# ACR MRI Accreditation Program Update

Donna M. Reeve, MS, DABR, DABMP
Department of Imaging Physics
University of Texas M.D. Anderson Cancer Center

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## Educational Objectives

- Present requirements of the new six-module ACR MRI program.
- Discuss the medical physicist / MR scientist qualifications and CME requirements.
- Describe small and large phantom image acquisition and analysis.
- Discuss considerations for specific scanner configurations in the accreditation and phantom image evaluation process.

## ACR accreditation

- *Purpose is to set quality <u>standards</u> for practices and to help continuously improve the quality of patient care*
- *To be <u>educational</u> in nature. The ACR Accreditation Programs evaluate qualifications of personnel, equipment performance, effectiveness of quality control measures, and quality of clinical images*

## ACR MRI Accreditation Program History

- 1996 – ACR MRI Program launched (whole body approach)
- 2000 – ACR MRI QC Manual
- 2005 – 3 Tesla magnets included
- 2006 – Documentation of QC and Annual System Performance Evaluation required
- 2008 – Modular approach

## MR Accreditation Program Statistics

*Program initiated in 1996. As of October 2008:*

- *4840 accredited MRI facilities with 5852 units*
- *5358 active facilities (accredited or under review) with 6569 units*

| *<u>Pass Rate FY 2002</u>* | |
|---|---|
| *Initial* | *69%* |
| *2nd attempt* | *93%* |
| *3rd attempt* | *99%* |

## New Modular Program

**Previous programs**

- Whole body
- Cardiac

⇨

- Head
- Spine
- Musculoskeletal (MSK)
- Body
- Magnetic Resonance Angiography (MRA)
- Cardiac

***Breast MR:** to be included with Breast Imaging Accreditation programs (Mammography, Stereotactic Breast Biopsy, Breast Ultrasound)

## Change in patterns of practice

1990's:

- General whole body MR imaging predominant
- ACR Whole Body program:
  - brain, C-spine, L-spine, knee exams submitted for all units
- Phantom images: ACR series and site-specific routine brain series submitted for accreditation
- Separate Cardiac program

## Change in patterns of practice

Current practice is varied:

- Large bore scanners – whole body imaging
- Large bore scanners dedicated to limited anatomic applications (e.g. neuro-, cardiac-, MSK-only )
- Single application specialty scanners (small bore orthopedic)

Modular program aligns accreditation with clinical use of each magnet

## ACR MRI Accreditation Program

- Additional guidance documents
- Guidance documents available *www.acr.org*
- Online application process
- Longer time period to acquire phantom and clinical images (+/- 1 month from phantom exam)

## ACR MRI Accreditation Program

- Unit based facility accreditation program: "For every unit must apply for all modules routinely performed on that unit for a facility to be accredited."
- Allowances made for loaner units and "emergency use of magnets"
  - <10 exams in 30 day period, or
  - <50 exams in any 12 month period
- MRI scanners dedicated to Interventional MRI and Radiation Therapy treatment planning are exempt.

## Submission materials

- Scanner information
- Annual medical physicist performance report
- Personnel qualifications and CMEs
- Clinical images for each module applying for
- Phantom images with site scanning data form
- Most recent quarter of QC data
- $$$$

## Cost of MR Accreditation

| | |
|---|---|
| Accreditation First unit: | $2400 (1-4 modules)<br>$2600 (5 modules)<br>$2800 (6 modules) |
| Second unit: | $2300 (1-4 modules)<br>$2500 (5 modules)<br>$2700 (6 modules) |
| Repeat: | $800 per unit clinical or phantom images<br>$1600 for both |

## Cost of MR Accreditation

| | |
|---|---|
| Add units (mid cycle) or add module (mid cycle) | $1600 per unit |
| Replacement certificate: | $65 per unit |

## Guidance documents

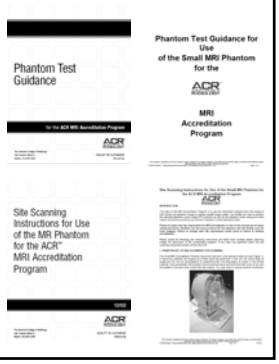
*www.acr.org*

MRI Accreditation Program Requirements

ACR

MRI Accreditation Program TESTING INSTRUCTIONS

ACR Technical Standards




## Clinical images – guidance documents

MRI Accreditation Program
Clinical Image Quality Guide

ACR
AMERICAN COLLEGE OF RADIOLOGY

Describes criteria ACR uses to evaluate clinical images submitted for each of the six modules:

| | |
|---|---|
| Head | Body |
| Spine | MRA |
| MSK | Cardiac |

To be covered by the next speaker

## 2004 ACR MRI Quality Control Manual

Radiologist's section

Technologist's section

Medical Physicist's section

*In the process of being revised.*


## MRI Quality Control program

- Weekly Tests described in Technologists' section of QC Manual
- Weekly required (daily recommended)
- ACR phantom or other phantom if meets criteria:
  - Relaxation and coil loading properties similar to tissue
  - Fits typical head coil
  - Easily and reliably positioned

## MRI Quality Control program

Technologist's Weekly/daily QC tests:

1. Center frequency
2. Table positioning
3. Setup and scanning
4. Geometric accuracy
5. High-contrast resolution
6. Low contrast resolution
7. Artifact analysis
8. Laser camera QC (if applicable)
9. Visual checklist

## Medical Physicist/MR Scientist

Medical Physicist:

Board Certification in radiological physics or diagnostic radiological physics (recommended*)

*Ref: ACR Accreditation Program Requirements, 2009*

Board Certification in appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

*Ref: ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of MRI Equipment, 2006*

## Medical Physicist/MR Scientist

MR Scientist:

A qualified MR Scientist is an individual who has obtained a graduate degree in a physical science involving nuclear MR or MRI. Should have 3 years documented experience in a clinical MRI environment.

*Refs: ACR Accreditation Program Requirements, 2009;*
*ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of MRI Equipment, 2006*

## Medical Physicist/MR Scientist

Continuing Medical Education:

As of July 2007, the medical physicist or MRI scientist must have earned at least 15 CME hours in MRI (half must be Category 1) in the prior 36 month period.

**Ref:** "MRI Accreditation Program Requirements", rev1-12-2009, www.acr.org

## Medical Physicist/MR Scientist

**Must** be familiar with

- principles of MRI safety for patients, personnel, public
- FDA guidance for MR diagnostic devices
- NMR physics and MRI technology, including function, clinical uses, performance specs of MRI equipment, calibration processes & performance testing hardware, procedures and algorithms.

Ref: "MRI Accreditation Program Requirements", rev1-12-2009, www.acr.org

## Medical Physicist/MR Scientist

**Must** have a working understanding of clinical imaging protocols and methods of their optimization.

Proficiency should be maintained by participation in continuing education programs of sufficient frequency to ensure familiarity with current concepts, equipment and procedures.

**Ref:** "MRI Accreditation Program Requirements", rev1-12-2009, www.acr.org

## Medical Physicist/MR Scientist

- May be assisted in obtaining test data by other individuals who must be properly trained and approved by the qualified MP/MR scientist in:
  - -testing techniques
  - -reason for and importance of the test results.
- Qualified MP/MR scientist must review and approve all measurements.
- Expected to provide direct on-site supervision.

**Ref:** "MRI Accreditation Program Requirements", rev1-12-2009, www.acr.org

## Medical Physicist or MR Scientist

- "You **must** utilize the services of a qualified medical physicist/MR Scientist for the Annual System Performance Evaluation.
- A qualified medical physicist/MR scientist **must** have the responsibility for overseeing the equipment QC program and for monitoring performance upon installation and routinely thereafter."
- The ACR **strongly recommends** using the services of a qualified medical physicist or MR scientist during both the process of accreditation and for oversight of your site's technologist quality control program."

## Medical Physicist: Annual System Performance Evaluation

Must include tests defined in 2004 ACR MRI Accreditation manual:

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

## Medical Physicist: Annual System Performance Evaluation

Must include tests defined in 2004 ACR MRI Accreditation manual:

Radiofrequency coil tests:

Volume coils
- SNR, Uniformity, Ghosting ratio

Surface coils
- Peak SNR

## Medical Physicist: Annual System Performance Evaluation

Must include evaluation of technologist QC program:

- *Setup/positioning accuracy*
- *Center frequency*
- *Transmit gain/attenuation*
- *Geometric accuracy*
- *Spatial resolution*
- *Low contrast detectability*
- *Artifact analysis*
- *Film QC*
- *Visual checklist*

## Additional recommended tests: *ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of MRI Equipment*

1. Physical and mechanical inspection
2. Phase stability
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. Spatial resolution and low contrast object detectability
10. Artifact evaluation
11. Film processor quality control (QC)
12. Hardcopy fidelity
13. Softcopy fidelity
14. Evaluation of MRI safety – environment and posting

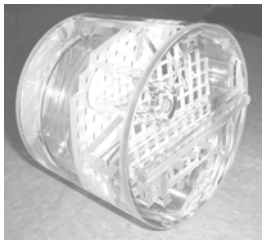
## Medical Physicist: Oversight of Quality Control program

- Train/advise technologist:
  - Daily/weekly QC phantom image acquisition
  - Image evaluation and measurements
- Establish baselines and define pass/fail criteria
- Advise the technologist how to respond to test failures
- Review QC results at regular intervals
- Communicate test results and recommend corrective actions

## Medical Physicist

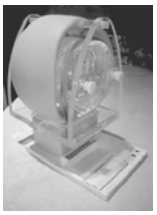
- Scanner purchase specifications
- Acceptance testing and scanner testing after major upgrade or repair
- Evaluate phantom images prior to acquisition of clinical exams and submission to ACR
- Evaluate protocols – meet ACR spatial and temporal resolution requirements
- Protocol development and optimization

## ACR MR Accreditation Phantoms



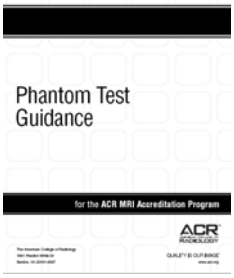
**$1050 "large phantom"**

Manufacturer: J.M Specialty Parts
San Diego, CA



**$780 "small phantom"**

## Guidance for Phantom tests

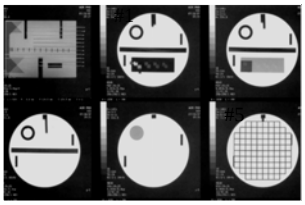


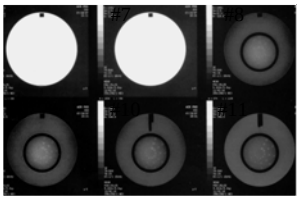


## Guidance for Phantom tests



## ACR (large) Phantom Analysis



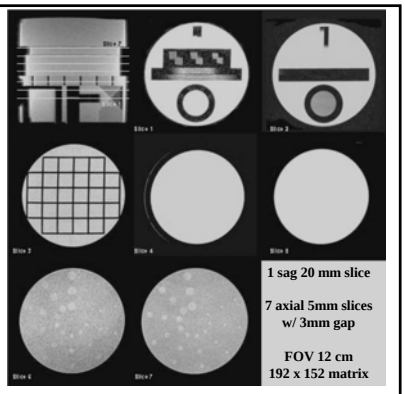


#1) Slice thickness and position, geometric accuracy, high contrast resolution
#5) Geometric accuracy
#7) Percent image uniformity, ghosting
#8-11) Low contrast object detectability, and slice position (in #11)

*Slide courtesy of E.F. Jackson, PhD*

## ACR (small) Phantom Analysis

Sag localizer) Geometric accuracy
#1) Slice thickness and position, geometric accuracy, high contrast resolution
#3) Geometric accuracy
#5) PIU, ghosting
#6-7) LCD

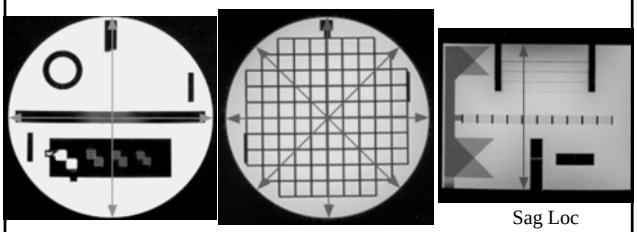



From "Phantom Test Guidance for Small MRI Phantom for the ACR MRI Accreditation Program"

## Phantom position

- Scan 3-plane localizer prior to acquiring sagittal series to optimize phantom position
  - Axial rotation
  - Sagittal tilt
  - Coronal alignment
- Poor phantom positioning may impact:
  - Low contrast detectability (LCD)
  - Uniformity (PIU)

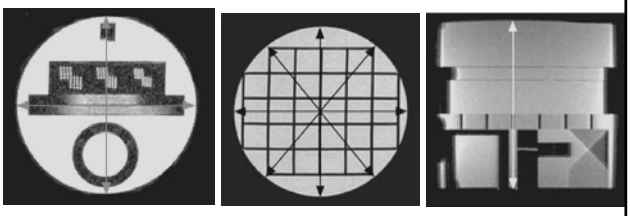
## Large phantom - Geometric Accuracy



Slice 1 Slice 5 Sag Loc

**Criteria: 190 ± 2 mm** **Criteria: 148 ± 2 mm**

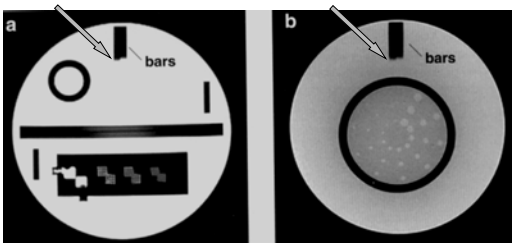
## Small phantom - Geometric Accuracy



Slice 1 Slice 3 Sag Loc

**Criteria: 100 ± 2 mm**

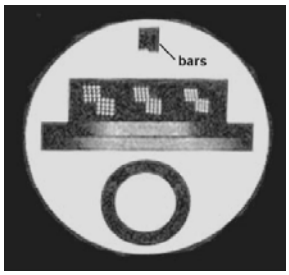
## Large phantom - Slice Position




Slice 1 Slice 11

Criteria: <5mm

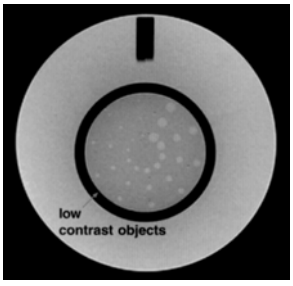
## Small phantom - Slice Position




Criteria: <5mm

Slice 1

## Large phantom – Low Contrast Detectability (LCD)



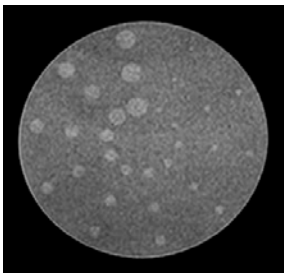

Slice 8: 1.4%
Slice 9: 2.5%
Slice 10: 3.6%
Slice 11: 5.1%

Criteria:

≤1.5T - at least 9 spokes (total)

3T - at least 37 spokes (total)

## Small phantom – Low Contrast Detectability (LCD)



Slice 7

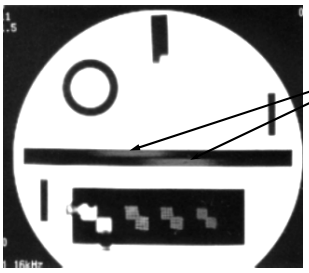
Slice 6: 3.6%

Slice 7: 5.1%

Criteria:

at least 9 spokes (total)

## Large phantom - Slice Thickness

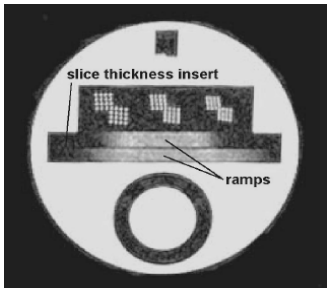


Two 10:1 ramps compensate for phantom tilt

0.2 •(top•bottom)/(top+bottom)

Average slice thickness must be **5.0 ± 0.7 mm**.

## Small phantom - Slice Thickness

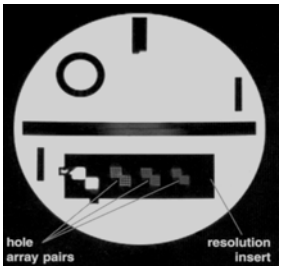



Two 10:1 ramps

0.2 •(top•bottom)/(top+bottom)

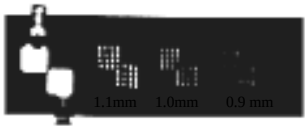
Average slice thickness must be **5.0 ± 0.7 mm**.

## Large phantom – High Contrast Spatial Resolution

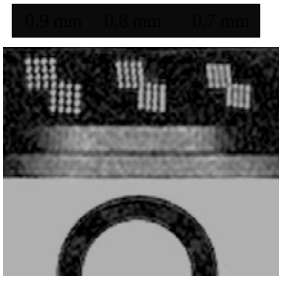



Must be able to resolve 1.0 mm holes vertically and horizontally.

25 cm FOV, 256 x 256 matrix
Pixels: 0.98 mm x 0.98 mm

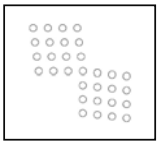



## Small phantom – High Contrast Spatial Resolution

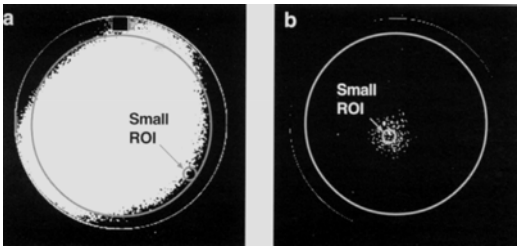



Must be able to resolve 0.8 mm holes vertically and horizontally.

12 cm FOV, 192 x 152 matrix
Pixels: 0.63 mm x 0.79 mm



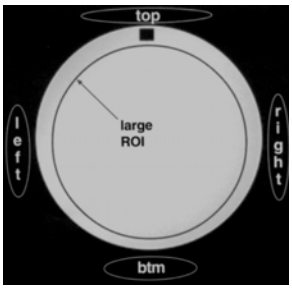
## Both phantoms - Percent Image Uniformity




PIU=[1-(max-min)/(max+min)] • 100

***1.5T: Criteria: PIU≥87.5%***
***3.0T: Criteria: PIU≥82 %***

## Both phantoms - Ghosting measurement




Ghost ratio =
|[(top+btm) - (left+right)]/(2 • large ROI)|

**Criteria: ≤ 0.025**

## Phantom images

- Which phantom?
- Which coil?
- Which images?

## Phantom Images – one set submitted for each scanner using one phantom (large or small)

1. ACR series: Sagittal T1
2. ACR Axial T1 SE
3. ACR Axial PD/T2 dual echo SE (T2 for MSK)
4. Site T1 series
   - T1W brain protocol - large phantom OR
   - T1W knee protocol – small phantom
5. Site T2 series
   - T2W brain protocol – large phantom OR
   - T2W knee protocol – small phantom

## Phantom images

Whole body systems that have both a head coil and knee coil
- Large phantom images acquired in head coil

Dedicated systems (e.g. large bore MSK-only or cardiac-only)
- May not have a head coil
- Call the ACR for guidance

Small bore orthopedic systems
- Small phantom images acquired in knee coil

## Phantom images

Impact on ACR phantom image quality
- Field strength
- Type of head coil
- Small bore systems

## Field strength, $B_0$

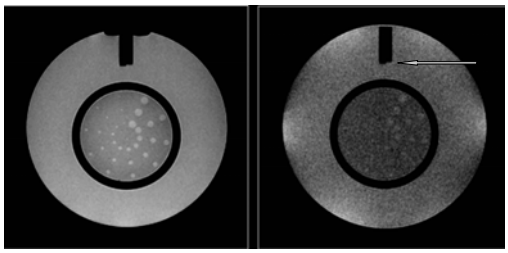
Higher field strength
- Advantages:
  - higher SNR (improved conspicuity)
  - SNR can be traded for
    - faster scan time (decrease averages)
    - increased resolution (larger matrix, thinner slices)

## Low field systems

Lower SNR

- Challenge: to pass low contrast detection test
- Clinical protocols modified to increase SNR
  - Increase number of averages (impacts scan time)
  - Narrow bandwidth (impacts chemical shift, geometric distortion)
  - Use of higher SNR pulse sequences
- Phantom alignment and slice position in LCD sections is important

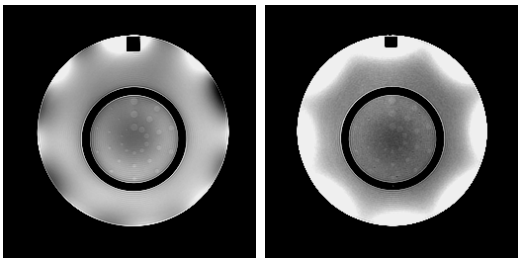
## SNR vs. Field strength



1.5T 0.2T

Slice 11 – Low Contrast Detection section of large ACR MRI phantom (ACR T1 series)

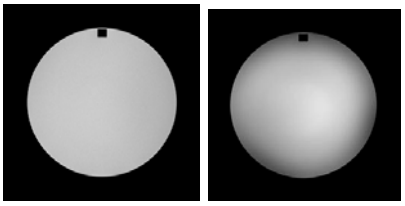
## SNR vs. Field strength



3.0T 1.5T

Slice 8 – Low Contrast Detection section of large ACR MRI phantom (8 channel array, ACR T1 series, SCIC)

## 3 Tesla systems – Dielectric effect



1.5T 3T

Decreased uniformity: Reduced RF penetration with increasing frequency

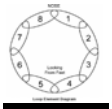
Apply Surface Coil Intensity Correction

*Impacts Uniformity measurement*

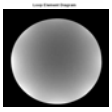
## Phased array coils

- Multiple small coil elements, independent receiver channels
- Higher SNR of small elements
- Multiple elements provide greater anatomical coverage
- Enable parallel imaging

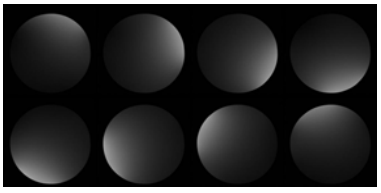
## Phased array coils



- Small coil elements improve SNR
- Multiple elements for anatomical coverage



***Composite image***



***MRI Devices 8 channel HR Brain array: Images acquired from individual channels***

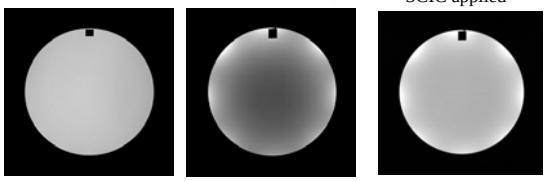
## 8 channel head coils

"If your facility uses an eight channel head coil, it is necessary to perform all phantom scans using the *surface coil intensity correction* option."

Reference: "ACR MRI Accreditation Program Testing Instructions", rev 1-13-2009, www.acr.org

## Uniformity vs. Coil

1.5T Quad head coil | 1.5T 8 channel array | 1.5T 8 channel array SCIC applied



ACR T1 series, Slice 7 – Uniform section of large ACR MRI phantom

## Dedicated MRI systems: small bore orthopedic

Magnet:
- low field to 1.5T
- Resistive systems
- Actively shielded superconductors

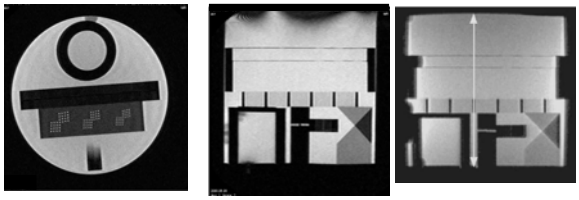
Gradient performance
- Low to high performance
- Up to 70 mT/m, 200T/m/sec

Range of bore and RF coil sizes
- ~145-180 mm

http://www.onimri.com/

## Dedicated MRI systems: small bore orthopedic

- Important to position phantom at center of bore
- Off-isocenter: potential for distortion due to gradient non-linearity and field inhomogeneity - could impact geometric accuracy measurements



## Summary

- ACR launched new modular ACR MRI program October 2008.
- Program allows facilities with dedicated or specialty MSK magnets to become accredited according to their clinical practice.
- MRI Accreditation is now available for a wide range of MRI system configurations and clinical uses.
- Multiple system configurations provide unique challenges for the medical physicist, who plays an important role in the accreditation process.