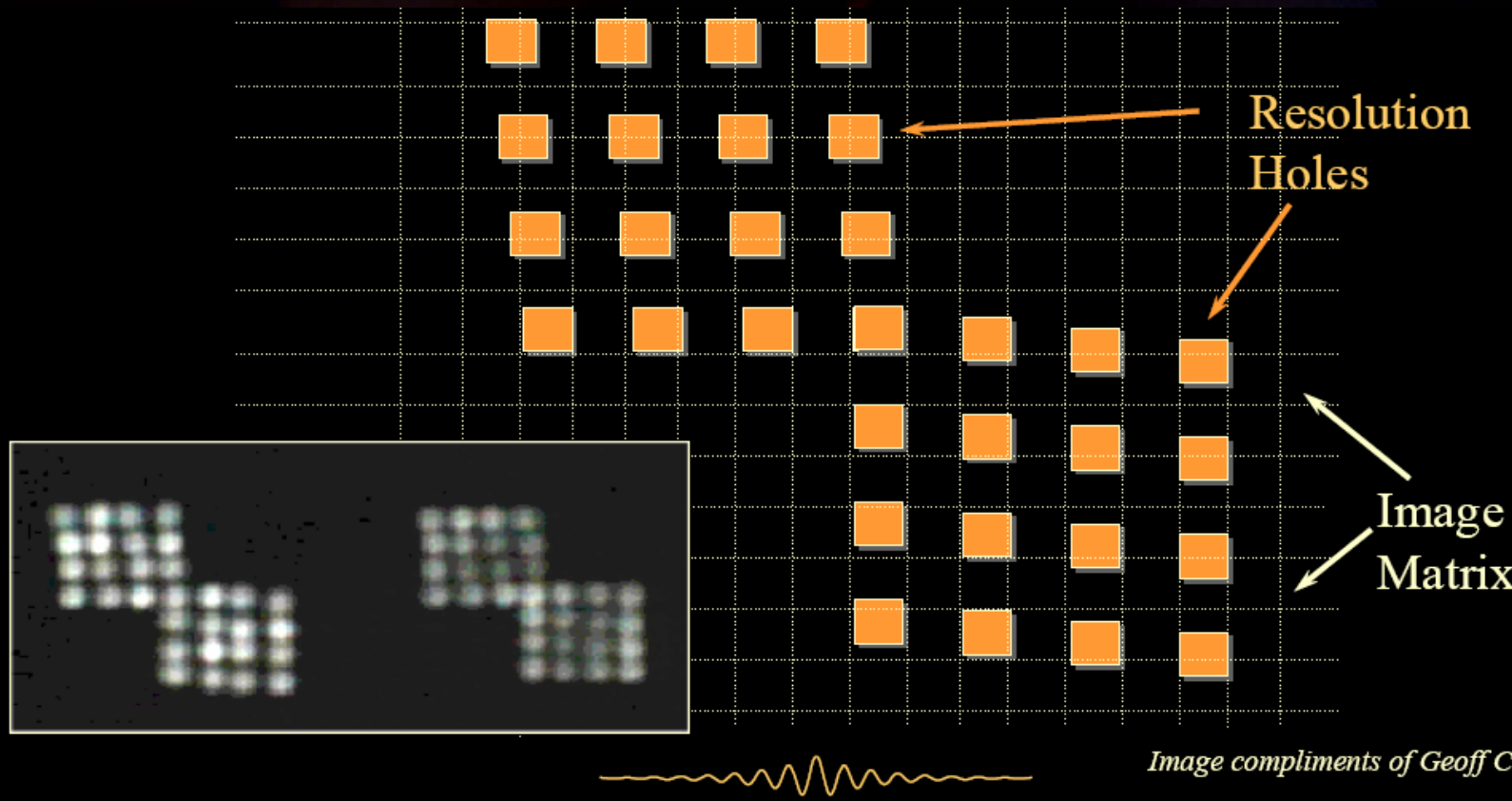


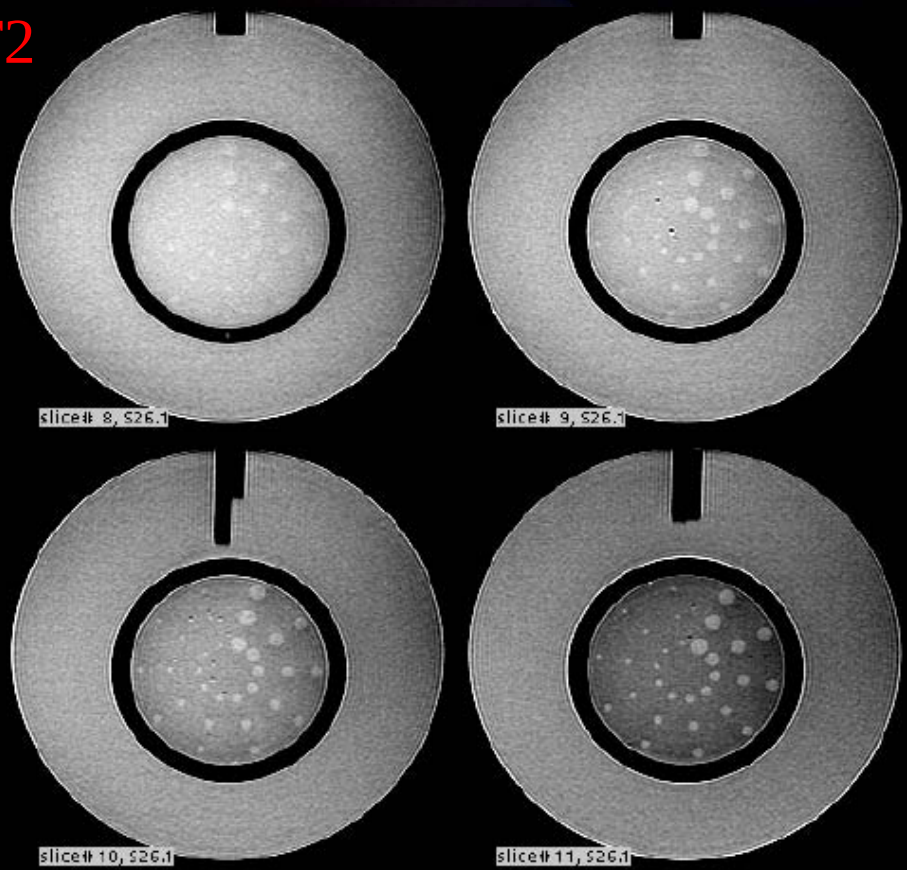
Image compliments of Geoff Clarke, PhD

Assessment of Low Contrast Detectability

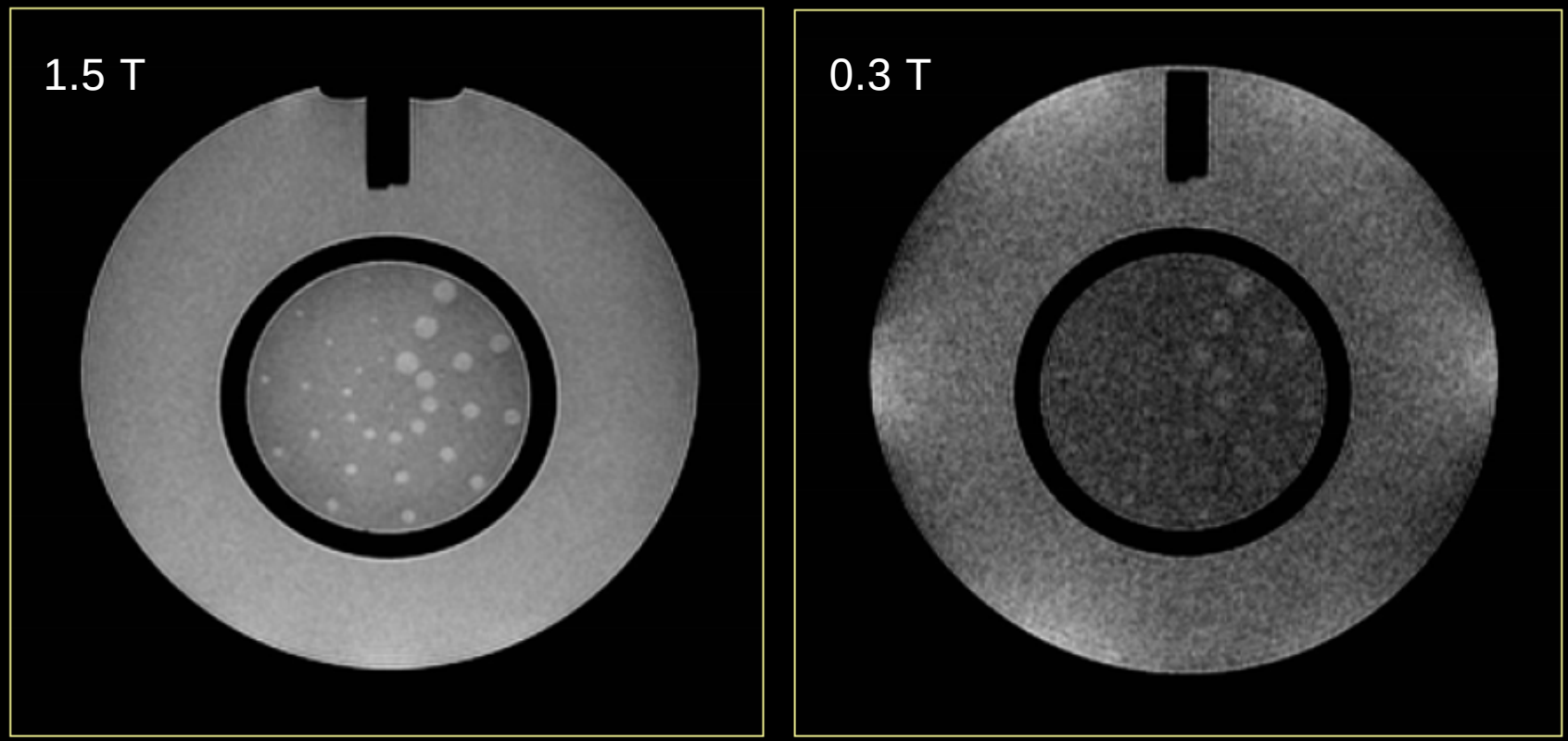
ACR T1 & T2 and Site T1 and T2
(if necessary)

Action Criteria:
Must see 9 continuous spokes

Slice 8:	1.4%
Slice 9:	2.5%
Slice 10:	3.6%
Slice 11:	5.1%



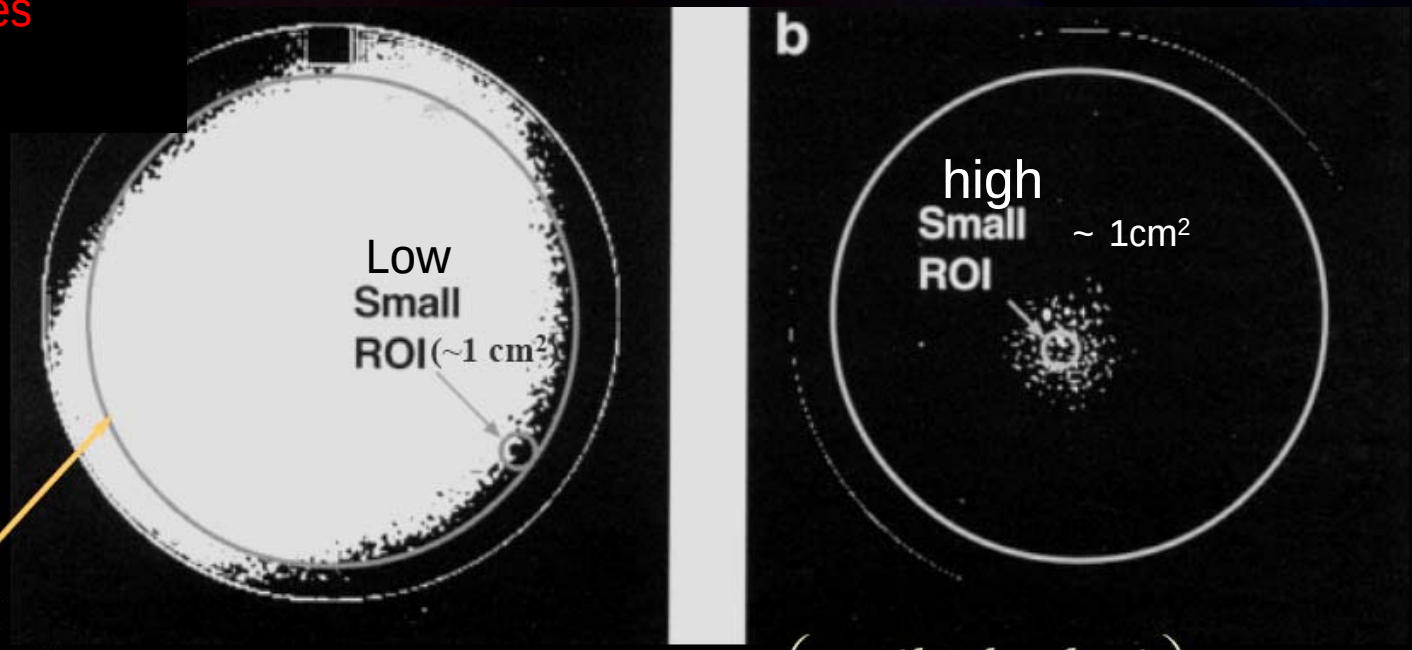
Low-Contrast Detectability Dependence on Field Strength



Assessment of Percent Image Uniformity (PIU)

ACR T1 and T2 Sequences

Slice 7



$$\text{percent integral uniformity} = 100 \times \left(1 - \frac{(high - low)}{(high + low)}\right)$$

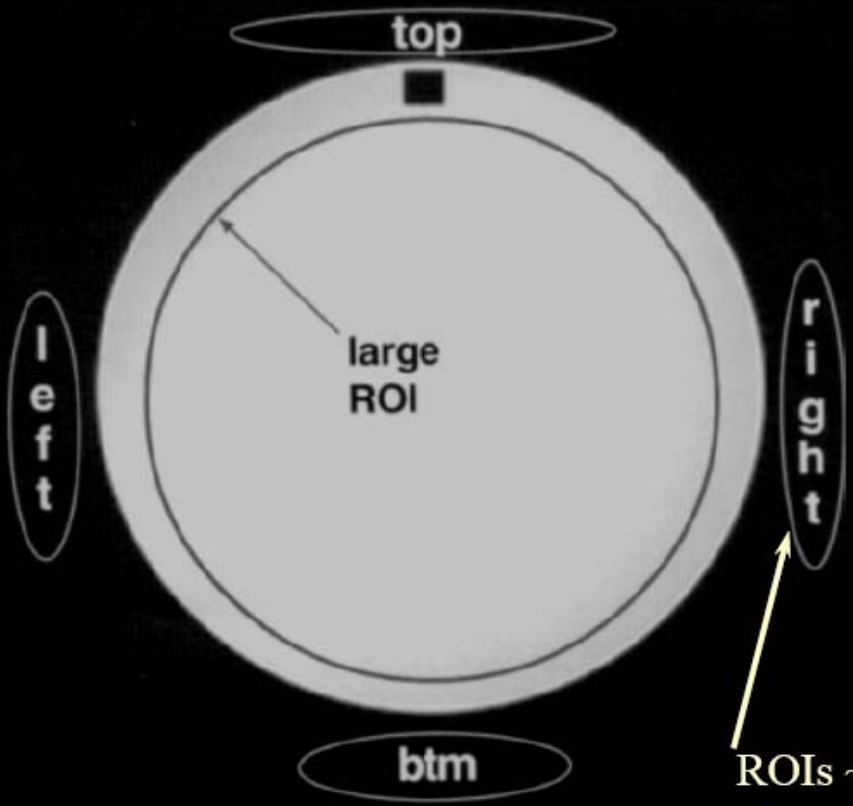
Criteria:

< 3.0T PIU > 87.5 %

3.0T PIU > 82.0 %

Note: If site uses an eight channel head coil, it is necessary to perform all phantom scans using the "surface coil intensity correction" option. It may be necessary to check with the service engineer for your particular system.

Assessment of Ghosting Level



ACR T1 Sequence

Slice 7

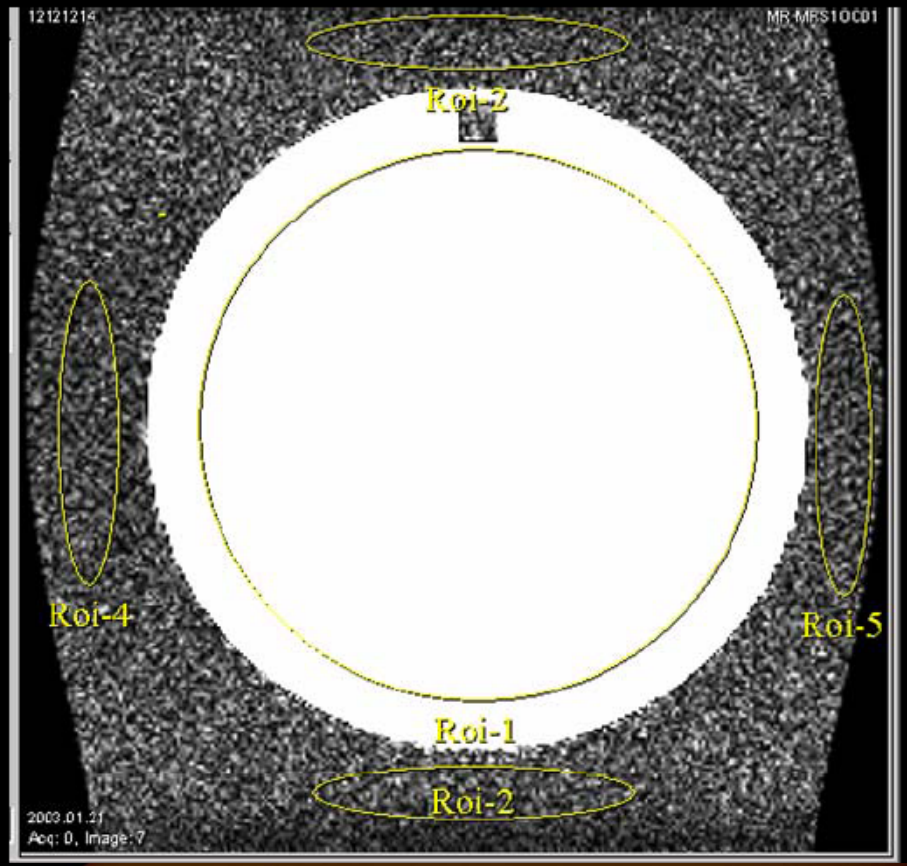
$$\text{Ghost ratio} = \frac{|(\text{top}+\text{bottom}) - (\text{left}+\text{right})|}{(2 \bullet \text{large ROI})}$$

Criteria: ≤ 0.025

ROIs ~ 10 cm^2 with ~4:1 length:width

Compliments of Geoff Clarke, Ph.D.

Ghosting



ACR T1 Sequence

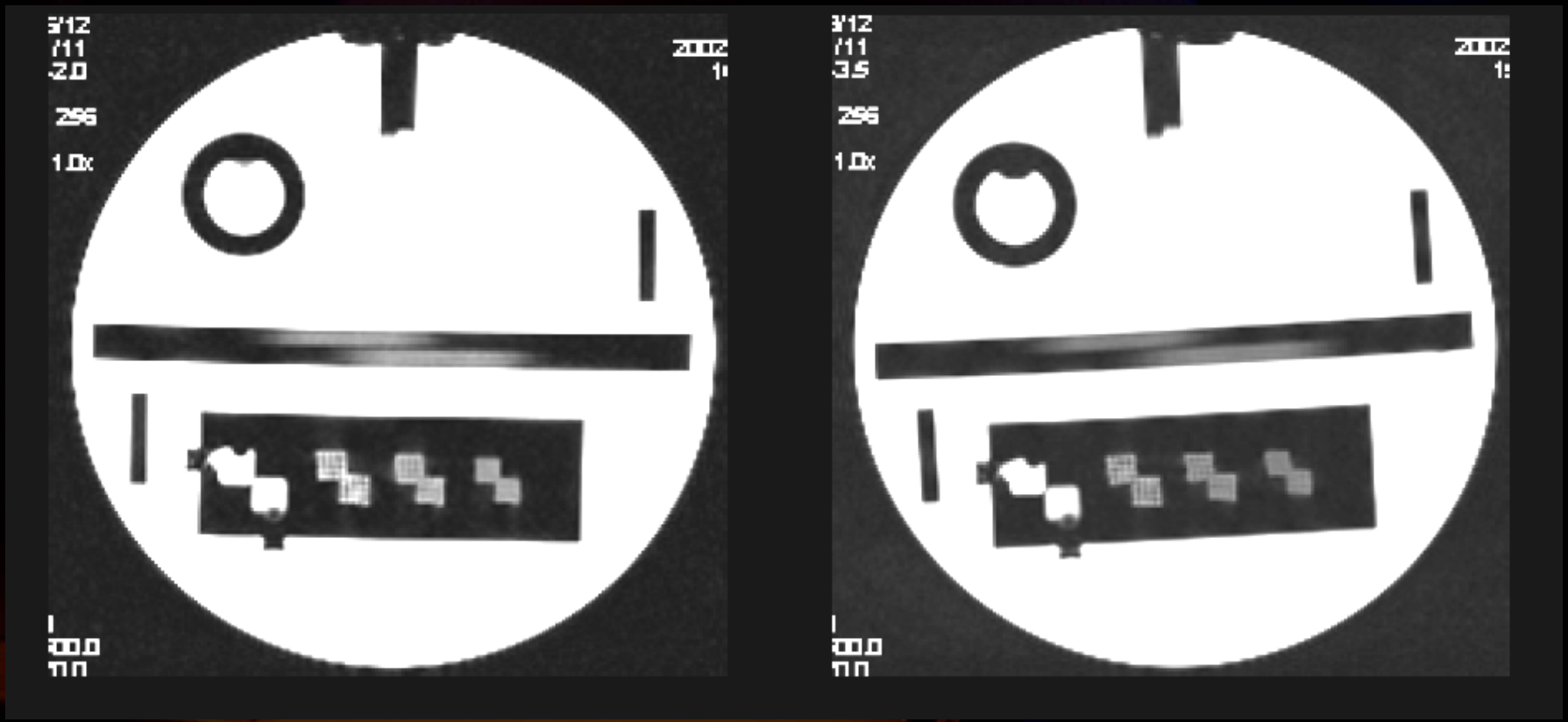
Slice 7

Window and level to make sure ROIs are in background noise! (Warping of image space due to gradient nonlinearity corrections.)

Compliments of Geoff Clarke, Ph.D.

A Common Failure Cause is Poor Phantom Positioning

In-plane Rotation

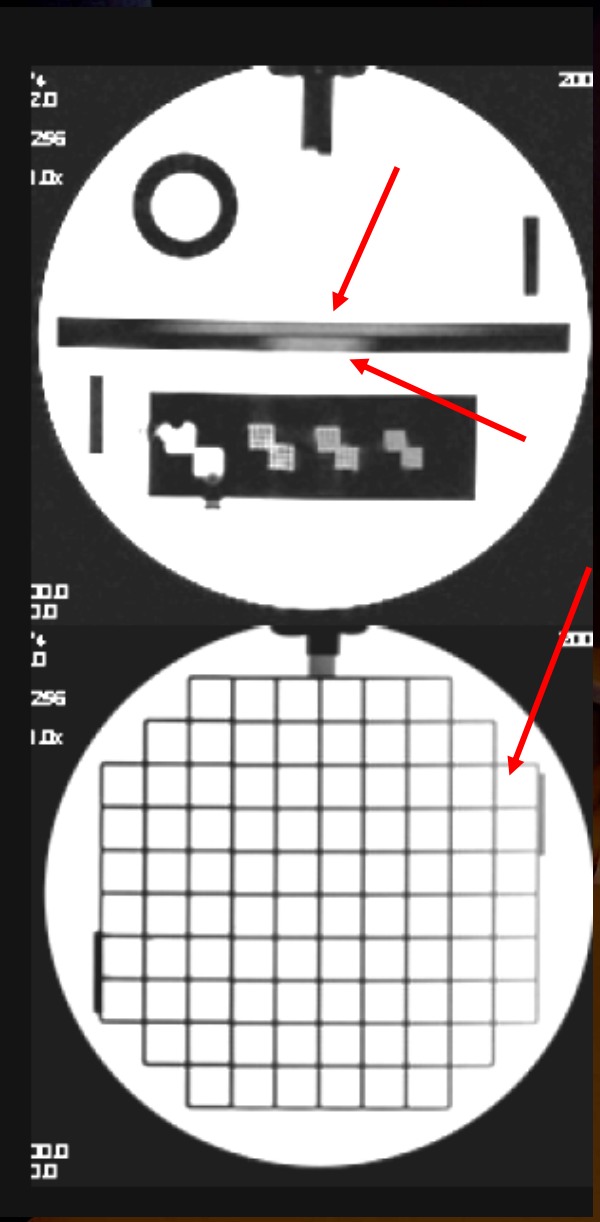


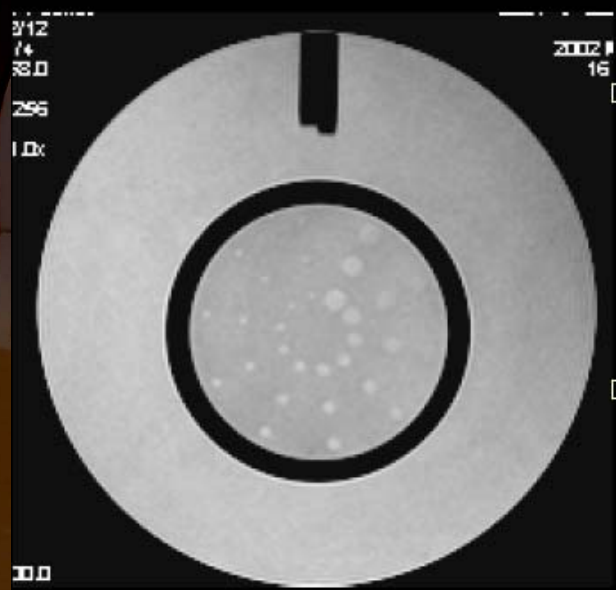
Compliments of Ed Jackson, Ph.D.

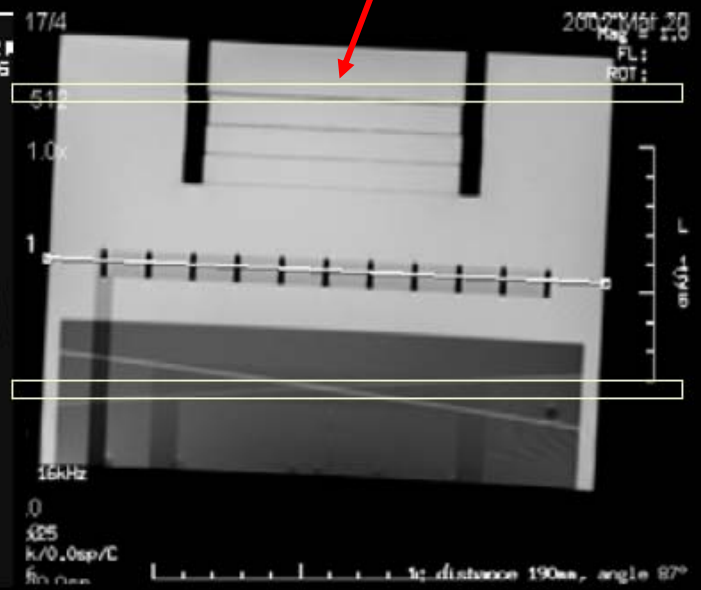
Poor Phantom Positioning

Rotation Right-to-Left

May effect slice thickness calculation, low-contrast detectability, etc





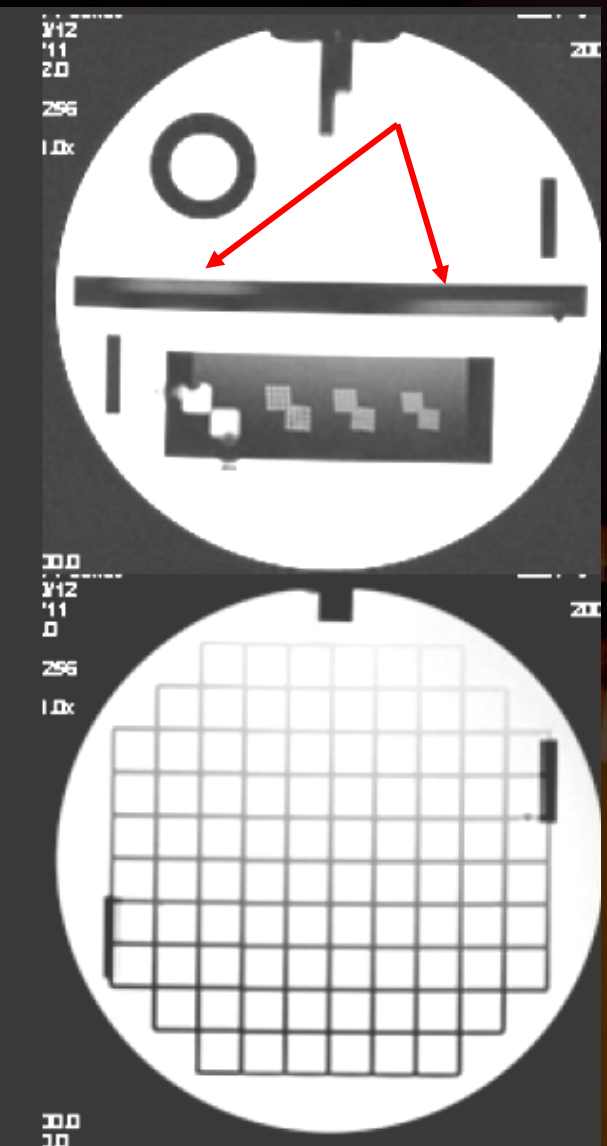


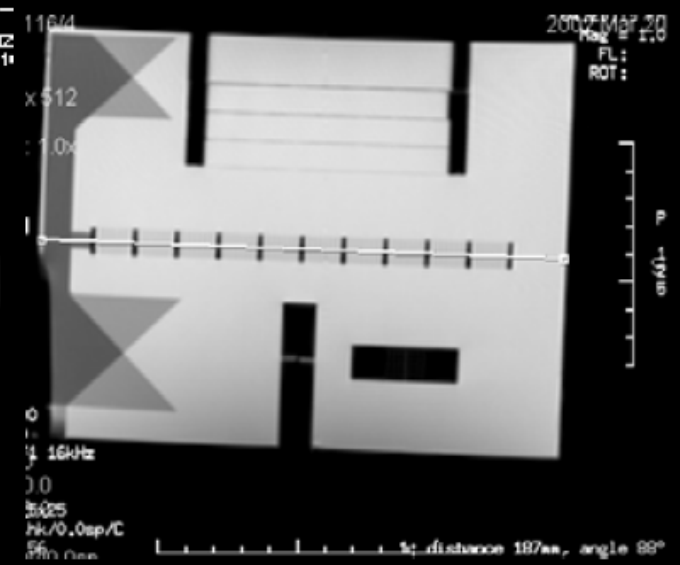
Compliments of Ed Jackson, Ph.D.

Poor Phantom Positioning

Rotation Anterior-Posterior

May effect slice thickness, low-contrast detectability and other measurements.





Compliments of Ed Jackson, Ph.D.

Submitting the Clinical Images for whole body accreditation

- *Routine brain examination (for headache)*
- *Routine cervical spine examination (for radiculopathy)*
- *Routine lumbar spine examination (for back pain)*
- *Complete routine knee examination (for internal derangement)*

Each set of clinical images will be evaluated for:

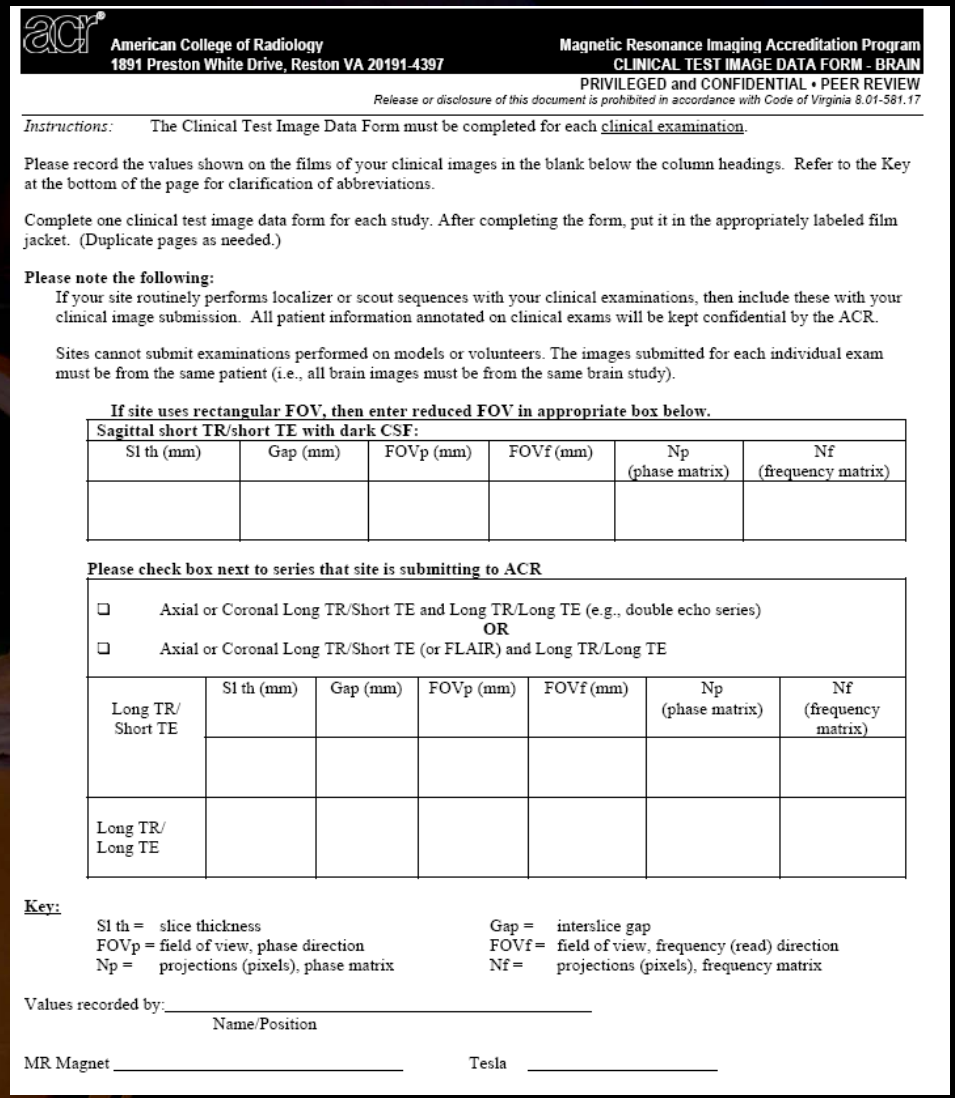
- *Pulse sequences and image contrast*
- *Filming technique*
- *Anatomic coverage and imaging planes*
- *Spatial resolution*
- *Artifacts*
- *Exam ID (All patient information on clinical exams will be kept confidential by the ACR)*

Within +/- 1 week of phantom images

Clinical Images: Whole body accreditation

Routine brain examination (for headache)

- *Sagittal short TR/short TE with dark CSF*
- *Axial or coronal long TR/short TE (or FLAIR)*
- *Long TR/long TE (e.g., long TR double echo)*



American College of Radiology
1891 Preston White Drive, Reston VA 20191-4397

Magnetic Resonance Imaging Accreditation Program
CLINICAL TEST IMAGE DATA FORM - BRAIN
PRIVILEGED and CONFIDENTIAL • PEER REVIEW
Release or disclosure of this document is prohibited in accordance with Code of Virginia 8.01-581.17

Instructions: The Clinical Test Image Data Form must be completed for each clinical examination.

Please record the values shown on the films of your clinical images in the blank below the column headings. Refer to the Key at the bottom of the page for clarification of abbreviations.

Complete one clinical test image data form for each study. After completing the form, put it in the appropriately labeled film jacket. (Duplicate pages as needed.)

Please note the following:

If your site routinely performs localizer or scout sequences with your clinical examinations, then include these with your clinical image submission. All patient information annotated on clinical exams will be kept confidential by the ACR.

Sites cannot submit examinations performed on models or volunteers. The images submitted for each individual exam must be from the same patient (i.e., all brain images must be from the same brain study).

If site uses rectangular FOV, then enter reduced FOV in appropriate box below.

Sagittal short TR/short TE with dark CSF:

Sl th (mm)	Gap (mm)	FOVp (mm)	FOVf (mm)	Np (phase matrix)	Nf (frequency matrix)

Please check box next to series that site is submitting to ACR

❑ Axial or Coronal Long TR/Short TE and Long TR/Long TE (e.g., double echo series)

OR

❑ Axial or Coronal Long TR/Short TE (or FLAIR) and Long TR/Long TE

	Sl th (mm)	Gap (mm)	FOVp (mm)	FOVf (mm)	Np (phase matrix)	Nf (frequency matrix)
Long TR/ Short TE						
Long TR/ Long TE						

Key:

Sl th = slice thickness
Gap = interslice gap
FOVp = field of view, phase direction
FOVf = field of view, frequency (read) direction
Np = projections (pixels), phase matrix
Nf = projections (pixels), frequency matrix

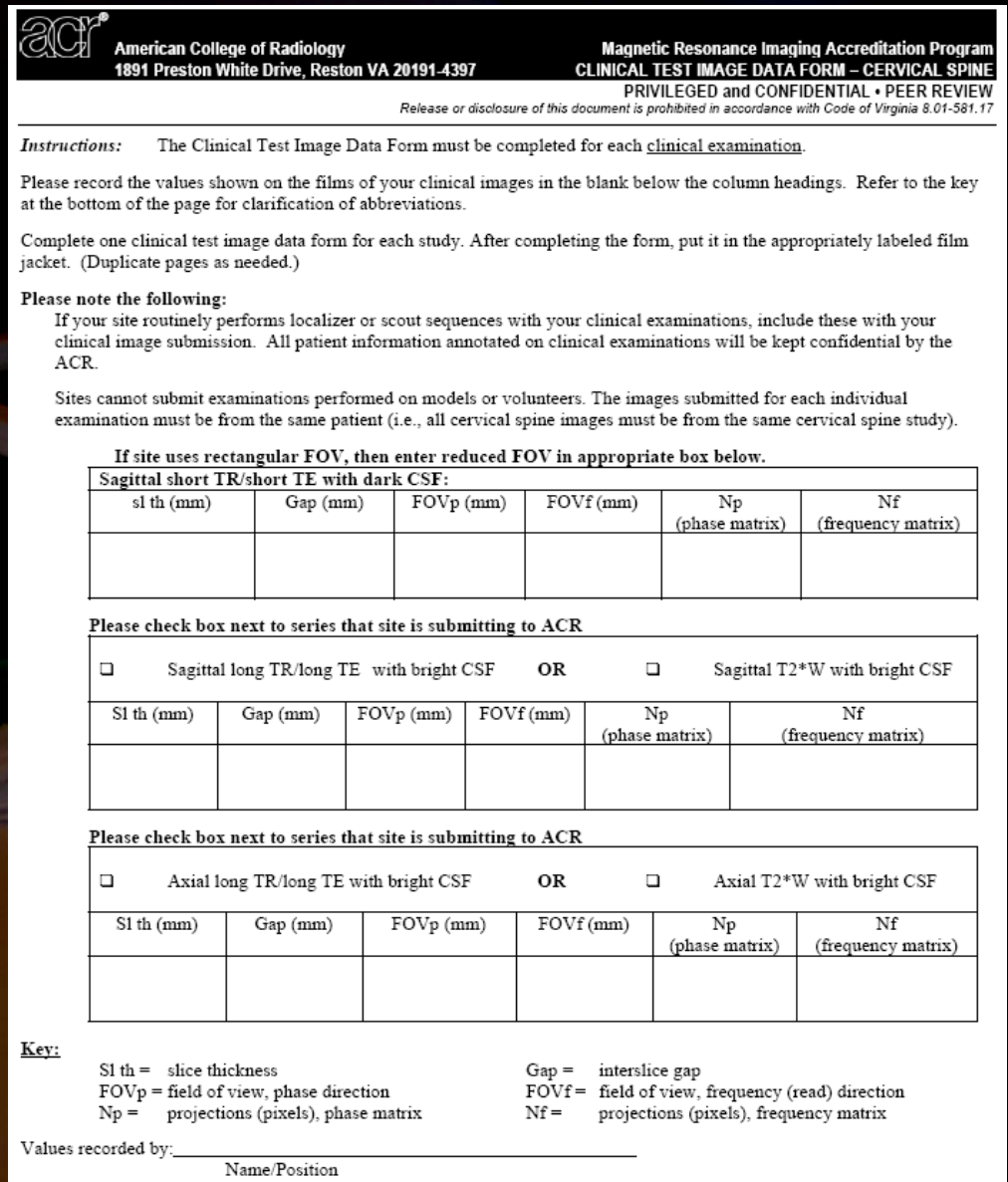
Values recorded by: _____
Name/Position

MR Magnet _____ Tesla _____

Clinical Images: Whole body accreditation

Routine cervical spine (for radiculopathy)

- Sagittal short TR/short TE or T2*W with dark CSF
- Sagittal long TR/long TE or T2*W with bright CSF
- Axial long TR/long TE or T2*W with bright CSF



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Magnetic Resonance Imaging Accreditation Program
CLINICAL TEST IMAGE DATA FORM – CERVICAL SPINE

PRIVILEGED and CONFIDENTIAL • PEER REVIEW

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Instructions: The Clinical Test Image Data Form must be completed for each clinical examination.

Please record the values shown on the films of your clinical images in the blank below the column headings. Refer to the key at the bottom of the page for clarification of abbreviations.

Complete one clinical test image data form for each study. After completing the form, put it in the appropriately labeled film jacket. (Duplicate pages as needed.)

Please note the following:

If your site routinely performs localizer or scout sequences with your clinical examinations, include these with your clinical image submission. All patient information annotated on clinical examinations will be kept confidential by the ACR.

Sites cannot submit examinations performed on models or volunteers. The images submitted for each individual examination must be from the same patient (i.e., all cervical spine images must be from the same cervical spine study).

If site uses rectangular FOV, then enter reduced FOV in appropriate box below.

Sagittal short TR/short TE with dark CSF:

sl th (mm)	Gap (mm)	FOVp (mm)	FOVf (mm)	Np (phase matrix)	Nf (frequency matrix)

Please check box next to series that site is submitting to ACR

❑ Sagittal long TR/long TE with bright CSF **OR** ❑ Sagittal T2*W with bright CSF

Sl th (mm)	Gap (mm)	FOVp (mm)	FOVf (mm)	Np (phase matrix)	Nf (frequency matrix)

Please check box next to series that site is submitting to ACR

❑ Axial long TR/long TE with bright CSF **OR** ❑ Axial T2*W with bright CSF

Sl th (mm)	Gap (mm)	FOVp (mm)	FOVf (mm)	Np (phase matrix)	Nf (frequency matrix)

Key:

Sl th = slice thickness
Gap = interslice gap
FOVp = field of view, phase direction
FOVf = field of view, frequency (read) direction
Np = projections (pixels), phase matrix
Nf = projections (pixels), frequency matrix

Values recorded by:_____
Name/Position

Clinical Images: Whole Body Accreditation

Routine lumbar spine (for back pain)

1. *Sagittal short TR/short TE with dark CSF*
2. *Sagittal long TR/long TE or T2*W with bright CSF*
3. *Axial short TR/short TE with dark CSF and/or long TR/long TE with bright CSF*

Complete routine knee examination (for internal derangement)

1. *Must include sagittal(s) **and** coronal(s) with at least one sequence with bright fluid*

Clinical Images: Submission Options

1. *All images (clinical and phantom) must be submitted within 4 months of receiving the full application. (The specific due date is on the labels sent by the ACR.)*
2. *Film Option: Each of the 4 clinical image types are labeled and placed in separate film jackets with the accompanying completed parameter data form.*
3. *Electronic Option: Submit two (2) CD-ROMs that are identical. Each CD-ROM must include copies of the same four clinical examinations. Each CD-ROM must include an embedded viewer. The viewer must meet minimum requirements that are specified in the instructions.*

Clinical Images Guidelines

Sequence	Slice thickness	Gap	Maximum Pixel Dimensions
Brain – Sagittal & Axial and/or Coronal	≤ 5 mm	≤ 2 mm	≤ 1.2 mm
Cervical Spine – Sagittal	≤ 3 mm	≤ 1 mm	≤ 1 mm
Cervical Spine – Axial	≤ 3 mm	≤ 1 mm	≤ 1 mm
Lumbar Spine – Sagittal	≤ 5 mm	≤ 1.5 mm	≤ 1.5 mm
Lumbar Spine – Axial	≤ 4 mm	≤ 1 mm	≤ 1.5 mm
Knee – Sagittal & Coronal	≤ 4 mm	≤ 1 mm	≤ .75 mm

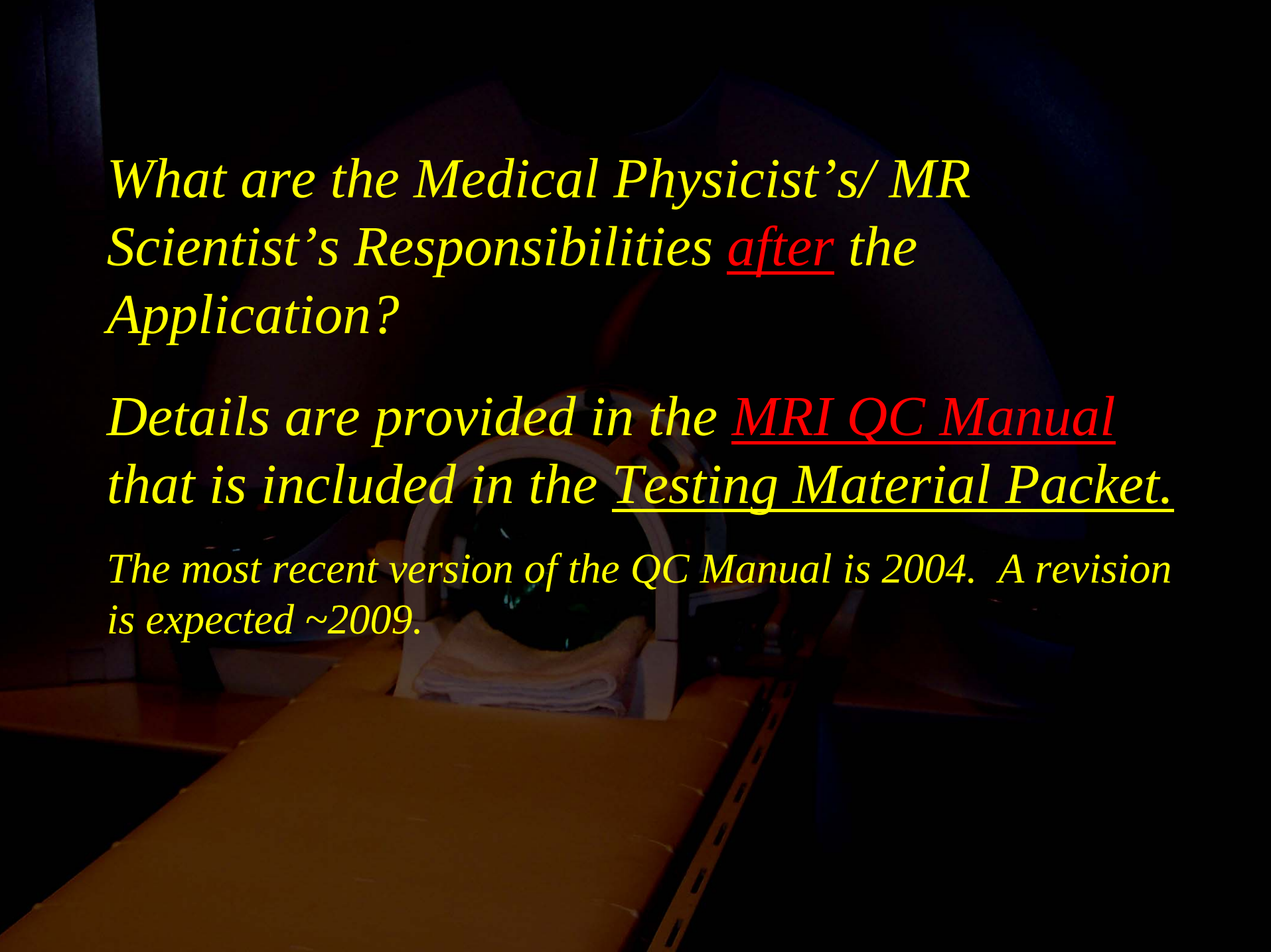
Accreditation Program Statistics

As of January 2, 2008:

- *4770 currently active facilities (accredited, applying or renewing)*
- *5804 units currently active*
- *3949 facilities currently accredited*
- *4721 units currently accredited*

Pass Rate	*FY 2002*	*(FY 1997)*
• *Initial*	*69%*	*(44%)*
• *2nd attempt*	*93%*	*(76%)*
• *3rd attempt*	*99%*	*(72%)*

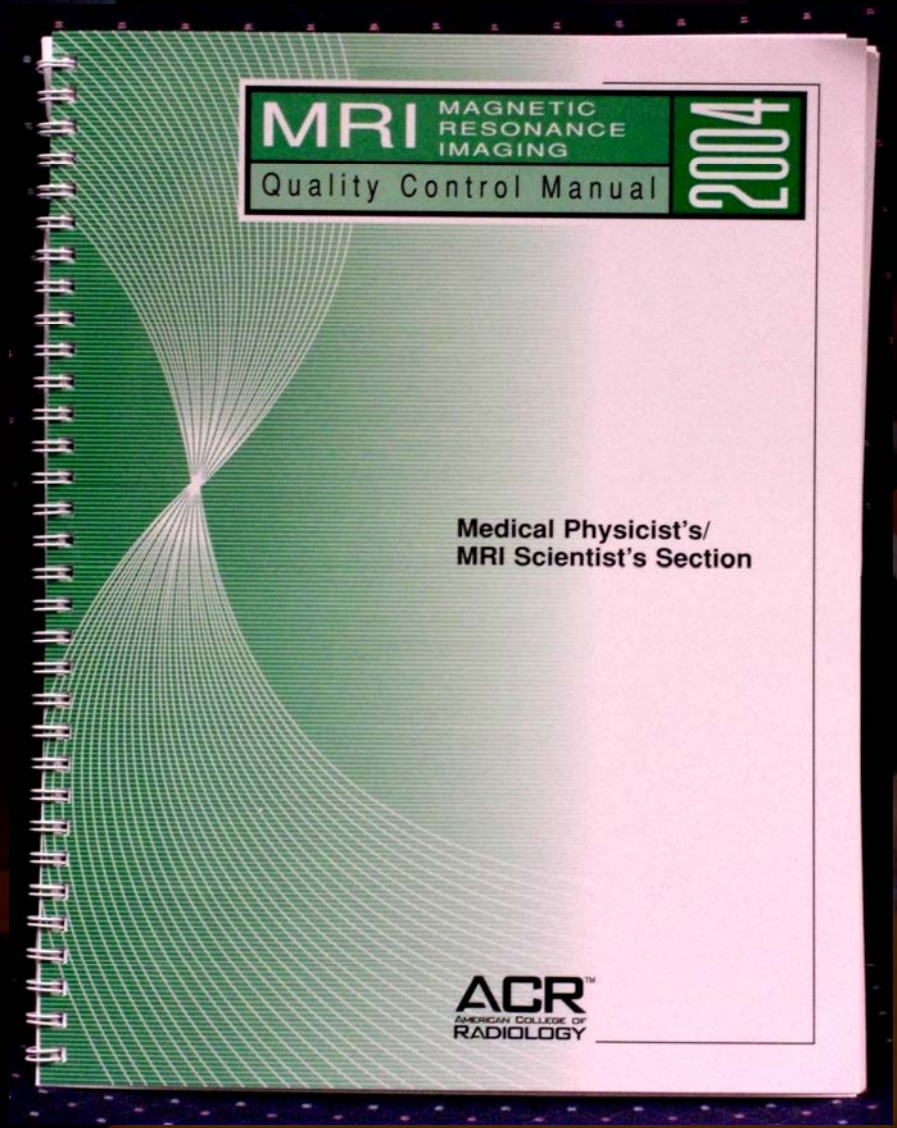
Note: Confidential reports with suggestions for correcting deficiencies are sent by the ACR between initial and 2nd attempts.



What are the Medical Physicist's/ MR Scientist's Responsibilities after the Application?

Details are provided in the MRI QC Manual that is included in the Testing Material Packet.

The most recent version of the QC Manual is 2004. A revision is expected ~2009.



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Establishing Action Limits for Technologist's QC program

Specific action limits are the responsibility of the medical physicist but must be at least as restrictive as the ACR recommended guidelines.

How to start?

1. *Service engineer should run all vendor tests to assure system is performing to vendor specifications*
2. *Collect "weekly" QC data for at least 10 days*
   - *Central frequency*
   - *Transmitter gain / attenuation*
   - *Geometric accuracy*
   - *High contrast resolution*
   - *Low contrast resolution*
3. *Record as "Baseline" in Technologist's QC notebook*

Establishing Action Limits

General approach: Determine mean and standard deviation (SD). May need to use ± 2SD depending upon the system.

1. *Central frequency expressed in ppm (typically ± 1.5 ppm)*

   (1.5 ppm @ 1.5T ~ 96 Hz or determined from statistical analysis)

2. *Transmitter Gain or Attenuation (expressed in dB)*

3. *Geometric Accuracy (± 2 mm)*

4. *High-Contrast Resolution (at least 1mm)*

5. *Low-Contrast Detectability (± 1 spoke)*

6. *Artifacts (any artifacts should be noted and image saved)*

Baseline and Action Limits for Laser Camera

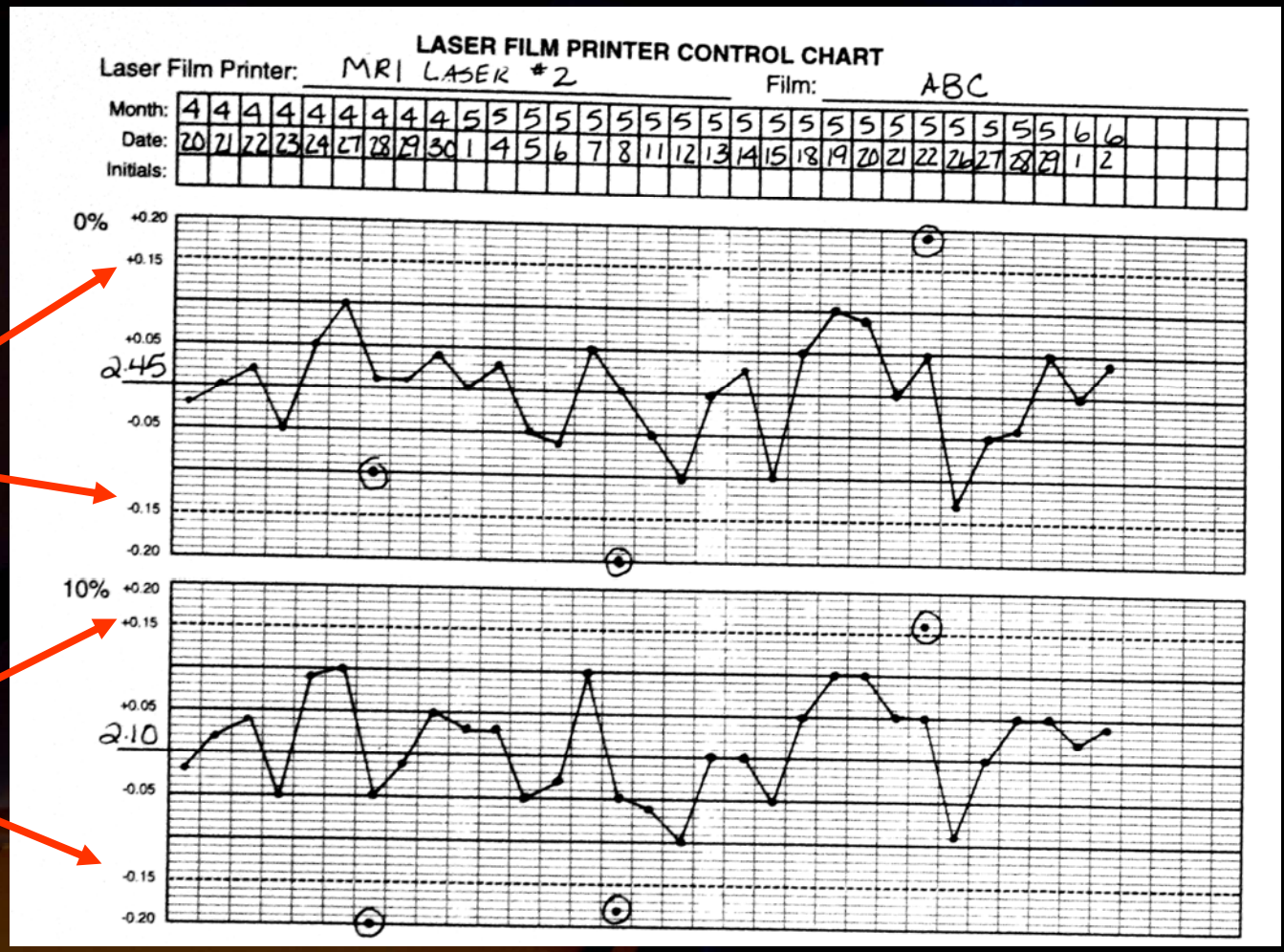
- *Laser camera QC*
  - *Establish operating levels (in consultation with service engineer)*
- *Acquire baseline data (SMPTE test pattern) and set control limits*
- *Document and review corrective actions*
  - *Problem isolation consultation (camera, processor and/or MR system)*

Recommended Optical Densities and Action Limits

SMTE Patch	*Optical Density*	*Control Limits*
0	*2.45*	*± 0.15*
10%	*2.10*	*± 0.15*
40%	*1.15*	*± 0.15*
90%	*0.30*	*± 0.08*

Established Action Limits

Corrective Actions



MRI Laser Film Printer Control Chart Example

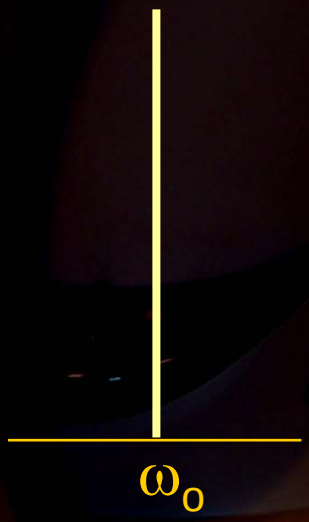
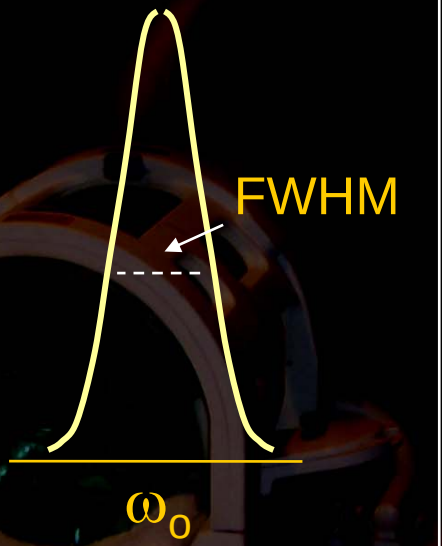
Annual Physics Equipment Performance Tests

Typically performed using ACR phantom and other (vendor) phantoms.

- *Magnetic field homogeneity*
- *Slice position accuracy*
- *Slice thickness accuracy*
- *RF coil performance*
  - *Signal-to-noise ratio (all coils)*
  - *Volume Coil image uniformity*
- *Interslice RF interference**
- *Phase stability (ghosting)*
- *Soft copy display integrity (monitors)*
- *Should also confirm that a safety program is in place*

** Requirement likely to be removed in next revision of QC manual*

Magnetic Field Homogeneity

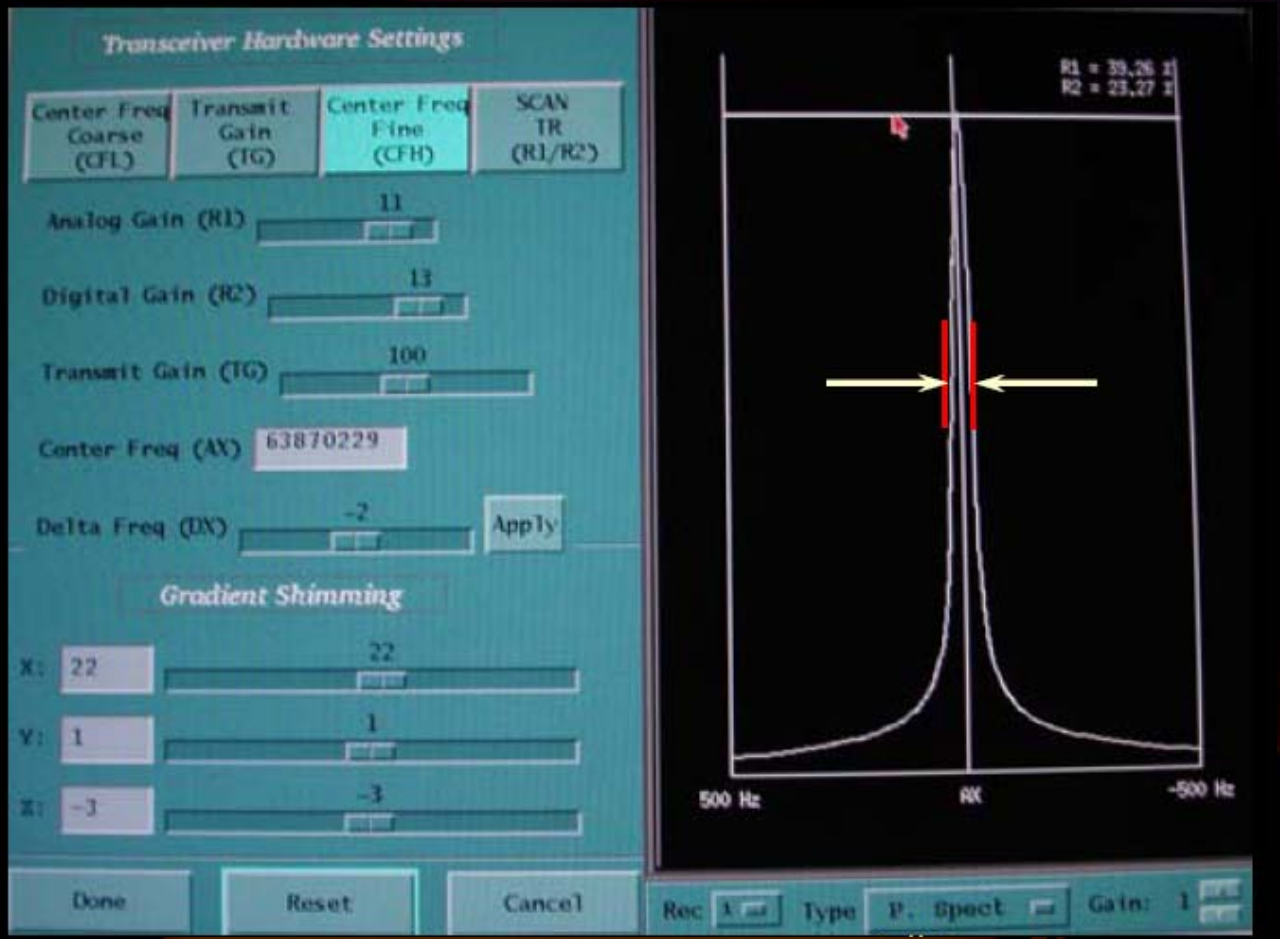
Ideal Homogeneity	*Good Homogeneity*	*Poor Homogeneity*
 *Denotes a totally uniform magnetic field. All signal is at resonant frequency, ωo.*	 *Fourier transform of signal produces a Lorentzian peak in well-shimmed magnet*	*Magnet field homogeneity can be characterized using FWHM of resonance peak*

Magnetic Field Homogeneity

"Head Equivalent" spheres provided by some vendors can be used for the homogeneity test. Sphere should be placed at the field isocenter.

If the sphere is provided with a "loading" cylinder it should be removed for the test.

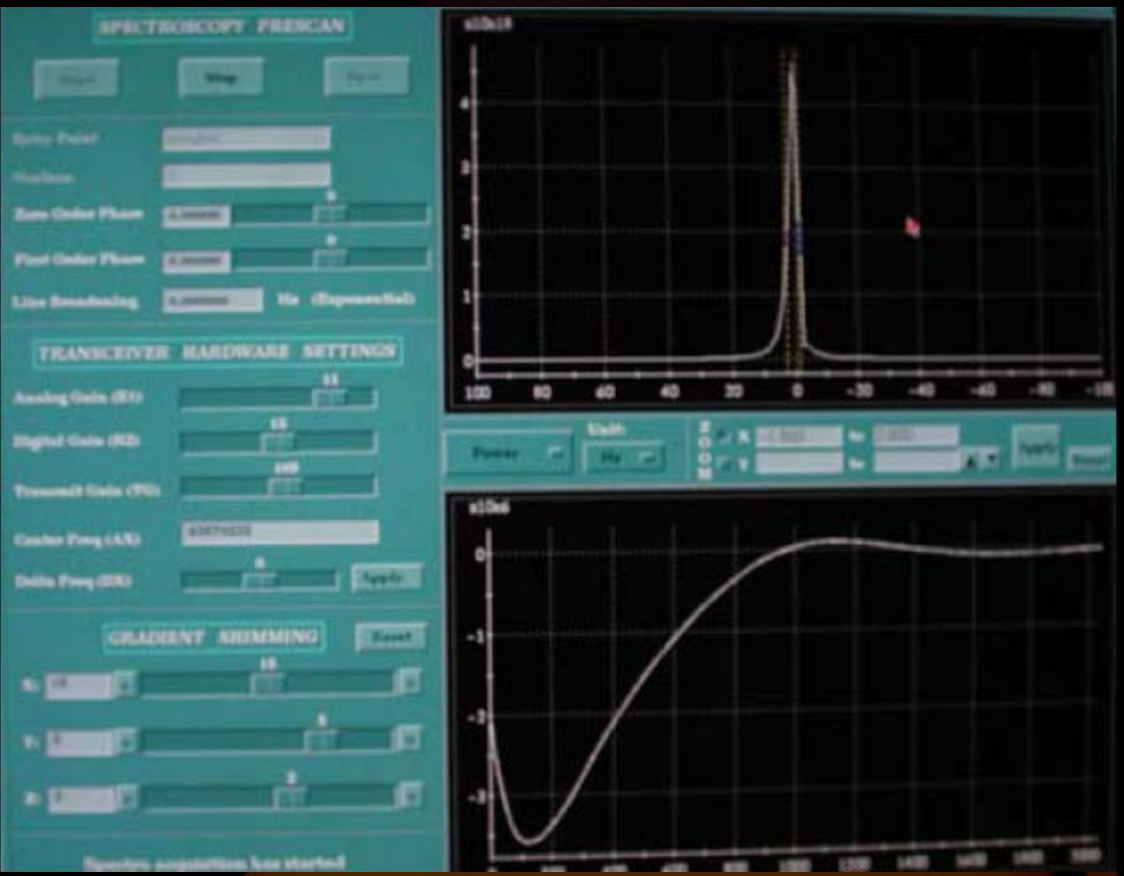
Magnetic Field Homogeneity



With the sphere in the head coil, use manual prescan.

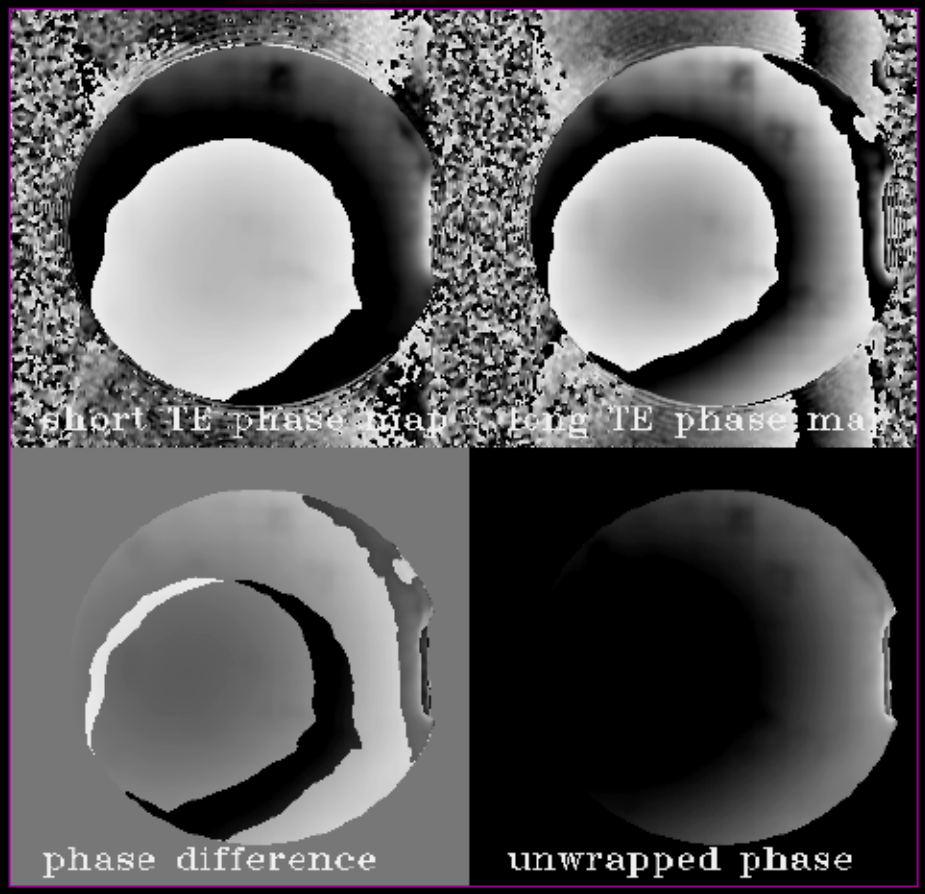
Adjust center frequency twice to determine the "full width at half maximum" of the spectrum

Magnetic Field Homogeneity



If scanner has spectroscopy capabilities, the spectroscopy prescan page can be used to measure "frequency spread"

Magnetic Field Homogeneity

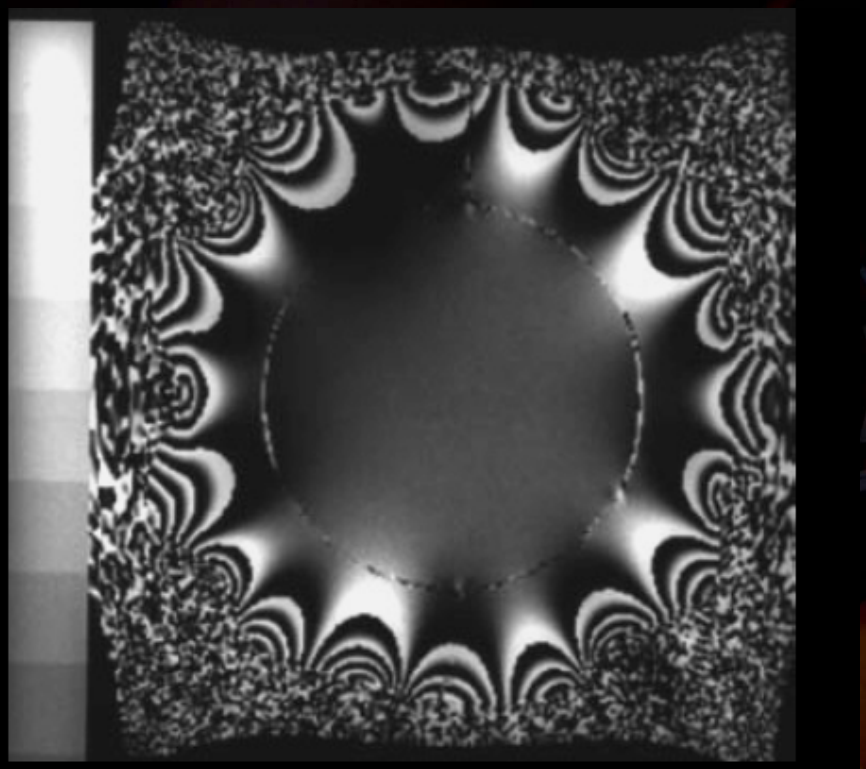


Phase (angle) images from GRE sequences with 10 ms difference in TE's

Original phaseimage and phase "unwrapped" immage.

The change in phase across the phantom is proportional to the inhomogeneity of the magnetic field

Magnetic Field Homogeneity



Field of View = 50 cm

Sampling Diameter = 22 cm

Inhomogeneity

3.19 Hz (0.050 ppm)

(1.5T = 64 MHz)

ppm = frequency spread (Hz)/ resonant frequency (MHz)

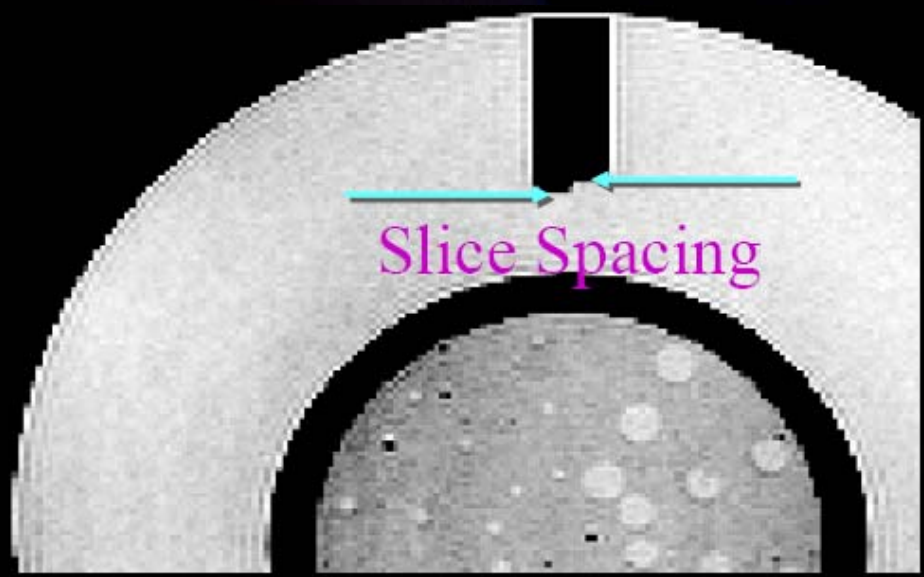
Compliment of Ed Jackson, Ph.D.

Magnetic Field Homogeneity

- *Either the FWHM technique (on a given spherical phantom) or the phase difference technique can be used to assess homogeneity.*
- *Alternative: On some systems it may not be possible to obtain phase angle images. For these systems you may have to use the service engineer's report on homogeneity for your site equipment records.*

Slice Position Accuracy

SLICE #1



SLICE #11

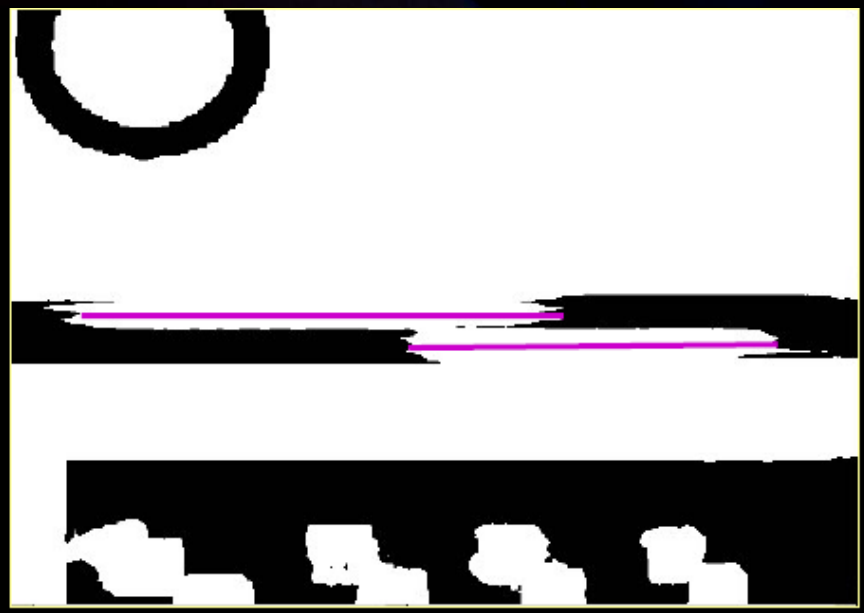
Crossed wedges should be of equal length if the slice position and spacing are accurate (if the phantom is not tilted)

This is a measure of the gradient calibration accuracy.

Slice Thickness Accuracy

Measurements:

- lower level to ½ average
- set window at <u>minimum</u>
- measure lengths of top and bottom ramps
- calculate slice thickness



$$slice\ thickness = 0.2 \times \frac{(top \times bottom)}{(top + bottom)}$$

Medical Physicist's Annual Equipment Performance Report

Recommended Equipment Performance forms are provided in the ACR QC Manual for use by the medical physicist.

Site & Equipment Data

B_o Homogeneity

Slice Position Accuracy

Slice Thickness Accuracy

MRI Equipment Performance Evaluation

Site: _____ Date: _____

MRAP Number: _____ Serial Number: _____

Equipment:

MRI System Manuafacturer: _____ Model : _____

Processor Manufacturer : _____ Model: _____

PACS Manufacturer: _____ Model: _____

ACR MRAP Phantom Number used: _____

1. Magnetic Field Homogeneity

Method Used (check one): Spectral Peak ___ Phase Difference ___

Other (describe) _____

Measured Homogeneity:	Diameter of Spherical Volume (cm)	Homogeneity (ppm)
	_____	_____
	_____	_____
	_____	_____

2. Slice Position Accuracy

From Slice Positionss #1 and #11 of the ACR Phantom:

Wedge (mm) [redacted]

=+ =

Slice Location #1 _____

Slice Location #11 _____

3. Slice Thickness Accuracy

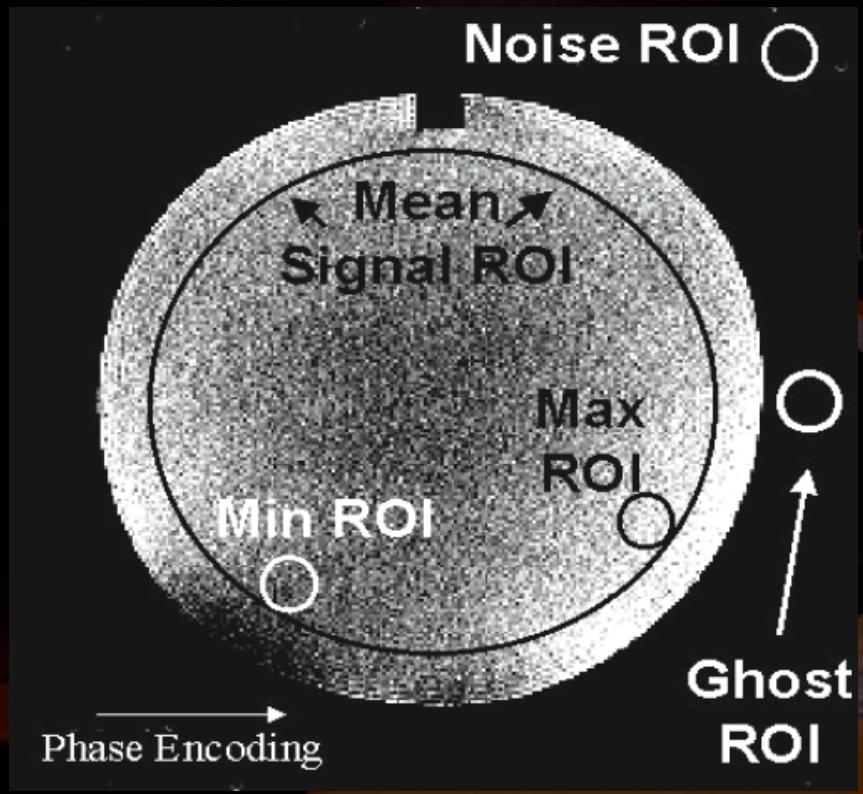
From Slice Position #1 of the ACR Phantom:

Slice Thickness (fwhm in mm) Top _____ Calculated slice Thickness (mm) _____

Bottom _____

Duplicate these forms so they will be available for repeated use.

Volume RF Coil Measurements



Must assess for every volume coil:

1. *SNR* (signal-to-noise ratio)*
2. *Uniformity (percent image uniformity: PIU)*
3. *Ghosting ratio*

* Note: For multi-element coils using multiple receive channels it may be necessary to use a different method for estimating noise than described in the ACR QC manual.

Use ACR Phantom slice #7

Image compliments of Geoff Clarke, Ph.D.

Volume Coils: SNR, Uniformity and Ghosting

- Uniformity performance criteria: PIU ≥ 90%

$$\text{percent integral uniformity} = 100 \times \left(1 - \frac{(high - low)}{(high + low)}\right)$$

- SNR (No significant change from baseline)

  (Mean Signal ROI) / (SD of Noise ROI)

- Percent Signal Ghosting : < 3%

  100 x | (Mean Ghost - Mean Noise) / (2 x Mean Signal ROI)

Surface RF Coil Measurements

1. *Use a phantom that most closely matches the coil geometry*
2. *Carefully record the geometry (best recorded with a photograph) so that it can be reproduced in subsequent measurements.*
3. *Measure and record the maximum SNR*
4. *ROI area ~ 0.15% of FOV*

(e.g. 256X256 ~ 100 pixels)

Maximum
Signal ROI

Noise ROI

Volume Coil Data

% Image Uniformity	Max Signal Min Signal
Signal-to-Noise	Mean Signal SD of Background Signal
Percent Signal Ghosting	Ghost Signal Mean Signal Background Signal

Surface Coil Data

Maximum Signal-to-Noise	Maximum signal SD of Background Signal

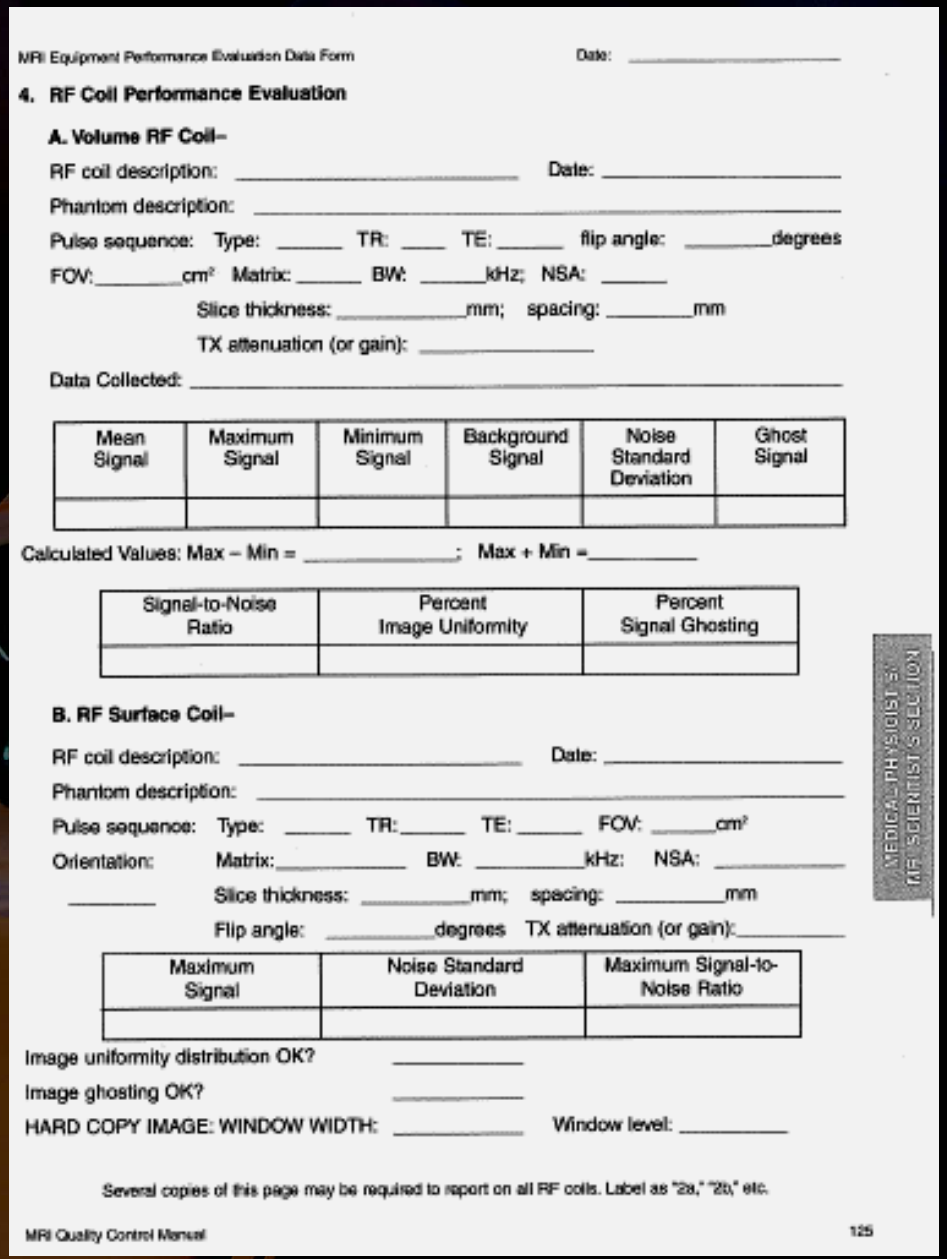
Medical Physicist's Annual Equipment Performance Report

Volume Coil

Calculated Values:
Uniformity
SNR
Ghosting

Surface Coil

Calculated Value:
Maximum SNR



MRI Equipment Performance Evaluation Data Form Date: _____

4. RF Coil Performance Evaluation

A. Volume RF Coil–

RF coil description: _____ Date: _____

Phantom description: _____

Pulse sequence: Type: _____ TR: ____ TE: _____ flip angle: _____degrees

FOV: _____cm² Matrix: _____ BW: _____kHz; NSA: _____

Slice thickness: _____mm; spacing: _____mm

TX attenuation (or gain): _____

Data Collected: _____

Mean Signal	Maximum Signal	Minimum Signal	Background Signal	Noise Standard Deviation	Ghost Signal

Calculated Values: Max – Min = _____; Max + Min = _____

Signal-to-Noise Ratio	Percent Image Uniformity	Percent Signal Ghosting

B. RF Surface Coil–

RF coil description: _____ Date: _____

Phantom description: _____

Pulse sequence: Type: _____ TR: _____ TE: _____ FOV: _____cm²

Orientation: _____ Matrix: _____ BW: _____kHz: NSA: _____

Slice thickness: _____mm; spacing: _____mm

Flip angle: _____degrees TX attenuation (or gain): _____

Maximum Signal	Noise Standard Deviation	Maximum Signal-to-Noise Ratio

Image uniformity distribution OK? _____

Image ghosting OK? _____

HARD COPY IMAGE: WINDOW WIDTH: _____ Window level: _____

Several copies of this page may be required to report on all RF coils. Label as "2a," "2b," etc.

MRI Quality Control Manual 125

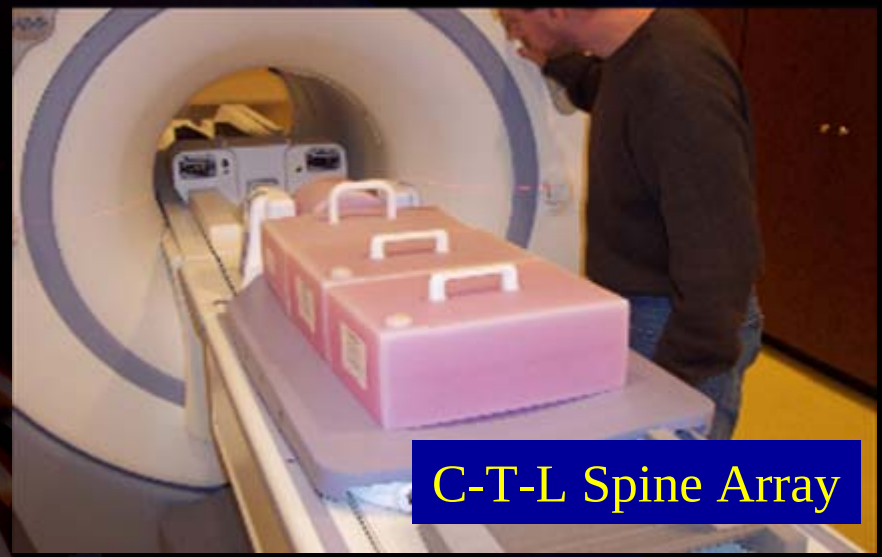
MEDICAL PHYSICIST'S / MR SCIENTIST'S SELECTION

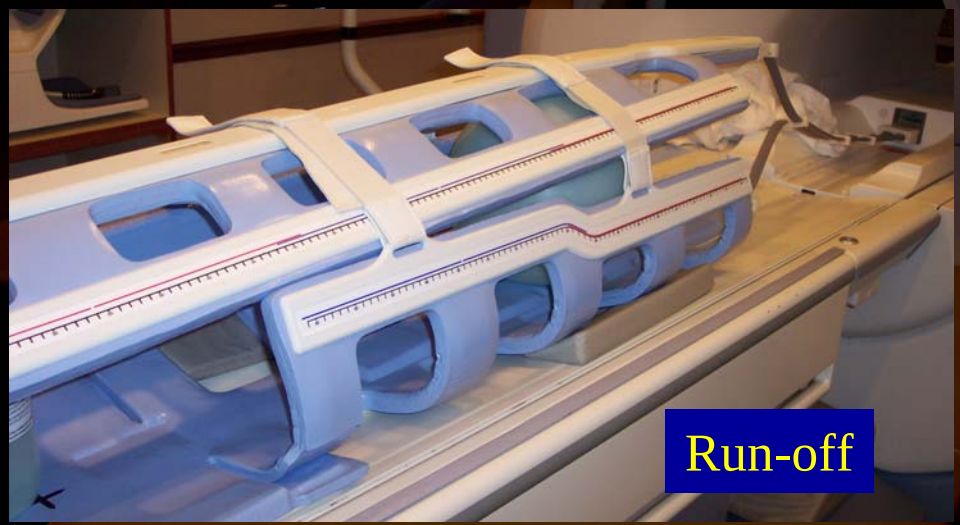
Question: How should you check multi-element and phased array coils?

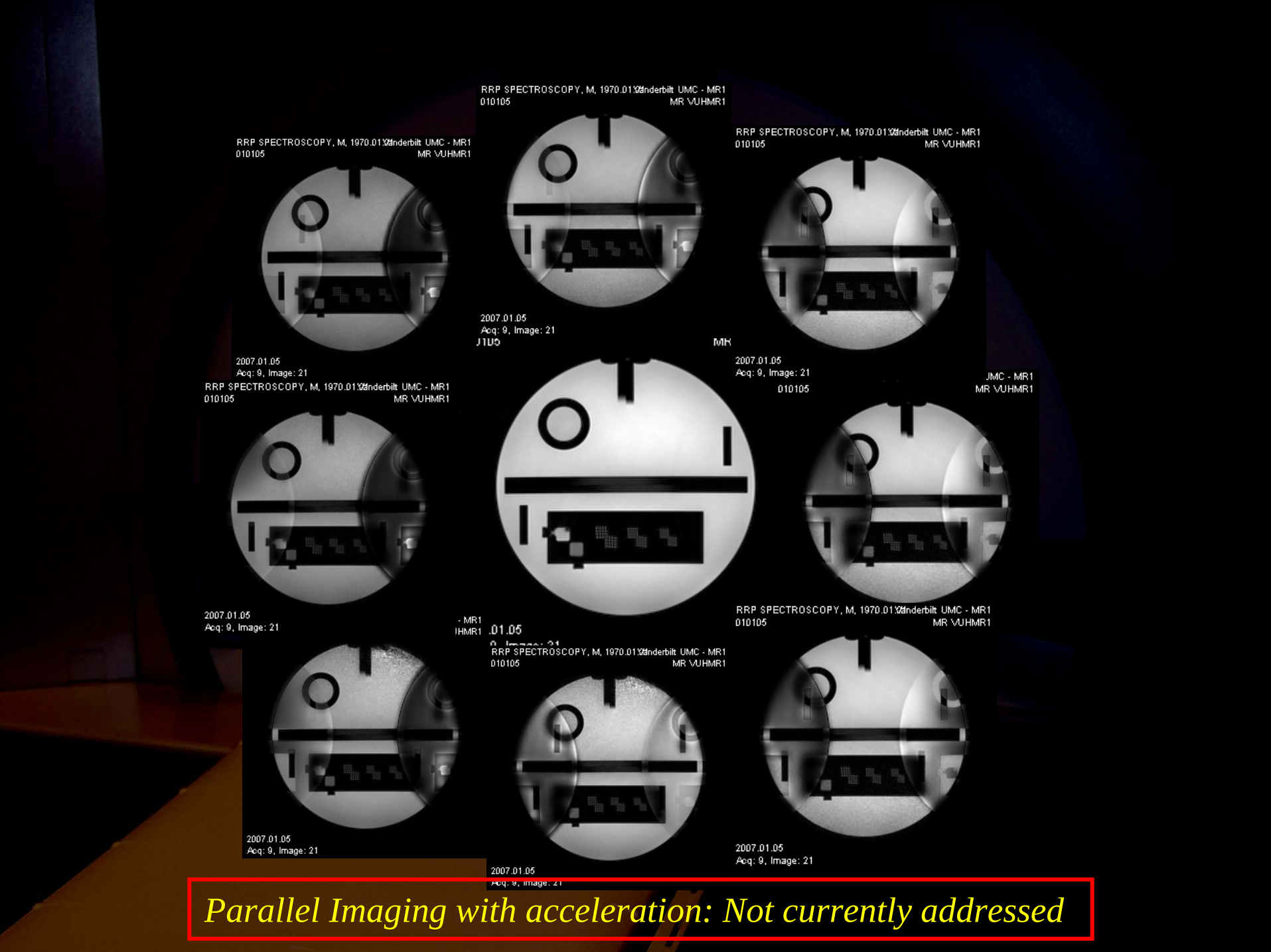
Phantom over coil element 3

Phantom over coil element 4

In most systems, it is possible to select individual elements and test as surface coils. If not available, test summed response in appropriate sized phantom.







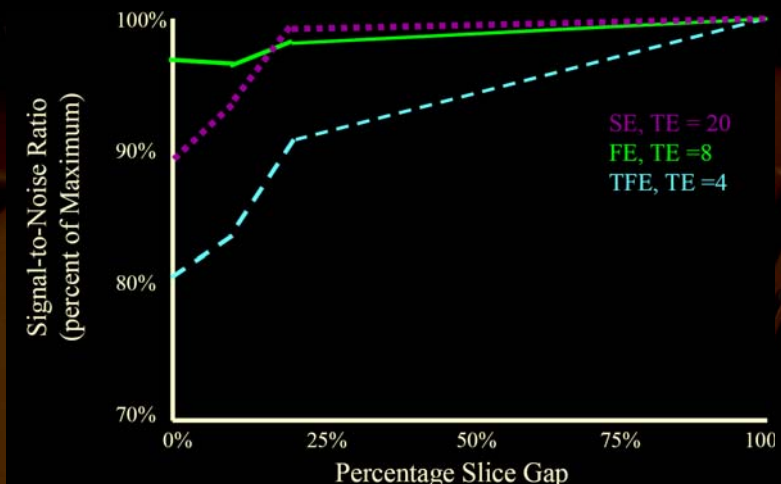
Parallel Imaging with acceleration: Not currently addressed

Slice Cross-Talk Measurement

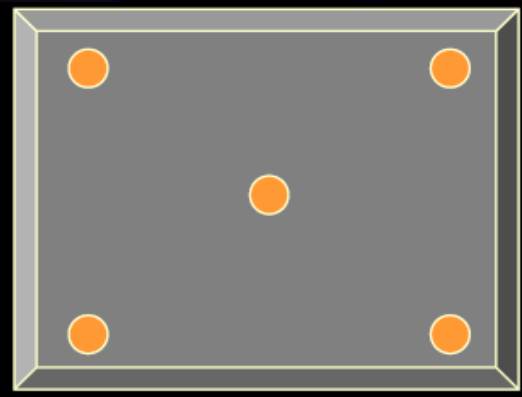
1. Position 5mm slices on the uniform volume (slice 7)
2. Repeat measurements decreasing the slice gap :

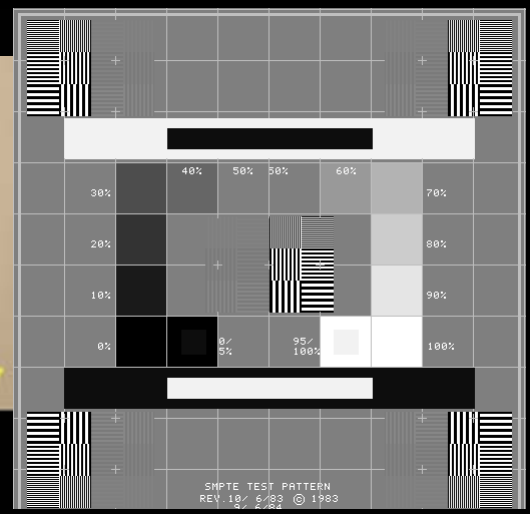
Series #	1	2	3	4
No. Slices	11	11	11	11
Slice Gap (mm)	min	0.5	1.0	5

- Measure the signal-to-noise ratio (SNR) for each of the image sets.
- Plot the SNR *vs.* percentage slice gap



Soft Copy Display



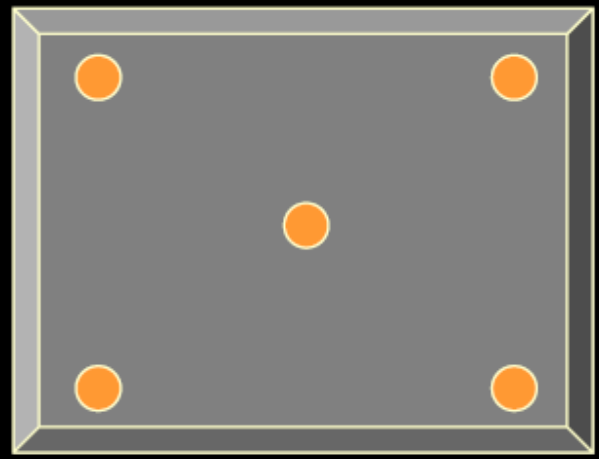


Requires the use of a precision luminance meter to make measurements from the monitor screen

Soft Copy Displays

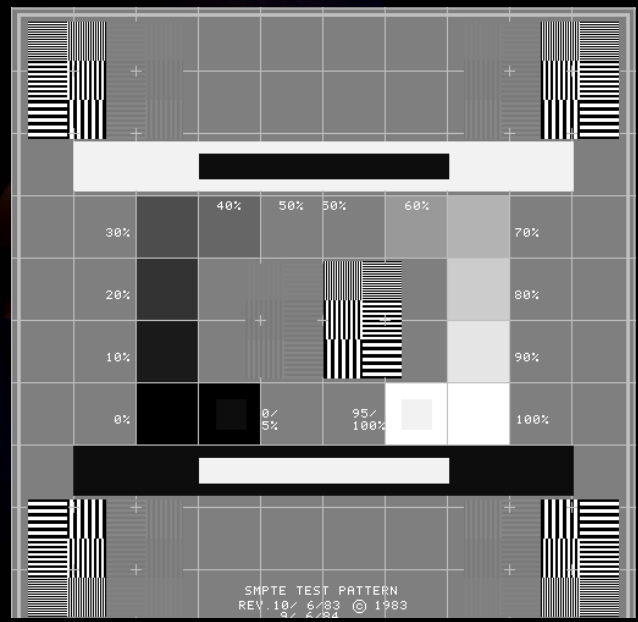
Four Tests:

1. *Max and Min luminance (L_{max} and L_{min})*
2. *Luminance uniformity*
3. *Resolution using SMTE pattern*
4. *Spatial accuracy (SMTE)*



Specifications:

1. *Max luminance (WL/WW = min): > 90 Cd/m^2*
2. *Min luminance: < 1.2 Cd/m^2*
3. *Uniformity: % difference = 200* (L_{max}- L_{min})/(L_{max}+ L_{min})*
4. *Resolution: display bar pattern of 100% contrast*
5. *Spatial accuracy: lines straight within +/- 5mm*



Medical Physicist's Annual Equipment Performance Report

RF Slice Interference

Soft Copy Displays

MRI Equipment Performance Evaluation Data Form Date: _____

5. Inter-slice RF Evaluation

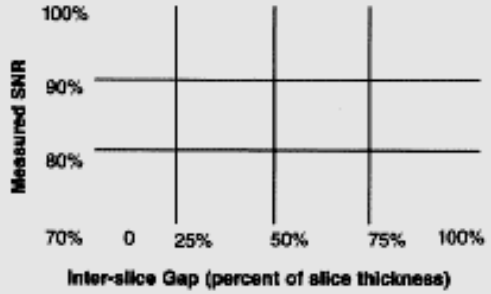
Phantom description: _____

Pulse sequence: Type: _____ TR: _____ TE: _____ FOV: _____ cm²

Matrix: _____ BW: _____ kHz; NSA: _____

Number of slices: _____ Flip angle: _____ degrees

Series Number	Slice Gap mm	Signal-to-Noise Ratio
1		
2		
3		
4		



6. Soft Copy Displays

Luminance Meter Make/Model: _____ Cal expires: _____

Monitor Description: _____

Luminance measured: Cd m⁻² Ft. lamberts (Circle correct units)

Monitor Description	Center of Image Display	Top Left Corner	Top Right Corner	Bottom Right Corner	Bottom Left Corner
Console					

Luminance Uniformity:

Average of values obtained in four corners of screen: _____ Cd m⁻².

Percent difference: _____ %

$$\% \text{ difference} = 200 * (L_{max} - L_{min}) / (L_{max} + L_{min})$$

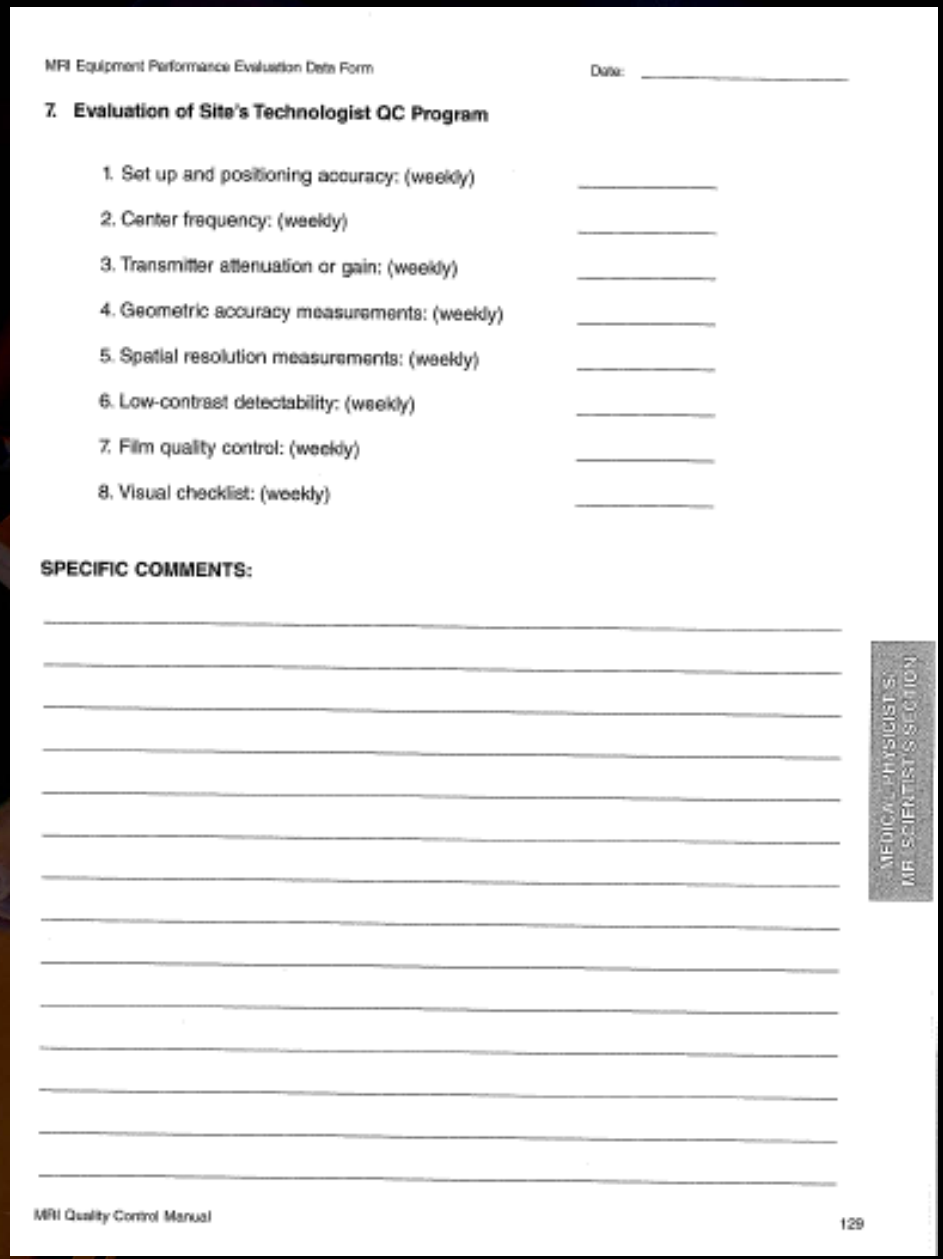
MRI Quality Control Manual 127

MEDICAL PHYSICIST'S / TECHNOLOGIST'S SECTION

Medical Physicist's Annual Equipment Performance Report

Review of Site's Routine QC Program

Medical Physicist's Recommendations for Improving QC Program



MRI Equipment Performance Evaluation Data Form

Date: _____

7. Evaluation of Site's Technologist QC Program

1. Set up and positioning accuracy: (weekly) _____
2. Center frequency: (weekly) _____
3. Transmitter attenuation or gain: (weekly) _____
4. Geometric accuracy measurements: (weekly) _____
5. Spatial resolution measurements: (weekly) _____
6. Low-contrast detectability: (weekly) _____
7. Film quality control: (weekly) _____
8. Visual checklist: (weekly) _____

SPECIFIC COMMENTS:

MEDICAL PHYSICIST'S MR SCIENTIST'S SECTION

MRI Quality Control Manual

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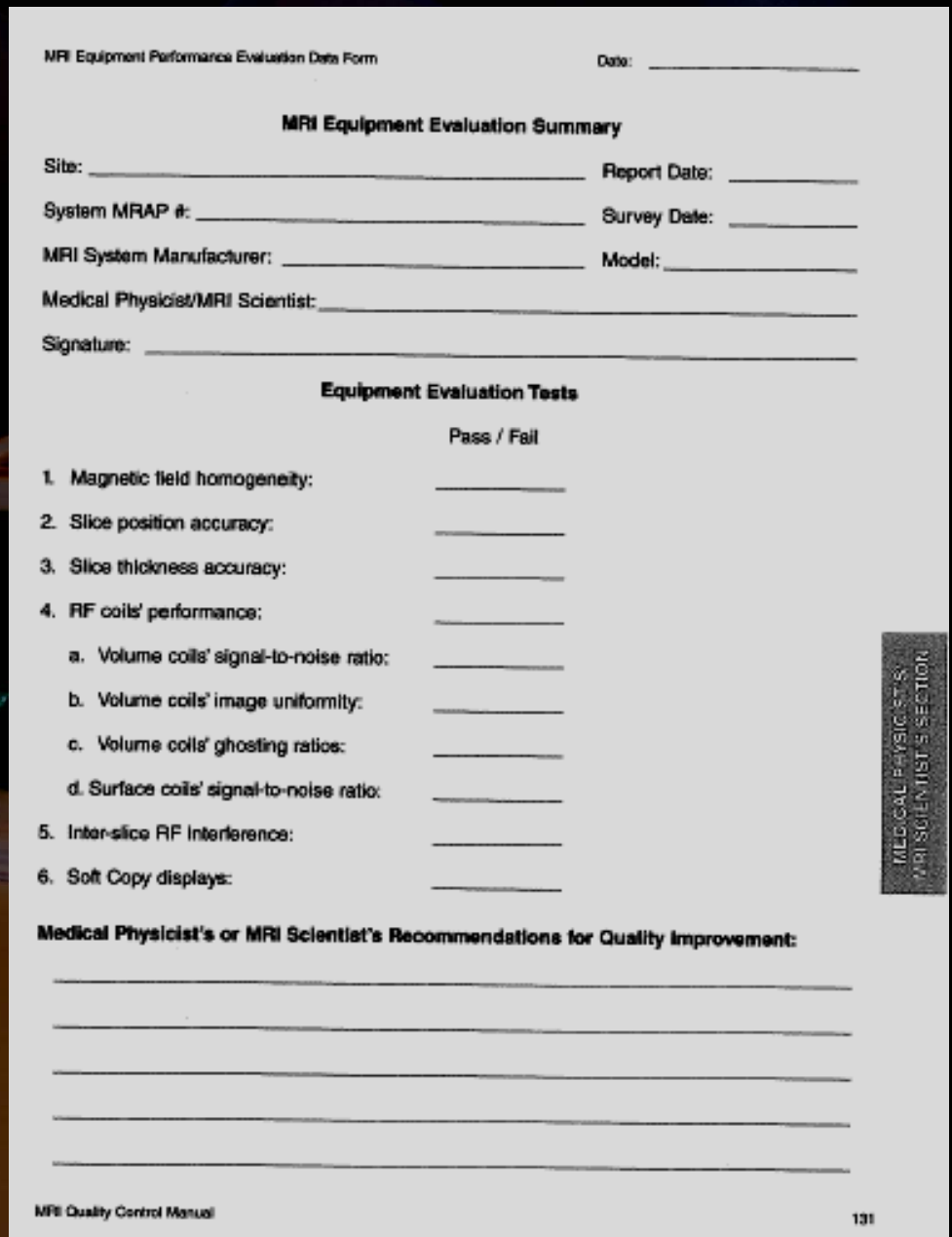
Medical Physicist's Annual Equipment Performance Report

Summary Sheet

It is very important that the consulting medical physicist provide recommendations for Quality Improvement and maintain frequent contact with the site QC Technologist to monitor the QC program and to assist in corrective actions.



MRI Equipment Performance Evaluation Data Form Date: _____

MRI Equipment Evaluation Summary

Site: _____ Report Date: _____

System MRAP #: _____ Survey Date: _____

MRI System Manufacturer: _____ Model: _____

Medical Physicist/MRI Scientist: _____

Signature: _____

Equipment Evaluation Tests

	Pass / Fail
1. Magnetic field homogeneity:	_____
2. Slice position accuracy:	_____
3. Slice thickness accuracy:	_____
4. RF coils' performance:	_____
a. Volume coils' signal-to-noise ratio:	_____
b. Volume coils' image uniformity:	_____
c. Volume coils' ghosting ratios:	_____
d. Surface coils' signal-to-noise ratio:	_____
5. Inter-slice RF interference:	_____
6. Soft Copy displays:	_____

MEDICAL PHYSICIST'S/ MRI SCIENTIST'S SECTION

Medical Physicist's or MRI Scientist's Recommendations for Quality Improvement:

_____

_____

_____

_____

_____

MRI Quality Control Manual 131

MRI QC Program Summary

Technologist

- *Performs weekly tests to assess image quality using the ACR phantom*
- *Performs weekly tests of hard-copy output*
- *Maintains QC Notebook (Very Important)*

MRI QC Program Summary

Medical Physicist / MR Scientist

- *Runs baseline tests of system performance*
- *Sets action limits for weekly ACR phantom tests*
- *Performs annual calibration checks with appropriate phantoms*
- *Reviews all QC program data (at least annually)*

MRI QC Program Summary

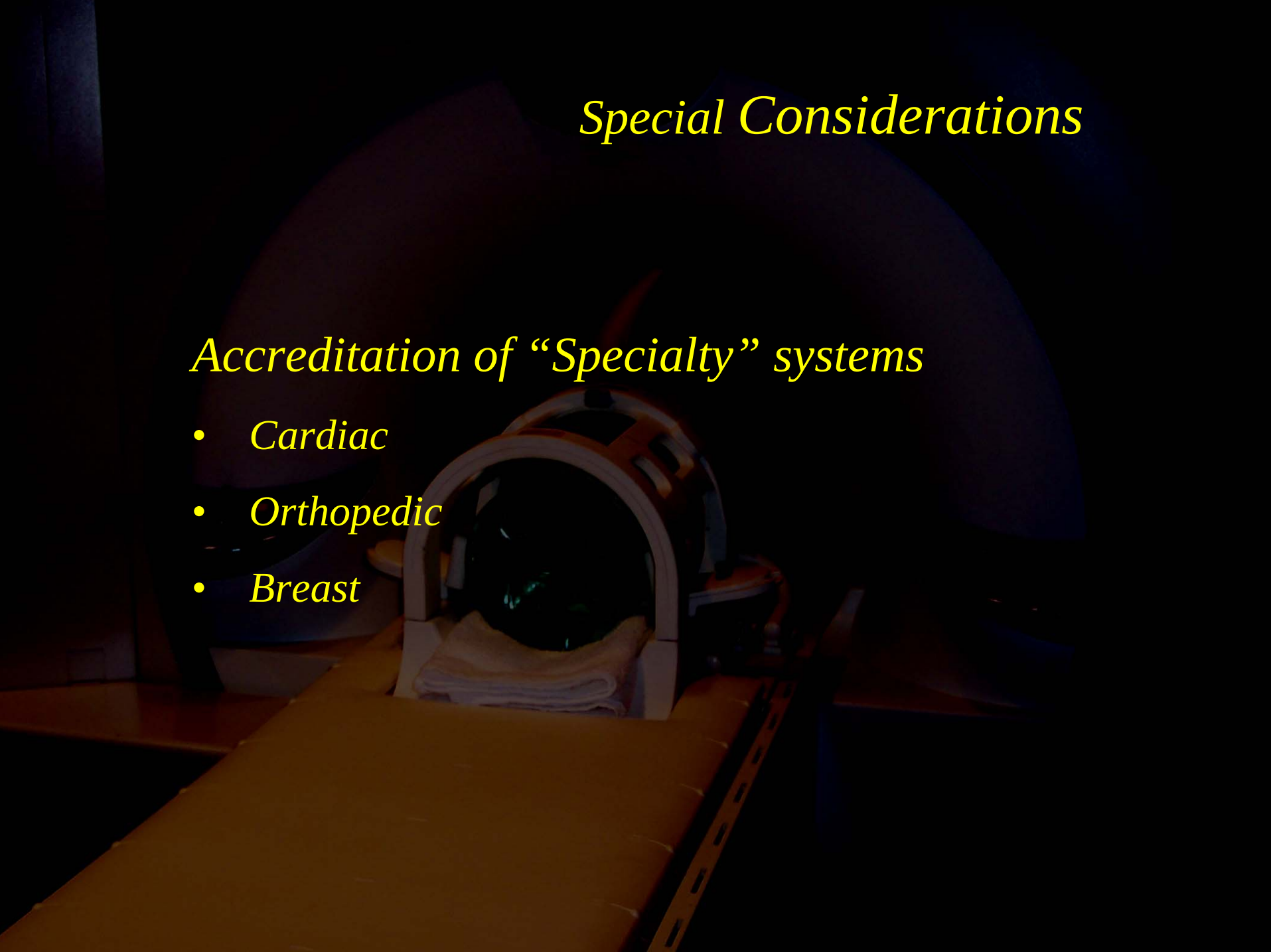
Radiologist

Ultimately responsible for all QA for the facility

Note:

All measurements, problems reported and actions required to resolve the problems must be recorded for review, as must all preventive maintenance and repair records from the vendor or service engineer.

New Requirements: Physician PEER review program and documentation of MRI safety policy.



Special Considerations

Accreditation of "Specialty" systems

- *Cardiac*
- *Orthopedic*
- *Breast*

Cardiac MRI Accreditation Module

Cardiac accreditation is very similar to whole-body accreditation, specifically it requires the same phantom measurements and technologist QA.

Phase-in plan for experience and CME

Sites renewing in July 2008	
Physicians and medical physicists/MR scientists must have earned at least 10 CME hours in the prior 24-month period. The 10 CME hours must be earned for each modality in which they are renewing (CT, MRI, nuclear medicine, PET and ultrasound).	Over the prior 24-month period, physicians reading: • CT, MRI, and ultrasound examinations must have read an average of 9 exams per month. • Nuclear medicine examinations must have read an average of 15 exams per month. • PET examinations must have read an average of 10 exams per month.
Sites renewing in July 2009	
Physicians and medical physicists/MR scientists must have earned at least 15 CME hours in the prior 36-month period. The 15 CME hours must be earned for each modality in which they are renewing (CT, MRI, nuclear medicine, PET and ultrasound).	Over the prior 24-month period, physicians reading: • CT, MRI, and ultrasound examinations must have read an average of 9 exams per month. • Nuclear medicine examinations must have read an average of 15 exams per month. • PET examinations must have read an average of 10 exams per month.

ACR Cardiac MRI Accreditation Module

Some differences in physician qualifications

Requirements for Physicians Supervising and Interpreting Cardiac MRI Examinations

Qualifications	Radiologists	Other Physicians
Initial	• Board certification in radiology or diagnostic radiology by: ○ ABR, ○ American Osteopathic Board of Radiology, ○ Royal College of Physicians and Surgeons of Canada, or ○ Le College des Medicins du Quebec, and • Supervision and/or performance of, as well as interpretation and/or review and reporting of, 75 Cardiac MRI examinations within the last 36 months. [1] OR • Completion of an Accreditation Council for Graduate Medical Education (ACGME) Radiology Residency Program, AND • have supervised interpretation of 75 cardiac MRI cases in the past 36 months AND • Completion of at least 40 hours of Category 1 Continuing Medical Education (CME) in cardiac imaging, including cardiac MRI, anatomy, physiology, and/or pathology or documented equivalent supervised experience in a center actively performing cardiac MRI.	**CARDIOLOGISTS[2]** Certification in cardiology by the American Board of Internal Medicine with completion of Level 2 training or higher Level 2 requirements • Board certification or eligibility, valid medical license, and completion of a 3-month (cumulative) specialty residency or fellowship in CMR AND • 150 CMR examinations in which 50 where the candidate is physically present, involved in the acquisition and interpretation of the case, AND • Completion of 30 hours of courses related to MR in general and/or CMR in particular Level 3 requirements • Board certification or eligibility, valid medical license, and completion of a 12-month (cumulative) specialty residency or fellowship in CMR AND • 300 CMR examination in which 100 where the candidate is physically present, involved in the acquisition and interpretation of the case, AND • Completion of 60 hours of courses related to MR in general and/or CMR in particular **NUCLEAR MEDICINE PHYSICIANS** • Completion of an ACGME approved training program in nuclear medicine AND • Specific training in MRI within an ACGME accredited training program OR • 160 hours of category 1 CME in MRI to include, but not limited to: MRI physics, recognition of artifacts, safety, instrumentation, and 40 hours specific to cardiovascular MRI. AND • Interpretation and reporting under the supervision of a qualified physician of at least 75 cases of MRI of the cardiovascular system during the past 36 months.
Continuing Experience	Radiologists reading Cardiac MRI examinations must have read 50 exams over the prior 24-month period. The cardiac examinations interpreted will count toward the overall continuing experience for other MR modules.	Cardiologists reading Cardiac MRI examinations must have continuing experience in accordance with level 2 requirements or higher – 50 examinations each year.
Continuing Education	Physicians must have earned at least 15 CME in MRI (half of which must be category 1) hours in the prior 36-month period and should include CME in Cardiac MRI as is appropriate to the physician's practice needs.	Cardiologists must have earned at least 30 hours of coursework in the prior 36 month period in accordance with level 2 requirements.

ACR Cardiac Accreditation Module

Some differences in Technologist Qualifications

Requirements for Radiologic Technologist and Medical Physicist/MR Scientist		
Qualifications	**Radiological Technologist**	**Medical Physicist/MR Scientist**
Initial	• ARRT or CAMRT registered as an MR technologist OR • ARRT registered and unlimited state license, and • 6 months supervised MRI clinical scanning experience AND (all technologists) • Cardiac MRI experience supervised by a qualified physician or a qualified technologist(required) • Experience in the intravenous administration of conventional MR contrast, supervised by a qualified physician or a qualified technologist. (required) • Maintain Basic Life Support (BLS) certification (recommended) • Be capable of using an automatic external defibrillator (AED).(recommended) ***Technologists practicing MRI scanning should be licensed in the jurisdiction in which he/she practices, if state licensure for MRI technologists exists.***	• Board certification in diagnostic radiological physics or radiological physics (recommended) OR • A qualified MR scientist has obtained a graduate degree in a physical science involving nuclear MR (NMR) or MRI and should have three years of documented experience in a clinical MRI environment.
Continuing Education	24 hours of Category A CME in MRI every two years (required), including cardiac MRI (recommended).	A qualified medical physicist must have earned at least 15 CME (half of which must be category 1) hours in the prior 36-month period.

ACR Cardiac MRI Accreditation Module

Little change in QC program requirements and Equipment testing

Technologist's Weekly QC Tests

- Center Frequency
- Table Positioning
- Setup and Scanning
- Geometric Accuracy
- High-Contrast Resolution
- Low-Contrast Resolution
- Artifact Analysis
- Film Quality Control
- Visual Checklist

Physicist/MR Scientist's Annual QC Tests

- Magnetic Field Homogeneity
- Slice Position Accuracy
- Slice Thickness Accuracy
- Radiofrequency Coil Checks
- Inter-Slice Radiofrequency Interference
- Soft-Copy Displays (Monitors)

ACR Cardiac MRI Accreditation Module: Clinical

Four complete patient examinations:

- *Black Blood Exam (1 R-R/Short TE) or PDW (2 R-R/short TE)*

  (Axial or short-axis, gated, base to apex, PDW or T1W, not Single Shot)

- *Delayed Gadolinium Enhanced Exam (two examinations)*

  (Short-axis cine, Long-axis cine, two-chamber vertical, four-chamber horizontal, IR prep w/ good blood-myocardium/infarct contrast)

- *Basic Cardiac Exam (one examination)*

  (Short- axis cine SS free precession or fast GE, LV base to apex)

  (Long-axis cine: two-chamber/vertical, four-chamber horizontal)

ACR Cardiac MRI Accreditation Module: Clinical

Recommended Clinical Spatial Resolution Parameters					
Sequence	**Slice Thickness**	**Gap**	**Temporal Resolution**	**Maximum In-Plane Pixel Dimension for phase**	**Maximum In-Plane Pixel Dimension for Frequency (Read)**
Black Blood Axial	≤ 8.0 mm	≤ 4.0 mm	N/A	≤ 2.5 mm	≤ 1.6 mm
Short Axis Cine	≤ 8.0 mm	≤ 2.0 mm	≤ 80 msec	≤ 3.1 mm	≤ 2.1mm
Long Axis Cine	≤ 8.0 mm	N/A	≤ 80 msec	≤ 3.1 mm	≤ 2.1 mm
Delayed Gadolinium Enhanced	≤ 10.0 mm	≤ 2.0 mm	N/A	≤ 3.1 mm	≤ 2.1 mm

Introducing the ACR "Small" Phantom for Small-field Orthopedic Systems (Accreditation expected in 2008-2009)

The proposed Orthopedic Module (scheduled for 2008) will utilize a special "Small" phantom for accreditation that will have some changes from the current large phantom.

e.g. Inside length = 100 mm

Inside diameter = 100 mm

High-contrast spatial resolution = 0.7, 0.8 and 0.9 mm holes

Personnel Requirements for Radiologic Technologist

- *ARRT or CAMRT registered as an MR technologist, or*
- *ARRT registered or unlimited state license and 6 months supervised MRI clinical scanning experience, or*
- *Associate or bachelor degree in allied health field, and certification in another clinical imaging field, and 6 months supervised MRI clinical scanning experience, or*
- *Performing MRI prior to and continuously since October 1996 and evaluated by responsible physician to assure competence, and*
- *15 hours of Category A CME in MRI every three years*

[Technologists must be licensed if state licensure for MRI technologists exist]

Technologist Qualifications

"Supervised MRI clinical scanning experience" means:

- *All training must be documented with clearly defined goals and objectives*
- *The technologist must be evaluated by the responsible physician*
- *The technologist must sign an attestation of training and submit to the ACR*

Requirements for Supervising and Interpreting Physicians

Option A: Board certification in Radiology or Diagnostic Radiology by the American Board of Radiology, American Osteopathic Board of Radiology, Royal College of Physicians and Surgeons of Canada or Le College des Medicins du Quebec and supervision/performance/review and reporting of 300 MRI examinations within the last 36 months.

Option B: Completion of accredited diagnostic residency program and performance/interpretation and reporting 500 MRI examinations in the past 36 months.

Option C: (MR imaging limited to a specific anatomical area) Completion of and accredited specialty residency and 200 hours of CME in MRI to include physics and instrumentation and clinical MRI in the subspecialty area and 500 MRI cases interpreted and reported over the past 36 months. For neurological MRI, at least 50 of the 500 cases shall have been MRA or the CNS.