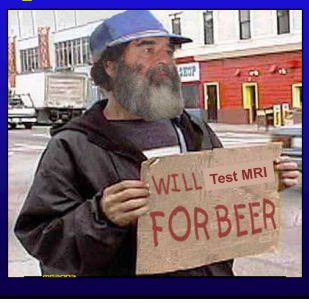
Nuts and Bolts of MRI Physics Tests

or

"Selling Preparation H"

Robert A. Bell, PhD
(858) 759-0150
bell3660@sbcglobal.net



Robert A. Bell, PhD

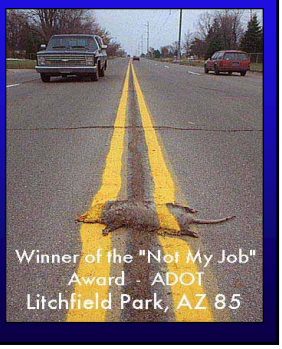
- Since 1987 RAB has provided independent consulting services to clients in 45 states, Canada, China, and Australia. Approximately 85% of my work is directly related to MRI. This is the only type of testing I conduct. Typical RAB clients are hospitals (~50%) and independent imaging centers (~50%).
- I welcome your questions and comments. (858) 759-0150 or bell3660@sbcglobal.net
- B.Sc and M.Sc. (CalTech, 1972)
- PhD in Chemistry (Princeton, 1976)
- From 1983 through 1986 RAB was GE's chief MRI technical specialist for the western third of US and all of Canada
- I've conducted about 2,000 tests of MRI units (0.18T to 3T)

Learning Objectives

- Explore the desired goals of annual testing (not necessarily the same as the requirements of testing) and suggest ways to sell your services
- Review the genesis of MRI accreditation (primarily ACR but will touch on ICAMRL and the Joint Commission)
- Discuss methods to help you streamline your testing while covering all the bases.

Why is Quality Control Often Problematic?

- QC is part of most imaging operations but usually not promoted
- Technologists often view QC as having minimal positive impact
- Managers often view QC as lost scanning time and lost $
- Payors have little impact at present because they don't understand QC
- QC can help imaging facilities achieve higher uptime by identifying problems before they become catastrophic



Which is the FALSE statement?

0% 1. Site managers often view QC and accreditation as lost scanner time and money.

0% 2. Technologists often view QC as having a minimal impact on system performance.

0% 3. QC is not a common part of most imaging operations.

0% 4. QC can help sites improve uptime and scanner performance.

0% 5. Payors can have a significant impact on the need for QC and accreditation

10 Countdown

Which is the FALSE statement?

1. Site managers often view QC and accreditation as lost scanner time and money.
2. Technologists often view QC as having a minimal impact on system performance.
3. QC is not a common part of most imaging operations.
4. QC can help sites improve uptime and scanner performance.
5. Payors can have a significant impact on the need for QC and accreditation

Reference: Discussion per fourth slide

10 Countdown

(Cost of Actual Study Heuristic)

(Risk of Injury to Patient) (Diagnostic Output Accuracy)

R.A. Bell and Associates

How Testing Can Influence Quality

- Cost Per Encounter: QC should enhance efficiency (can't be burdensome) and should help to ensure the MRI is available (improve uptime and throughput)
- Risk To Patient/Personnel: MR safety policies and procedures should protect patients and personnel (lower liability), MRI testing should help to identify broken or faulty components
- Diagnostic Information Content: Is the system running in an optimal fashion? Are the coils working well? Are the monitor and filming devices properly rendering images? Are the techs trained to notice any changes in technical performance? Are there any significant image artifacts?

R.A. Bell and Associates

Which is Usually NOT a Potential Patient Risk in the MRI Environment?

20% 1. Questionable RF Screen Room Integrity
20% 2. Broken RF Coil Cables
21% 3. Ferro-Magnetic Objects in the Scanroom
20% 4. Metal Particles in the Patient's Eye
19% 5. Surgical Implants

R.A. Bell and Associates

Which is Usually NOT a Potential Patient Risk in the MRI Environment?

1. Questionable RF Screen Room Integrity
2. Broken RF Coil Cables
3. Ferro-Magnetic Objects in the Scanroom
4. Metal Particles in the Patient's Eye
5. Surgical Implants

Reference: ACR Guidance Document for Safe MR Practice: 2007", by Kanal, et al., published in AJR: 188, June 2007

Quality Improvement Incentives

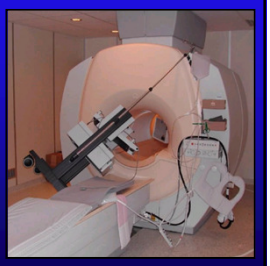
- **CARROT:** Better throughput (more $ per hour), Enhanced reputation in the community, Pay for performance (P4P) initiatives, Accreditation (ACR, IAC, JC), etc.
- **STICK:** MIPPA per accreditation (ACR, IAC, JC), Pre-authorization/gate keeper organizations, Loss of reputation in local community, Potential litigation from errors, etc.

Positive Aspects of System Evaluation (Selling QC!)

- Scanners yield more consistent performance with appropriate service attention. QC provides a check on service.
- Referrers and payors have more confidence in the quality of MRI exams
- Opportunities exist for greater operational efficiency (better uptime performance)
- The program encourages a higher level of operator confidence and attention to system performance (improved knowledge base)

MIPPA Recognized MRI QC Programs

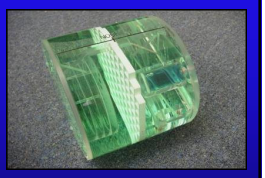
- ACR requires accredited MRI sites to have weekly and annual MRI quality control programs that meet the minimal standards outlined in the ACR's Quality Control Manual
- ICAMRL requires annual testing and an on-site QC program
- JC requires testing of all medical equipment and management of safety risks in MRI



R.A. Bell and Associates

ACR Technical Testing Can Meet the Requirements of the Other Two Programs

- ACR technical testing evaluates equipment and reviews local MRI safety policies/procedures annually. It also requires weekly on-site quality control and assesses the results annually.
- These procedures can be adopted by sites utilizing either ICAMRL or JC accreditation
- The ACR MRI phantom is a relatively inexpensive device that provides a wide range of test data



R.A. Bell and Associates

Suggestions for Optimal Testing

- Know the Equipment
- Know the Accreditation Rules
- Streamline Your Testing
- Sell Your Expertise as a Partner

R.A. Bell and Associates

KNOW THE EQUIPMENT

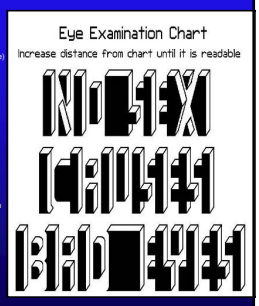
- Accreditation testing requires knowledge of MRI physics principles and familiarity with the devices examined. If you have not tested a particular model get help from someone who has. Don't try to fake it!
- You should be able to run the MRI scanner largely without assistance from techs or service. (Would you trust your car to a mechanic who couldn't drive it?)
- Some vendors' MRI units require special service software. Make connections with appropriate vendor reps as necessary.

KNOW THE RULES

- Each accreditation program has specific rules but they are not the same across programs
- For ICAMRL and JC, the local MRI physics expert can recommend the details of the MRI technical program and the phantom to be used (voted in by the site's MR Quality Control Committee)
- Ensure your testing covers all of the required ACR parameters. Failure to do so may delay your client's accreditation until the report meets ACR's standards.

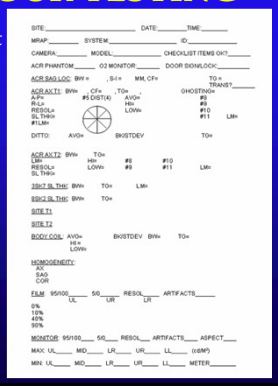
What does ACR Require?

1. Background and weekly on-site QC testing:
   - Date of test and date of report
   - Location and type of MRI system with system ID
   - MRAP number
   - Tester's name and signature (tests must be done by the person writing the report)
   - Verification of Visual Checklist items (scan room RF integrity, MRI alignment lights and table functionality, magnetic fringe field warning signs, etc.)
   - Evaluation of previous year's weekly QC, visual checklist, and film densitometry (if camera is in use) with statement of action limits for future weekly QC testing
   - Review of site's brain T1 and T2 series with ACR phantom
2. Evaluation of ACR standard tests in the head coil (ACR sagittal, T1, and T2 tests):
   - Geometric distortion in all three orthogonal planes (sagittal and T1)
   - High contrast resolution in the phase and the frequency directions (T1 and T2)
   - Slice thickness accuracy (T1 and T2)
   - Slice location accuracy (T1 and T2)
   - Ghosting ratio (T1)
   - Low contrast object detectability (LCD disk spokes) (T1 and T2)
   - Image intensity uniformity (IIU) (T1 and T2)
   - Center Frequency (CF) and Transmit Gain (TG)
3. System magnetic field homogeneity:
   - Per vendor specifications with a description of the method (in the absence of vendor specifications see the ACR MRI QC Manual for suggested guidelines)
4. System monitor:
   - Maximum and minimum luminance in the four corners and the center, its uniformity, and evaluation of any significant artifacts
   - The appropriate high and low contrast resolution, spatial accuracy, and contrast setting per the SMPTE pattern grayscale distribution (95/100 and 5/0)
5. Film (if camera is in use):
   - Faithfully represents the SMPTE pattern shown on the system monitor, evaluation of any significant artifacts, and verify site densitometry readings for 0%, 10%, 40% and 90%
6. Specialty coils:
   - Testing of all specialty coils used clinically (listed by model and serial number) with a description for each per test technique, phantom and set up used, results obtained, and Transmit Gain (TG) for each coil
   - For each volume coil the results must include SNR, ghosting ratio, image intensity uniformity, and artifact analysis
   - For each other coil (non volume) testing must include SNR and artifact analysis
7. Review of site's MR Safety Policies and Procedures with suggestions for improvement



STREAMLINE YOUR TESTING

- Have all necessary equipment with you
- Verify the ACR phantom, other phantoms, and set-up equipment are at the site
- Have a defined test plan (makes testing more efficient and helps to avoid missing data)
- Recommend service conduct a PM prior to testing


SITE:_____ DATE:_____TIME:_____
MRAP:_____ SYSTEM:_____ ID:_____
CAMERA:_____ MODEL:_____ CHECKLIST ITEMS OK?:_____
ACR PHANTOM:_____ O2 MONITOR:_____ DOOR INTERLOCK:_____
ACR SAG LOC: BW = , S-I = MM, CF= TO =
TRANS?_____
ACR AX T1: BW= CF= TO= GHOSTING=
A/P= #5 DIST(4) AVG= #9
R-L= HI= #10
RESOL= LOW= #11 LMI=
SL THK=
#1LMI=
DITTO: AVG= SK/STDEV TO=
ACR AX T2: BW= TO=
LMI= HI= #8 #10
RESOL= LOW= #9 #11 LMI=
SL THK=
3SH T SL THK: BW= TO= LMI=
8SH 2 SL THK: BW= TO=
SITE T1
SITE T2
BODY COIL: AVG= SK/STDEV BW= TO=
HI=
LOW=
HOMOGENEITY:
AX
SAG
COR
FILM 95/100_____ 50_____ RESOL_____ ARTIFACTS_____
UL UR LR
0%
10%
45%
90%
MONITOR: 95/100_____ 50_____ RESOL_____ ARTIFACTS_____ ASPECT_____
MAX: UL_____ MID_____ LR_____ UR_____ LL_____ (cd/M²)
MIN: UL_____ MID_____ LR_____ UR_____ LL_____ METER_____

R.A. Bell and Associates

You Don't Have to Use ACR Forms

- As long as your test report includes all ACR requirements you can use your own format. Make PASS and FAIL very obvious and include a comment on the first page for every failure.


2012 ANNUAL ACR TESTING OF A SIEMENS 3T VERIO MRI FOR XYZ HOSPITAL

SYSTEM: Siemens Verio 3T
LOCATION: Anytown, CA
MRAP: 00000.01
DATE OF TEST: 6-01-001-2

This report also contains methods and discussions per the ACR MR annual benchmark testing. Please share this report with your service vendor if you wish and direct any questions they may have to me (858-759-0150).

EQUIPMENT EVALUATION TESTS:

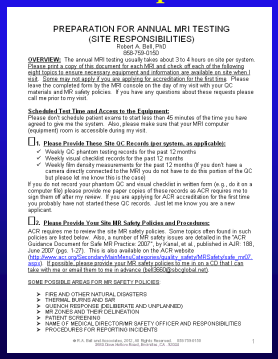
Please note that failure of one or more of the following criteria do not constitute failure of ACR accreditation. The annual system testing is designed to help sites identify technical aspects that may need attention from service or staff

1. Table/Room Assessment	PASS
2. Console Assessment	PASS (see comments)
3. Center Frequency/Transmit Gain	PASS
4. Image Intensity Uniformity (IIU)	PASS
5. Geometric Distortion	PASS
6. High Contrast Spatial Resolution	PASS
7. Low Contrast Detectability	PASS
8. Artifacts	PASS
9. Laser Camera QC	NA
10.Magnetic field homogeneity	PASS
11.Slice position accuracy	PASS
12.Slice thickness accuracy	PASS (see comments)
13.RF coil performance	PASS
14.System monitor	PASS (see comments)
15.Review of QC Data, Vis Chklst, Film	PASS (see comments)
16.Review of site MR safety policies	See section 5

COMMENTS: During testing there was an error message that the RF had exceeded its limits and I had to reboot the system. Slice thickness measurements for 5mm, 5mm, and 8mm indicate actual thicknesses about 10% larger than nominal. Service should check this. There were minor "burn" artifacts to the lower center and right on the monitor. If these impede image viewing and cannot be removed the monitor should be replaced. In the weekly QC reports I suspect the high contrast resolution data is being misread by staff. The weekly QC reports show many instances of 1.1mm resolution but I have routinely found 0.9mm for this system. Please check the weekly QC procedures against the ACR MRI QC manual to ensure proper recording.

R.A. Bell and Associates

Site Responsibilities and Follow Up


PREPARATION FOR ANNUAL MRI TESTING
(SITE RESPONSIBILITIES)
Robert A. Bell, PhD
858-759-0150

OVERVIEW: The annual MRI testing usually takes about 3 to 4 hours on site per system. Please print a copy of this document for each MR and check off each of the following eight topics to ensure necessary equipment and information are available on site when I visit. Some may not apply if you are applying for accreditation for the first time. Please leave the completed form by the MR console on the day of my visit with your QC materials and MR safety policies. If you have any questions about these requests please call me prior to my visit.

Scheduled Test Time and Access to the Equipment:
Please don't schedule patient exams to start less than 45 minutes of the time you have agreed to give me the system. Also, please make sure that your MRI computer (magnet) room is accessible during my visit.

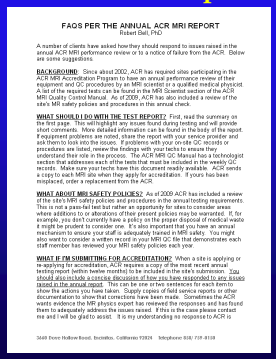
☐ 1. **Please Provide These Site QC Records (per system, as applicable):**
- ✓ Weekly QC phantom testing records for the past 12 months
- ✓ Weekly visual checklist records for the past 12 months
- ✓ Weekly film density measurements for the past 12 months (if you don't have a camera directly connected to the MR you do not have to do this portion of the QC but please let me know this is the case)

If you do not record your phantom QC and visual checklist in written form (e.g., do it on a computer file) please provide me paper copies of these records as ACR requires me to sign them off after my review. If you are applying for ACR accreditation for the first time you probably have not started these QC records. Just let me know you are a new applicant.

☐ 2. **Please Provide Your Site MR Safety Policies and Procedures:**
ACR requires me to review the site MR safety policies. Some topics often found in such policies are listed below. Also, a number of MR safety issues are detailed in the "ACR Guidance Document for Safe MR Practice: 2007", by Kanal, et al, published in AJR: 188, June 2007 (pgs. 1-27). This is also available on the ACR website. (http://www.acr.org/SecondaryMainMenuCategories/quality_safety/MRSafetyIndx_mnGC.aspx) If possible, please provide your MR safety policies to me in an e-CD that I can take with me or email them to me in advance (bell3660@sbcglobal.net).

SOME POSSIBLE AREAS FOR MR SAFETY POLICIES

- FIRE AND OTHER NATURAL DISASTERS
- THERMAL BURNS AND SAR
- QUENCH RESPONSE (DELIBERATE AND UNPLANNED)
- MR ZONES AND THEIR DELINEATION
- PATIENT SCREENING
- NAME OF MEDICAL DIRECTOR/MR SAFETY OFFICER AND RESPONSIBILITIES
- PROCEDURES FOR REPORTING INCIDENTS


FAQS PER THE ANNUAL ACR MRI REPORT
Robert Bell, PhD

A number of clients have asked how they should respond to issues raised in the annual ACR MRI performance review or to a notice of failure from the ACR. Below are some suggestions:

BACKGROUND: Since about 2002, ACR has required sites participating in the ACR MRI Accreditation Program to have an annual performance review of their equipment and QC procedures by an MRI scientist or a qualified medical physicist. A list of the required tests can be found in the MRI Scientist section of the ACR MRI Quality Control Manual. As of 2009, ACR has also included a review of the site's MR safety policies and procedures in this annual check.

WHAT SHOULD I DO WITH THE TEST REPORT? First, read the summary on the first page. This will highlight any issues found during testing and will provide short comments. More detailed information can be found in the body of the report. If equipment problems are noted, share the report with your service provider and ask them to look into the issues. If problems with your on-site QC records or procedures are listed, review the findings with your techs to ensure they understand their role in the process. The ACR MRI QC Manual has a technologist section that addresses each of the tests that must be included in the weekly QC records. Make sure your techs have this document readily available. ACR sends a copy to each MRI site when they apply for accreditation. If yours has been misplaced, order a replacement from the ACR.

WHAT ABOUT MRI SAFETY POLICIES? As of 2009 ACR has included a review of the site's MRI safety policies and procedures in the annual testing requirements. This is not a pass-fail test but rather an opportunity for sites to consider areas where additions to or alterations of their present policies may be warranted. If, for example, you don't currently have a policy on the proper disposal of medical waste it might be prudent to consider one. It's also important that you have an annual mechanism to ensure your staff is adequately trained in MRI safety. You might also want to consider a written record in your MRI QC file that demonstrates each staff member has reviewed your MRI safety policies each year.

WHAT IF I'M SUBMITTING FOR ACCREDITATION? When a site is applying or re-applying for accreditation, ACR requires a copy of the most recent annual testing report (within twelve months) to be included in the site's submission. You should also include a concise discussion of how you have responded to any issues raised in the annual report. This can be one or two sentences for each item to show the actions you have taken. Supply copies of field service reports or other documentation to show that corrections have been made. Sometimes the ACR wants evidence the MR physics expert has reviewed the responses and has found them to adequately address the issues raised. If this is the case please contact me and I will be glad to assist. It is my understanding no response to ACR is

3440 Dove Hollow Road, Bucksbin, California 93924 Telephone: 831/ 731-8138

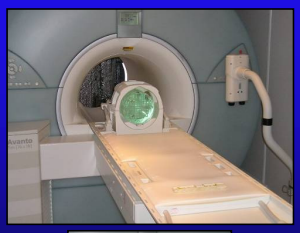
R.A. Bell and Associates

Make Yourself Valuable as a Partner

- Encourage the local decision makers to embrace QC (explain carrot and stick)
- Make your testing as PAINLESS as possible (convenient schedule, LNT, remove bubbles in the phantom, etc.)
- While you are on site testing, offer to conduct an in-service to help local techs understand their weekly QC procedures and responsibilities
- Include a check the five technical MRI scans the site will submit for accreditation
- Respond to questions (via phone/email) and help with possible appeals should the site fail a portion of accreditation

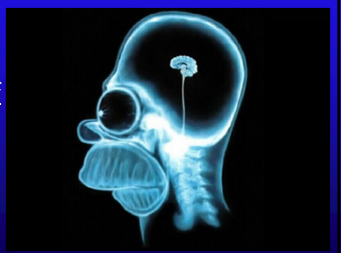
Tips for Efficiency

- Start with the ACR phantom in the head coil and take all five required head studies, slice thickness, and the body coil test
- While one study is acquiring, you can analyze the data from the previous study and review the previous year's QC.
- Then test each specialty coil (as indicated by the site)
- Finish with homogeneity, film, and monitor testing.
- IT'S NOT OUR JOB TO FIX IT!



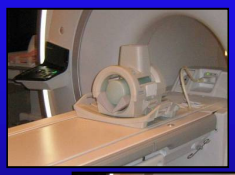
Head Coil Studies

- ACR now requires acquisition of ALL FIVE technical scans submitted for accreditation as part of the annual testing
- ACR Sagittal Study
- ACR T1 Axial Study
- ACR T2 Axial Study
- SITE T1 Axial Study
- SITE T2 Axial Study

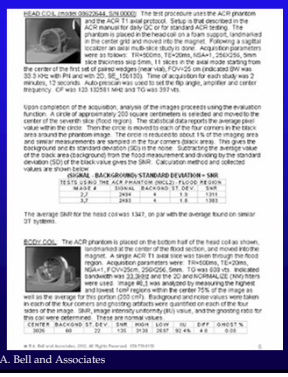


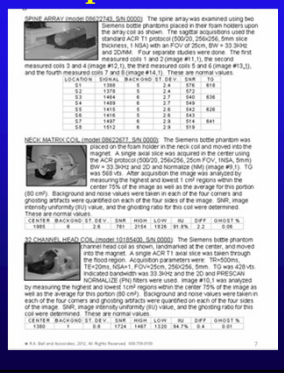
Specialty Coils

- For all volume coils one must include analysis of SNR, ghosting ratio, and image intensity uniformity
- For non-volume coils one must conduct SNR and artifact analysis
- Don't forget to include model number, serial number, and Transmit Gain
- You need only test those coils the site states it uses clinically



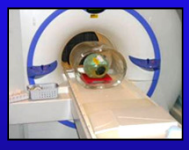
Include a Description

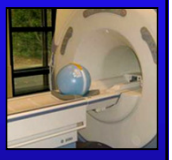


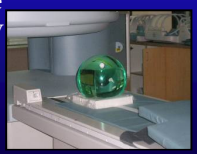


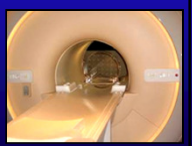
Homogeneity

- There are a variety of methods to evaluate homogeneity. Use the one that works best for the type of equipment and the phantoms you have available. This may also depend on the access to service software that you have.



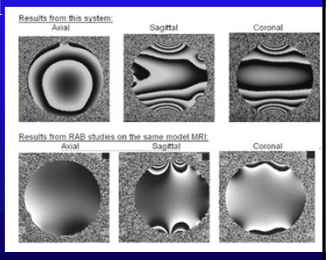






Phase Contrast Method

- Use GRE study and flood phantom (sphere is best)
- Select TE per the field strength (1.5T = 15.6ms, 3T = 7.8 ms, 0.5T = 47ms)
- Do Phase Reconstruction
- Each black to white transition equals 0.5ppm

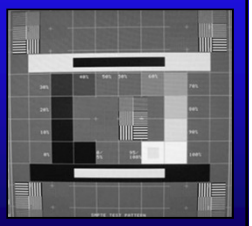


Reviewing Site Records

- Check center frequency shift to ensure drift rate is within vendor specs.
- Check Transmit Gain variation (RF health)
- Check distances, resolution, and spokes data
- Provide Action Limits for CF, TG, geometric distortion, high contrast resolution, and spoke count (low contrast disks)
- Review MR Safety policies and procedures with suggestions for improvement

Other Tests

- Monitor: SMPTE pattern for 0%/5% and 95%/100%, geometric distortion, low contrast resolution, max and min luminance as well as uniformity. Look For Artifacts!
- Film: Does the film faithfully represent what is seen on the monitor? Check optical densities for 0%, 10%, 40%, and 90% SMPTE grayscales. Look For Artifacts and variations across the film (6 on 1)



Which is NOT part of the ACR Annual MRI Testing Program

19% 1. Magnet Homogeneity Check
23% 2. RF Crosstalk Test
19% 3. Slice Thickness Test
22% 4. Examination of All Coils Used Clinically
18% 5. System Monitor Luminance Testing

R.A. Bell and Associates

Which is NOT part of the ACR Annual MRI Testing Program?

1. Magnet Homogeneity Check
2. RF Crosstalk Test
3. Slice Thickness Test
4. Examination of All Coils Used Clinically
5. System Monitor Luminance Testing

Reference: Slide #18 and ACR MRI QC Manual

R.A. Bell and Associates

Which is NOT a Reason to View the SMPTE Pattern as Part of ACR Testing

19% 1. ACR tells us to do it
21% 2. Check for proper high/low contrast resolution
21% 3. Check for proper grayscale distribution
19% 4. Check for artifacts in the monitor
21% 5. Check for proper monitor refresh rate

R.A. Bell and Associates

Which is NOT a Reason to View the SMPTE Pattern as Part of ACR Testing?

1. ACR tells us to do it
2. Check for proper high/low contrast resolution
3. Check for proper grayscale distribution
4. Check for artifacts in the monitor
5. Check for proper monitor refresh rate

Reference: Discussion during slide #30

How Can Proper MRI Testing and Weekly QC Affect Imaging Operations?

21% 1. Decrease system availability
20% 2. Improve diagnostic content
19% 3. Exacerbate patient risk
20% 4. Increase system downtime
21% 5. Prevent timely vendor service

How Can Proper MRI Testing and Weekly QC Affect Imaging Operations?

1. Decrease system availability
2. Improve diagnostic content
3. Exacerbate patient risk
4. Increase system downtime
5. Prevent timely vendor service

Reference: Discussion during slide #7

SUMMARY

- MRI QC and annual testing can benefit the site through enhanced uptime and optimal imaging performance.
- MRI physics services should be an integral AND PAINLESS part of the site's quality control.
- Competent annual physics testing is the most important check on the quality of vendor service
- *If your testing is not competent and painless please send me your client list.*

R.A. Bell and Associates

Acknowledgements:

- My thanks to Dr. Joseph Och and to the AAPM for this opportunity to speak.
- Thanks also to Marge Innovera for data analysis, my fact checker Ella Fynoe, Candice B. Rittenoff for tax and travel help, and to Xavier Breath for reviewing my talk.
- Thank you for your kind attention. I welcome your comments or questions. (bell3660@sbcglobal.net, 858-759-0150)

R.A. Bell and Associates