Physicist’s Role in ACR MRAP Accreditation
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MARP
Medical & Radiation Physics, Inc.
disclosure

◆ ACR MRAP Physics subcommittee
◆ ACR MRAP phantom reviewer
◆ consulting diagnostic physicist
  ◆ GE, Siemens, Philips, Toshiba, Marconi, Hitachi, Fonar
  ◆ 0.2T – 3T
◆ MRI surveys
  • 2006 – 17 surveys
  • 2007 – 33 surveys
  • 2008 – 48 surveys
  • 2009 – 43 surveys
United Healthcare will require accreditation for reimbursement by 4th quarter of 2009
- MRAP (ACR)
- ICAMRL (IAC)
- outpatient imaging centers
- accreditation started by Dec. 31, 2009

Medicare Improvements for Patients and Providers Act (MIPPA)
- providers of advanced imaging services to be accredited by January 1, 2012
  - Part B
- ACR
- IAC
- TJC
ACR MRAP vs IAC ICAMRL

- **MARP MRI surveys**
  - 43 accredited MRI clients
    - 42 ACR (2 in process)
    - 1 IAC
    - 2 expired
  - 54 MRI scanners

- **MARP CT surveys**
  - 43 accredited CT clients
    - 41 ACR (2 in process)
    - 2 IAC
  - 146 CT scanners
ACR accreditation process & phantom

- **ACR accreditation process**
  - **online application**
    - information
      - contact
      - site
      - personnel
      - MRI unit
      - selection of modalities & exams
      - payment
  - **submission**
    - clinical Images
    - phantom Images
  - **continuing requirements of accreditation**
- **phantom & phantom tests**
online application

◆ online application
  ◆ Section 1:
    • contact and general site information
  ◆ Section 2:
    • MRI unit information
    • selection of modalities & exams
  ◆ Section 3:
    • personnel information
      • physicians
      • medical physicists / MR scientist
      • technologist
    • payment
  ◆ 45-day submission window starts at payment
online application

◆ information
  • magnet
  • practice

◆ credentials
  • physicians
  • technologists
  • physicists

◆ modules
  • head
  • spine
  • MSK
  • body
  • MRA
  • cardiac

◆ fees
  • Accreditation / Reinstate
    • $2400 for 1 - 4 modules
    • $2600 for 5 modules
    • $2800 for 6 modules
  • subsequent magnets / same site
    • $2300 for 1 - 4 modules
    • $2500 for 5 modules
    • $2700 for 6 modules
  • repeat
    • $800 for phantom or clinical
    • $1600 for both

◆ all magnets at site must be accredited
◆ 45 day submission period begins
qualifications & responsibilities

- MRI supervising physician
  - responsible for MRI protocols
  - **approves all aspects** of the testing materials submission before sending them to the ACR

- lead MRI technologist
  - main contact person with ACR
  - **should** be the primary person who completes accreditation forms and documents

- qualified medical physicist / MR scientist
  - **should** be responsible for supervising your facility’s weekly QC and the annual system performance evaluation
    - MRI FAQs v1.1.doc
  - closely involved with the phantom portion of your testing materials submission
  - assist the supervising physician and lead technologist with your routine clinical protocols
physicist – initial qualifications (January 1, 2010)

- **Board Certified**
  - American Board of Radiology or
    - Diagnostic Radiological Physics or Radiological Physics
  - American Board of Medical Physics or
    - Diagnostic Imaging Physics or Magnetic Resonance Imaging Physics
  - Canadian College of Physicists in Medicine or
    - Diagnostic Radiology Physics or Magnetic Resonance Imaging Physics

OR

- **Not Board Certified in Required Subspecialty**
  - Graduate degree in medical physics, radiologic physics, physics, or other relevant physical science or engineering discipline from an accredited institution, and
  - Formal coursework in the biological sciences with at least
    - 1 course in biology or radiation biology, and
    - 1 course in anatomy, physiology, or similar topics related to the practice of medical physics
  - 3 years of documented experience in a clinical MRI environment

OR

- **Grandfathered**
  - Conducted surveys of at least 3 MRI units between January 1, 2007 and January 1, 2010
MR scientist

- graduate degree in a physical science involving nuclear MR or MRI
- 3 years documented experience in a clinical MRI environment
physicist – continuing qualifications

- **experience**
  - 2 MRI surveys in 24 months

- **education**
  - 15 CMEs in MRI in 36 months
    - ½ category 1
ACR accreditation - initial questions

- when is the due date?
  - has the initial fee been sent?
- is there an ACR phantom?
  - has it been ordered
  - are there manufacturer phantoms?
- is there a laser printer?
  - is there a densitometer?
- can CD-ROMs be burned?
  - from scanner?
  - from PACS?
- how much will you do?
  - evaluation
  - phantom
  - QC
  - paperwork /webwork for submission
  - clinical images
**submission**

- **ACR clinical image and phantom review**
  - sent by ACR after receiving application
    - arrives ~ 30 days after application
  - includes MRAP number and due date
    - due 45 days after application
  - includes instructions, parameter data forms, and labels
    - everything (but labels) is available on-line
      - www.acr.org
- reaccreditation application similar
- web-based submissions
clinical images

- required from every magnet at practice location
- 4 sets of images
  - original 14 x 17 films
    - (hard copy submissions only)
    - or refilmed from original tapes or discs

- electronic submission
  - CD-ROM with embedded viewer
  - must include functions of:
    - window/level
    - magnification
    - region of interest
      - area
      - pixel mean
      - pixel standard deviation
    - distance measurement
    - access to DICOM header

- must be obtained within 30 days (before or after) of the acquisition of phantom images
clinical images - evaluation

- radiologist reviews for:
  - pulse sequence and image contrast
  - filming technique (hard copy submissions only)
  - anatomic coverage & imaging planes
  - spatial resolution
  - artifacts
  - exam ID

- should be “best work”
- normal or near normal exams
  - as little pathology as possible
- complete examinations
- volunteers not allowed
clinical images

- **current (~ Nov 2008)**
  - site chooses modalities & exams
    - head
    - spine
    - MSK
    - body
    - MRA
    - cardiac
  - one exam from each modality selected
    - at least one must be a specialty exam

- **former**
  - all sites submitted same 4 series
    - brain
    - cervical spine
    - lumbar spine
    - knee
  - current accreditations have be converted to:
    - head
    - MSK
    - spine

---

75 accredited facilities found for search.

**Advanced Imaging San Marcos**
1330 Wonder World Drive
Suite 202
San Marcos, TX 78666
Phone: 512-353-5535
- Head,
- MSK,
- Spine
Expires: 08/21/2011
**clinical images**

- **head**
  - Brain for transient ischemic attack (TIA)
  - Internal auditory canal (IAC/temporal bone) for hearing loss
  - Brain for suspected demyelinating disease*
  - Pituitary with dynamic contrast enhancement*
  - Orbits for vision loss*

- **spine**
  - Lumbar Spine
  - Thoracic Spine
  - Cervical Spine*
  - Cervical Spine with contrast for intramedullary disease*

- **MSK**
  - Knee such as for internal derangement
  - Shoulder such as for internal derangement
  - Wrist such as for internal derangement*
  - Elbow such as for internal derangement*
  - Forefoot for Morton’s neuroma*

- **body**
  - Male pelvis such as for prostate cancer
  - Renal
  - Hepatobiliary to Include MRCP*
  - Female pelvis such as for uterine or adnexal disease*

* specialty exam
**clinical images**

- **MRA**
  - Brain
  - Carotid
  - Thoracic aorta
  - Distal peripheral runoff
  - High resolution arch and carotid*
  - Abdomen for renal artery stenosis *

- **cardiac**
  - Black blood
  - Basic
  - Delayed enhanced cine 1
  - Delayed enhanced cine 2
  - Delayed enhanced cine + black blood*

* specialty exam
Clinical Images

- Sites choose modalities
  - 1-6 modalities selected
- Sites choose exams
  - 4-6 exams
  - One specialty exam for each module
  - Should choose exams they do & do well

MR Accreditation Clinical Image Quality Guide

- Image quality for each exam
  - Maximum examination time
  - Required sequences
  - Pulse sequence & image contrast
  - Anatomical coverage & imaging planes
  - Spatial resolution

<table>
<thead>
<tr>
<th>Required Sequences</th>
<th>Category A: Pulse Sequence and Image Contrast</th>
<th>Category C: Anatomical coverage and imaging planes (Failure to meet these specifications will result in failure.)</th>
<th>Category D: Spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial, sagittal or coronal dark fluid</td>
<td>Must have good discrimination between the brain and CSF</td>
<td>Axial must cover convexity to foramen magnum</td>
<td>Slice thickness ≤ 5.0 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coronal must cover entire brain from anterior to posterior cranial vault</td>
<td>Gap ≤ 2.0 mm if axial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sagittal must cover entire brain</td>
<td>In plane pixel (read) ≤ 1.0 mm</td>
</tr>
<tr>
<td>Sagittal T2 FLAIR</td>
<td>Must have good water suppression</td>
<td>Sagittal must cover entire brain</td>
<td>In plane pixel (phase) ≤ 1.2 mm</td>
</tr>
<tr>
<td></td>
<td>The CSF must be hypo or isointense with the white matter</td>
<td></td>
<td>Pixel area ≤ 1.2 mm²</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>In plane pixel (phase) ≤ 1.2 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pixel area ≤ 1.2 mm²</td>
</tr>
<tr>
<td>Axial bright fluid</td>
<td>The CSF must be hyperintense relative to the brain</td>
<td>Axial must cover from convexity to foramen magnum</td>
<td>Slice thickness ≤ 5.0 mm</td>
</tr>
<tr>
<td></td>
<td>Must have good contrast between the gray matter and white matter</td>
<td></td>
<td>Gap ≤ 2.0 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In plane pixel (read) ≤ 1.0 mm</td>
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<tr>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pixel area ≤ 1.2 mm²</td>
</tr>
<tr>
<td>Axial or coronal dark fluid post contrast</td>
<td>Must have good discrimination between the brain and CSF</td>
<td>Axial must cover from convexity to foramen magnum</td>
<td>Slice thickness ≤ 5.0 mm</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
clinical images

- all images (clinical & phantom) must be submitted by the due date on the labels sent by the ACR
- each of the 4 image types are labeled and placed in film jackets with completed parameter data form
  - pulse sequence
  - FOV
  - acquired matrix
  - slice thickness
  - slice gap
- electronic submission
  - 2 CDROMS with embedded viewer
quantitative phantom testing
MRI accreditation phantom

- specific ACR MRI accreditation phantom is used
- specific protocols for T1 and T2 are provided in the site instructions with the full application
  - phantom site scanning instructions at www.acr.org
- each site is required to submit phantom images using the ACR protocol
  - and phantom images using its own routine T1 and T2 weighted scan protocol for head examinations
- same phantom images for all modalities on full-sized magnet
  - smaller phantom used for extremity-only magnets
phantom image submission - films & data required

- **films**
  - 12-on-1 films of all 4 series

- **data**
  - Dicom PC CD-ROM
    - preferred method
    - each series in separate directory
    - make certain data are easily located
    - make certain images are accessible by Osiris software
      - do not use embedded viewer
      - do not use compressed images
  - site archive format (tape or disk) is no longer acceptable
## Phantom Image Data

**Conversion of Media to Dicom PC CD-ROM**

- Provided by some manufacturers
  - Fonar

- Available on newer workstations / PACS environments
  - Make certain images on CD can be located & opened by Osiris

**Provided by DesAcc, Inc.**

- HTML format on CD-ROM available for
  - Elscint (5¼")
  - GE (most 5¼" & most DAT)
  - Hitachi (5¼")
  - Philips (5¼" & 12")
  - Siemens (5¼" & 12")
  - Toshiba (5¼")

- $200-250 + $25 shipping
- ~ 2-3 weeks turnaround
- [http://www.desacc.com](http://www.desacc.com)
- 312 930-5617
phantom image data – CD-ROM

- available on newer workstations / PACS environments
- DICOM only CD
  - with DICOMDIR
- MRAP applications as of Nov 2007:
  - 8798 units
  - 6052 facilities
- label CD

- MRAP accredited as of May 2010
  - 5437 facilities
  - 431 facilities under review
- ICAMRL accredited as of May 2010
  - 268 facilities
phantom data CD-ROM

- uncompressed DICOM images
  - $256 \times 256 \times 2 = 131072$ bytes
phantom data CD-ROM

- embedded readers often compress images
Osiris 4.19

- free DICOM viewer
- used by ACR reviewers
- download at http://www.sim.hcuge.ch/osiris/01_Osiris_Presentation_EN.htm
- make certain Osiris can open images
make certain Osiris can open .dcm files

- Osiris correctly opens
  - uncompressed DICOM files

- Osiris may not open
  - compressed files
    - note: 61kB vs 131 kB
  - nonDICOM files
  - proprietary files
Osiris 4.19

- **check:**
  - navigation through images
  - window & level work
  - zoom
  - ROIs
  - DICOM headers
- **make certain Osiris does not crash with your data**
- **most consoles produce good CD-ROMs**
  - GE
  - Siemens
  - Philips
  - Toshiba
  - Fonar ?
  - Hitachi ???
- **many PACS systems do not produce acceptable CD-ROMs**
  - proprietary and or compressed formats
check images before submitting

compressed image

wrong gap
### Pulse Sequence Acquisition Parameters

<table>
<thead>
<tr>
<th>Study</th>
<th>Pulse Sequence</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>FOV (cm)</th>
<th>Number of Slices</th>
<th>Slice Thickness (mm)</th>
<th>Slice Gap (mm)</th>
<th>Matrix</th>
<th>Receiver Band-Width (kHz)</th>
<th>Scan Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>ACR Sagittal locater</td>
<td>Spin Echo</td>
<td>260</td>
<td>20</td>
<td>25</td>
<td>1</td>
<td>26</td>
<td>N/A</td>
<td>126 256 256</td>
<td>0.58</td>
</tr>
<tr>
<td>8</td>
<td>ACR Axial T1</td>
<td>Spin Echo</td>
<td>560</td>
<td>20</td>
<td>25</td>
<td>1</td>
<td>50</td>
<td>N/A</td>
<td>256 256</td>
<td>2.18</td>
</tr>
<tr>
<td>9</td>
<td>ACR Axial T2 Double-echo</td>
<td>Spin Echo</td>
<td>2000</td>
<td>2060</td>
<td>25</td>
<td>11</td>
<td>50</td>
<td>5.0</td>
<td>256 256</td>
<td>8.56</td>
</tr>
<tr>
<td>10</td>
<td>Your Name</td>
<td>Spin Echo</td>
<td>2000</td>
<td>2060</td>
<td>25</td>
<td>11</td>
<td>50</td>
<td>5.0</td>
<td>256 256</td>
<td>8.56</td>
</tr>
<tr>
<td>11</td>
<td>Your Name</td>
<td>SE</td>
<td>3500.00</td>
<td>1130.00</td>
<td>11</td>
<td>5</td>
<td>5.0</td>
<td>256 256</td>
<td>208 312 1200.00</td>
<td>3.30</td>
</tr>
</tbody>
</table>

### Additional Details
- **SR Number:** 0156
- **Testing Performed by:** JESUS A. PEREZ
- **Date of Testing:** 12/14/2009
- **Scan Options Used on the ACR Spin-echo T1- and T2-Weighted Axial Brain Scan:**
  - T1w: 0.6/195 T2w: 20s
  - T1w Fat Sat: 80 T2w Turbo Fat Sat:
- **Serial Number of Phantom used for testing:** 0156
continuing requirements of accreditation program

- weekly QC
- annual tests
- ACR has the right to perform random site and/or film inspections
quality control

- **effective August 2002:**
- **weekly tests** *(initially daily):*
  - central frequency
  - transmitter gain /attenuation
  - geometric accuracy
  - spatial resolution
  - low-contrast detectability
  - image artifact assessment
- **weekly:**
  - laser film QC
  - visual checklist
- **annual:**
  - physicist/MR scientist performance evaluation & QC review

- **effective July 2005:**
- for renewal, site must send:
  - 3 months QC/printer data
  - annual survey report
    - dated within 12 months
    - documentation of corrections for failures
- QC and annual survey are now required for initial applications too
ACR MRI large phantom

- J.M. Specialty Parts
  11689-Q Sorrento Valley Road
  San Diego, CA 92121
  (858) 794-7200
- $1050
  - previously $730
- delivery
  - 6-8 weeks without MRAP number
  - 2-3 weeks with MRAP number
  - order without MRAP, then call to add MRAP
ACR MRI small phantom

- J.M. Specialty Parts
  11689-Q Sorrento Valley Road
  San Diego, CA 92121
  (858) 794-7200

- $780
Phantom Test Guidance for the ACR MRI Accreditation Program

- describes tests
- instructions
- performance criteria
- reasons for failure
- available from www.acr.org
- “large phantom” = old phantom
Site Scanning Instructions for use of the MRI Phantom for the ACR MRI Accreditation Program

- phantom positioning
- pulse sequences
- film and data instructions
- sent to site with full application
- available from ACR
phantom pulse sequences

- 2 ACR sequences
  - T1
  - T2
- identical for all sites
- extremity-only sites use different ACR sequences for small phantom

- 2 site sequences
  - T1
  - T2
- site specific
  - may be used to increase SNR in order to pass low-contrast tests on low-field units
ACR sequences

**regular phantom**

- 1 sagittal localizer slice
  - T1: SE
  - TR=200 ms, TE=20 ms
  - 25 cm FOV, 256x256, 20 mm slice
  - 1 NEX (NSA, NAQ, AVE)
- 2 sets of 11 axial slices
  - 25 cm FOV, 256x256
  - 1 mm pixels
  - 5 mm slice, 5 mm gap
  - 1 NEX (NSA, NAQ, AVE)
  - T1:
    - SE, TR=500 ms, TE=20 ms
  - T2:
    - SE, TR=2000 ms, TE=20/80 ms
    - Use 2nd echo only

**small phantom**

- 1 sagittal localizer slice
  - T1: SE
  - TR=200 ms, TE=__ ms
  - 12 cm FOV, 192x152, 20 mm slice
  - 1 NEX (NSA, NAQ, AVE)
- 2 sets of 7 axial slices
  - 12 cm FOV, 192x152
  - 0.625 mm x 0.79 mm pixels
  - 5 mm slice, 3 mm gap
  - 1 NEX (NSA, NAQ, AVE)
  - T1:
    - SE, TR=500 ms, TE=20 ms
  - T2:
    - SE, TR=2000 ms, TE=20 ms
    - only 1 echo

**all sites must use the same ACR sequences**

- slight modifications allowed if scanner cannot set them
  - T1: SE, TR=515 ms, TE=20 ms (Toshiba Opart)
  - T2: SE, TR=500 ms, TE=90/25 ms (Fonar)
- document other scan parameters on site data sheet
required phantom tests

- geometric accuracy
- high-contrast spatial resolution
- slice thickness accuracy
- slice position accuracy
- image intensity uniformity
- percent signal ghosting
- low-contrast object detectability
- image artifacts
pre-scanning procedures

- magnet should be checked by service engineer prior to acquisition

- alignment is important
  - center of head coil
  - computer paper
  - straight
  - use bubble level
  - centered SI, LR & AP
  - make localizer slice in all 3 planes
  - use grid to check centering
  - record position for future use
alignment of ACR phantom
sagittal localizer slice

Nose

Chin

Table
sagittal localizer slice

- set up 11 axial slices for all 4 series
  - 5 mm thick with 5 mm gap
    - small phantom: 7 axial slices, 5 mm slice, 3 mm gap

- notes
  - if geometric accuracy is off, low contrast slices 8-11 may not be accurate
  - phantom wedges and LCD insert 11 may not be perfectly aligned
  - some units have protocols which number slices opposite of the ACR recommendations
  - may not start renumbering at "1" for each series
  - make note of which image is 2nd echo on T2
11 axial slices & localizer
7 axial slices & localizer on small phantom
geometric accuracy

- sagittal localizer & ACR axial T1 slices 1 & 5
  - specific window & level:
    - window as narrow as possible
    - set level where ½ of water is dark (mean)
    - set window width = mean value
      & window level = ½ mean value

- window/level must be set separately for localizer & axial T1
  - both axial slices use same window/level

- small phantom
  - sagittal localizer & ACR axial slices 1 & 3
geometric accuracy - measurements

- sagittal localizer
  - top-bottom (z)
  - 148 mm
  - small phantom = 100 mm
- action limits
  - ± 2 mm

- slice 1 & 5 of ACR axial T1
  - horizontal & vertical (x & y)
  - diagonal on slice 5 (3 for small)
  - 190 mm
  - small phantom = 100 mm
  - different W/L than localizer
- action limits
  - ± 2 mm
geometric accuracy - notes

- image may be bowed
  - accurate at one location, inaccurate at another
  - measure in the center

- bubble may obscure top of slice
  - measure at angle

- localizer & axial slices need different W/L

- operator may know the actual values and aim for them

- open short bore magnets may use geometric corrections
  - Siemens – Large FOV or 2D distortion correction
high-contrast spatial resolution

- **measurements**
  - use slice 1 of ACR T1 & ACR T2
  - magnify slice 1 by 2 to 4
  - observe UL holes; adjust window/level
    - observe rows: if all 4 holes in a single row are distinguishable, score image as resolved at this hole size
    - view all three sets (1.1 mm, 1.0 mm, 0.9 mm)
    - score = smallest holes resolved
  - repeat for LR array with columns of holes

- **performance criteria: 1.0 mm**

- **small phantom**
  - 0.9 mm, 0.8 mm, 0.7 mm sets
  - pixel size = 0.625 x 0.79 mm
  - performance criteria: 0.8 mm
slice thickness accuracy

- slice 1 of ACR T1 & ACR T2
  - crossed ramps (10:1 slope)
  - measure mean
    - magnify by 2 to 4
    - adjust window/level to see signal ramps
    - 2 ROIs
    - mean of middle of each signal ramp
    - take average
  - measure width
    - lower level to ½ average
    - set window at minimum
    - measure lengths of top and bottom ramps
- calculate slice thickness
- performance criteria:
  - 5.0 ± 0.7 mm

slice thickness = 0.2 \times \frac{top \times bottom}{top + bottom}
slice thickness - notes

- edges of ramps difficult to determine
  - Gibbs artifacts
  - noise (low field magnets)
- display may give max-min signal (or use relative scale)
  - use Osiris
- 1 mm measurement error = 1/10 mm error in slice thickness
- same for small phantom
slice thicknesses measurements

- **Hitachi Airis II**
  - ROI scale different than WL scale
  - “Jump level to ROI mean”
    - sets level to mean of ROI
    - displays mean using WL scale
    - manually reduce level to $\frac{1}{2}$
    - manually reduce width to 1

- **Toshiba Opart & Vantage**
  - ROI scale different than WL scale
  - no simple workaround
  - burn CD
    - use Osiris or Osirix
slice position accuracy

◆ measurements
  - use slices 1 & 11 of ACR T1 & ACR T2
    - only slice 1 of small phantom
  - magnify by 2 to 4 & adjust window/level
  - measure difference of left & right bars
    - if left bar is longer assign a minus sign to the length
slice position accuracy

- **performance criteria:**
  - magnitude of bar length difference $\leq 5$ mm.
    - actual displacement is $1/2$ of the measured difference (wedges have 45° slopes)
    - operator may strive for more precision than is necessary
    - phantom wedges & disks may not be perfectly aligned
    - small phantom
      - slice 1 only
image intensity uniformity

slice 7 of ACR T1 & T2

- make large ROI (195-205 cm²)
  - small phantom: 54-56 cm² on slice 4

- low-signal region:
  - set window width to minimum
  - lower level until entire ROI is white
  - raise level until 1 cm² region of black appears
  - use 1 cm² ROI to record mean of this low-signal region

- high-signal region:
  - raise level until only 1 cm² region of white remains
  - use 1 cm² ROI to record mean of this high-signal region

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

◆ performance criteria:

PIU ≥ 87.5%

• if there is not a well-defined high/low intensity level…
  …uniformity is very high!

◆ same for small phantom

◆ for 3.0T:

PIU ≥ 82% (July 2005)
image intensity uniformity – 8-channel coils

- **smaller coil**
  - harder to setup
  - poorer uniformity

- **corrections**
  - Surface Coil Intensity Correction (SCIC) – GE
  - Prescan Normalization (Siemens)
  - “CLEAR” (Philips)
    - “Quadrature” vs “SENSE”
**percent signal ghosting**

- **use slice 7 of ACR T1**
  - make large ROI (195-205 cm²)*
    - record mean
    - small phantom: 54-56 cm² on slice 4
  - make 4 elliptical ROIs
    - 10 cm² with 4:1 ratio
    - left, right, top, bottom
    - record mean of each

ghosting ratio = \[
\frac{(top + bottom) - (left + right)}{2 \times (\text{large ROI})}
\]

- **performance criteria:**
  - ghosting ratio ≤ 0.025 (2.5%)
low-contrast object detectability

- slices 8-11
- both ACR series
- both site series
- adjust window/level for optimum contrast.
low-contrast object detectability

- 4 slices with low-contrast holes
  - slices 8-11
    - decreasing contrast levels (11→8)
  - 10 spokes per slice
    - 3 holes per spoke
    - decreasing size (clockwise)

- count complete spokes
  - all 3 disks must be discernible
    - more apparent than background
  - end with last complete spoke

- for phantom review:
  - all slices are counted
  - total score = discernible spokes from all four slices
low-contrast object detectability – small phantom

- 2 slices with low-contrast holes
  - slices 6-7
    - decreasing contrast levels (7 → 6)
  - 10 spokes per slice
    - 3 holes per spoke
    - decreasing size (clockwise)
low-contrast object detectability

- **performance criteria**
  - each ACR series should have a total score of at least 9 spokes
    - 4 slices for large phantom (9/40)
    - 2 slices for small phantom (9/20)
  - for 3.0T, the total score must be at least 37 spokes.
  - must pass both ACR series or both site series
low-contrast object detectability

- **causes of failure:**
  - incorrectly positioned slices
    - contrast based on partial volume averaging
  - tilted phantom
  - warped slices / $B_0$ inhomogeneity correction software
  - incorrect slice thickness
  - ghosting
  - inadequate SNR
low-contrast object detectability

◆ notes:
  - several lower spokes may be visible but cannot be counted due to artifact obscuring one of the higher-level spokes
  - window/level each slice separately
  - start with highest contrast and move down.
  - site may need to change their protocol
    - (especially for low field magnets)
low-contrast: high vs. low field

- slice 11 - ACR T1 series

1.5 T

0.3 T
artifacts

ACR series
artifacts are evaluated

site series
artifacts are NOT evaluated
artifacts

DC Offset (ACR series)
- acceptable

susceptibility (ACR series)
- questionable
artifacts

wraparound (site series)  acceptable

ghosting (ACR T2)  questionable
**homogeneity**

- required for annual survey & initial evaluation
- concerns
  - geometric distortion?
  - problems with fat saturation?
- methods
  - spectral
  - phase-difference
  - visual distortion
homogeneity – spectral analysis

- measures frequency of signal-producing phantom in magnet
  - DSV
    - ↑ homogeneity at center & with ↓ FOV
    - Δ FOV… Δ phantom size
- spectrum displayed on screen (Hz)
- homogeneity measured in ppm
- compare to specs or baseline values
homogeneity – spectral analysis

- manual prescan
  - GE
- EPI tuning
  - Elscint
- FWHM (Hz)

$$\text{ppm} = \frac{\text{Hz}_{\text{FWHM}}}{\text{MHz}_{\text{LarmorFrequency}}}$$

- volume ~ phantom

<table>
<thead>
<tr>
<th>Orientation</th>
<th>DSV (cm)</th>
<th>PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSV</td>
<td>27</td>
<td>0.38</td>
</tr>
</tbody>
</table>
homogeneity – spectral analysis

- **Siemens**
  - “system”
  - “adjustments”
- check “confirm adjustments”
phase-difference (Philips)

- shim_check
  - option under phantom studies
  - FFE, fixed technique & FOV
- 40 cm cylindrical phantom
  - holder to center phantom
  - 3 orientations
- view real images
  - count B→W transitions
**shim_check (Philips)**

- **example:**
  - 1.5T, FFE, TR=400, TE=16, 30º, 450 mm FOV
  - B→W = 1 ppm

- **example:**
  - coin taped to phantom
shim_check (Philips)

- **example:**
  - 1.5T, FFE, TR=400, TE=16, 30°, 450 mm FOV
  - B→W = 1 ppm

<table>
<thead>
<tr>
<th>Orientation</th>
<th>DSV (cm)</th>
<th>PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>transverse</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>sagittal</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>coronal</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>transverse</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>sagittal</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>coronal</td>
<td>20</td>
<td>2</td>
</tr>
</tbody>
</table>
homogeneity – geometric distortion

- most low-field open magnets do not have software to check homogeneity
  - observe effects on geometric distortion
    - lower bandwidth
  - warped images

7.4 kHz 3.6 kHz
different bandwidths

- measure distortion in frequency-encoding direction with different bandwidths (Clarke & Chen)

\[
MFH(\text{ppm}) = \frac{\left(BW_1 \times BW_2\right) \times \left(x_1 - x_2\right)}{\left(\gamma / 2\pi\right) B_0 \text{FOV} \left(BW_2 - BW_1\right)}
\]

BW = 33 Hz (8448 kHz)
FE45 TR=256, TE=45, 7 mm, FA=70°, FOV=20cm

BW = 244 Hz (62464 kHz)
FE5.0 TR=256, TE=5, 7 mm, FA=20°, FOV=20cm

<table>
<thead>
<tr>
<th>Direction</th>
<th>SI ppm</th>
<th>AP ppm</th>
<th>LR ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI</td>
<td>2.68</td>
<td>0.84</td>
<td>0.31</td>
</tr>
</tbody>
</table>

148.1 cm
151.6 cm
coils

- must be checked annually
  - SNR
  - ghosting
  - uniformity
volume coils

- similar to head coil
  - uniformity
    - mean
    - high
    - low
  - SNR
    - mean
    - background noise
- ghosting
  - mean
  - background signal
  - ghost signal (PE direction)
- phased-array coils
  - may be treated as volume if they have volume configuration
surface coils

- max SNR
  - max ROI
  - background noise
- uniformity
  - subjective
- ghosting
  - subjective
- phased-array coils
  - may be treated multiple surface coils if you can distinguish the location of the arrays

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Max ROI</th>
<th>Background StdDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>axial</td>
<td>1828.85</td>
<td>3.47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Survey Date</th>
<th>Max SNR</th>
<th>RF Drive Scale</th>
<th>Uniformity OK?</th>
<th>Ghosting OK?</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 31, 2007</td>
<td>527.0</td>
<td>1.04</td>
<td>good</td>
<td>none</td>
</tr>
<tr>
<td>May 18, 2006</td>
<td>518.6</td>
<td>1.09</td>
<td>good</td>
<td>none</td>
</tr>
<tr>
<td>May 24, 2005</td>
<td>509.8</td>
<td>1.01</td>
<td>good</td>
<td>slight</td>
</tr>
<tr>
<td>May 11, 2004</td>
<td>467.2</td>
<td>1.05</td>
<td>ok</td>
<td>none</td>
</tr>
</tbody>
</table>
phased-array coils

- multiple types

~ volume coil

~ multiple surface coils (arrays distinguishable)

more complicated
**recommendations**

- **be familiar with process**
  - read QC manual, phantom guidance & site instructions
  - set up worksheet or computer program
  - let site know if they will pass phantom portion

- **scan early in the process**
  - site may need to adjust protocols prior to acquisition of clinical and phantom images
  - before application to let site know condition of magnet prior to due date
  - magnet may be “in specs” and still fail part of the test
  - magnet may need corrections prior to phantom submission
recommendations

- **physician**
  - two-month window to get clinical images
  - may need to adjust protocols

- **service engineer**
  - magnet should be in top shape prior to obtaining images

- **technologist**
  - needs assistance in setting up QC
  - schedule ~ 5 hours
conclusion

- **physicist**
  - there is no reason a site should fail the phantom portion of the MRI Accreditation program if they are being assisted by a physicist
  - phantom materials submitted by physicist should be usable by ACR
  - physicist should be able to perform all tests required by ACR
application & submission resources

- www.acr.org
  - application & submission documents
    - all changed ~ November 2008
  - phantom submission & site scanning documents
    - unchanged for large phantom
    - added small phantom ~ November 2008
Physicist’s Role in ACR MRAP Accreditation
May 2010

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