MAYO CLINIC

MR Protocol Review

Clinical Opportunities for Physicists

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AAPM Spring Clinical Meeting
New Orleans, LA
March 2017

No conflict of interest to declare

AAPM Newsletter March/April 2017

- Physics Summit on Imaging Physics – Dr. Thomadsen, AAPM President-Elect's Report
  - "The future of imaging physics is very much more uncertain than the issues discussed at the summit"
  - "Other than [QA] testing and review, further interactions between the medical physicist and the facility depends on the largess of its director since there is no identifiable revenue stream for imaging physics as there is for therapy"
  - "This is a big loss for the facility, the patients, and the medical physicist"

Technical to Clinical Transition - How?

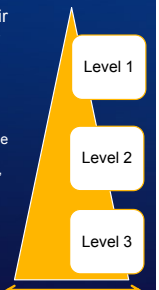
- PROTOCOLS

"It is the scanner protocols NOT accreditation that determines individual patient care"

– Dr. William Pavlicek, Chair Medical Physics, Radiology, Mayo Arizona

Technical to Clinical Transition - How?

- Diagnostic Work and Workforce Study Subcommittee (DWWSS) – Dustin Gress, Chair
  - **Level 1:** Well defined, mandated by either regulatory requirements or national accreditation programs and are required to be performed by or under the supervision of a medical physicist. Example, annual physics QA
  - **Level 2:** Somewhat mature, but non-mandatory to be performed by a medical physicist. Medical physicists add value when performing these services. Example, designing a fluoroscopy safety program per Report 168 NCRP
  - **Level 3:** Neither well defined nor mandated by authorities outside the healthcare institution. Broadly categorized as research or developmental services. Example, dual-energy CT dose optimization



Technical to Clinical – MR Safety

- MRI safety policy review
  - Level 2 activity mainly carried out by physicians and MRI technologists in many settings
  - ACR Expert Panel on MR Safety publications, most recent 2013
  - ACR MRI Accreditation Program 2015 requirement annual review of MR safety program an explicit (Level 1) medical physicist responsibility

Technical to Clinical – CT Protocol

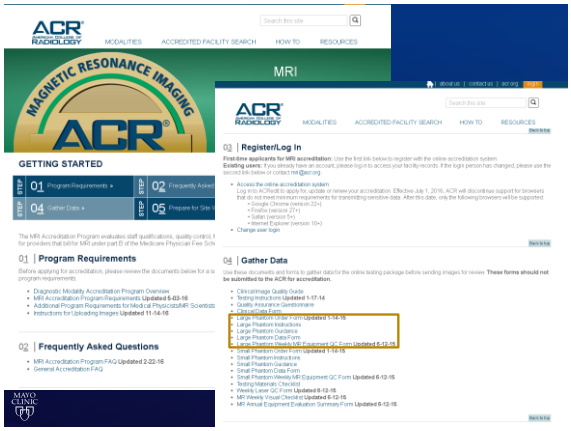
- CT protocol review committee participation
  - Established at Level 2 with the publication of AAPM MPPG #1a
  - Became Level 1 service for all Joint Commission-accredited facilities effective July 1, 2015 with new accreditation requirements for diagnostic imaging
- MR can learn from CT protocol efforts!

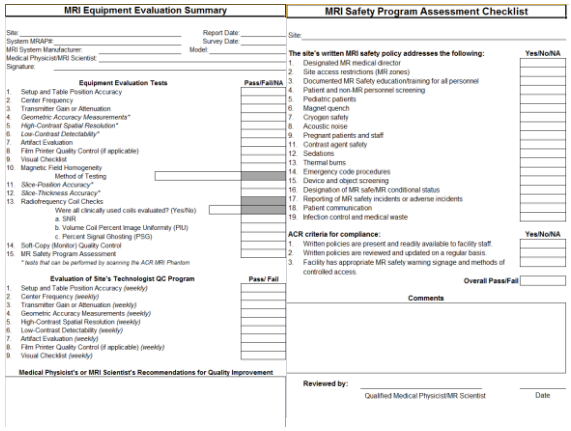
"Imitation is the sincerest form of flattery"

MR Protocol – DWWSS Level of Service

- **Level 1**: Required for accreditation under mandatory physicist supervision
  - Parameter review for ACR physics phantom QC
  - Annual MR safety survey
    - Acoustic noise – GE Silent, Siemens Quite
- **Level 2**: Structured, needed for accreditation or patient care, medical physicists involvement not required
  - ACR parameter review for clinical MR protocols
  - Low-SAR protocol development- Pacemakers, Neurostimulators
- **Level 3**: Neither well defined nor mandated, primarily research and clinical development activities
  - Image acquisition optimization – fat sat, metal artifact reduction
  - New sequences, hardware, software
  - Bonus material!

MR Protocol Review





MRI Equipment Evaluation Summary

Site: Report Date:
System MRAPH: Survey Date:
MRI System Manufacturer: Model:
Medical Physicist/MRI Scientist:
Signature:

Equipment Evaluation Tests	Pass/Fail/NA
1. Setup and Table Position Accuracy	
2. Center Frequency	
3. Transmitter Gain or Attenuation	
4. *Geometric Accuracy Measurements**	
5. *High-Contrast Spatial Resolution**	
6. *Low-Contrast Detectability**	
7. Artifact Evaluation	
8. Film Printer Quality Control (if applicable)	
9. Visual Checklist	
10. Magnetic Field Homogeneity	
Method of Testing	
11. *Slice-Position Accuracy**	
12. *Slice-Thickness Accuracy**	
13. Radiofrequency Coil Checks	
Were all clinically used coils evaluated? (Yes/No)	
a. SNR	
b. Volume Coil Percent Image Uniformity (PIU)	
c. Percent Signal Ghosting (PSG)	
14. Soft-Copy (Monitor) Quality Control	
15. MR Safety Program Assessment	

Evaluation of Site's Technologist QC Program	Pass/ Fail
1. Setup and Table Position Accuracy *(weekly)*	
2. Center Frequency *(weekly)*	
3. Transmitter Gain or Attenuation *(weekly)*	
4. Geometric Accuracy Measurements *(weekly)*	
5. High-Contrast Spatial Resolution *(weekly)*	
6. Low-Contrast Detectability *(weekly)*	
7. Artifact Evaluation *(weekly)*	
8. Film Printer Quality Control (if applicable) *(weekly)*	
9. Visual Checklist *(weekly)*	

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

* *Tests that can be performed by scanning the ACR MRI Phantom*

MRI Safety Program Assessment Checklist

Site:

The site's written MRI safety policy addresses the following:	Yes/No/NA
1. Designated MR medical director	
2. Site access restrictions (MR zones)	
3. Documented MR Safety education/training for all personnel	
4. Patient and non-MR personnel screening	
5. Pediatric patients	
6. Magnet quench	
7. Cryogen safety	
8. Acoustic noise	
9. Pregnant patients and staff	
11. Contrast agent safety	
12. Sedations	
13. Thermal burns	
14. Emergency code procedures	
15. Device and object screening	
16. Designation of MR safe/MR conditional status	
17. Reporting of MR safety incidents or adverse incidents	
18. Patient communication	
19. Infection control and medical waste	

ACR criteria for compliance:	Yes/No/NA
1. Written policies are present and readily available to facility staff.	
2. Written policies are reviewed and updated on a regular basis.	
3. Facility has appropriate MR safety warning signage and methods of controlled access.	

Overall Pass/Fail

Comments

Reviewed by:

Qualified Medical Physicist/MR Scientist — Date

Phantom QA Acquisition Protocol

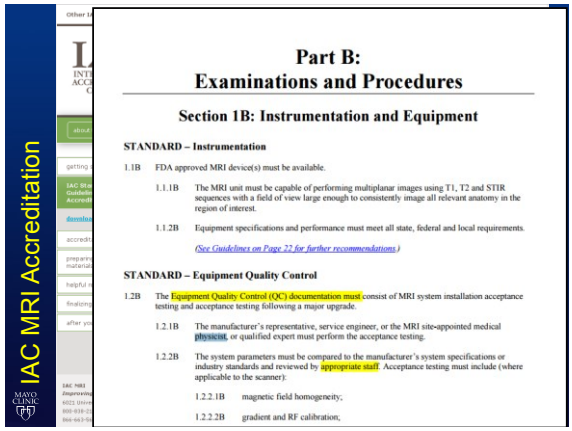
Pulse Sequence Acquisition Parameters

In the box below each parameter:
Record actual values if they differ from the prescribed protocol parameters **or**
Place a check mark to indicate use of prescribed parameter.
Fill in ***all*** *parameters for "Your Site's Axial T1- and T2-weighted Brain Scan."*

	a Study	b Pulse Sequence	c TR (ms)	d TE (ms)	e FOV (cm)	f Number of Slices	g Slice Thickness (mm)	h Slice Gap (mm)	i NEX	j Matrix	k Routine Receive Band-Width (kHz)	l Scan Time (min:sec)
8.	ACR Sagittal locator	Spin Echo	*200*	*20*	*25*	*1*	*20*	*N/A*	*1*	*256*	*256*	*0:56*
								N/A				
9.	ACR Axial T1	Spin Echo	*500*	*20*	*25*	*11*	*5*	*5*	*1*	*256*	*256*	*2:16*
10.	ACR Axial T2 Double-echo	Spin Echo	*2000*	*20/80* /	*25*	*11*	*5*	*5*	*1*	*256*	*256*	*8:56*
11.	Your Site's Axial T1 weighted Brain Scan				*Freq:* *Phase:*	*11*	*5*	*5*				
12.	Your Site's Axial T2 weighted Brain Scan				*Freq:* *Phase:*	*11*	*5*	*5*				

13. Scan Options Used on the ACR Spin-echo T1- and T2-weighted Axial Scans: _____
14. Scan Options Used on "Your Site's Axial T1- and T2-weighted Brain Scans:" _____
15. Serial number of phantom used for testing _____

IAC MRI Accreditation



Part B:
Examinations and Procedures

Section 1B: Instrumentation and Equipment

STANDARD – Instrumentation

1.1B FDA approved MRI device(s) must be available.

1.1.1B The MRI unit must be capable of performing multiplanar images using T1, T2 and STIR sequences with a field of view large enough to consistently image all relevant anatomy in the region of interest.

1.1.2B Equipment specifications and performance must meet all state, federal and local requirements.

(See Guidelines on Page 22 for further recommendations.)

STANDARD – Equipment Quality Control

1.2B The Equipment Quality Control (QC) documentation must consist of MRI system installation acceptance testing and acceptance testing following a major upgrade.

1.2.1B The manufacturer's representative, service engineer, or the MRI site-appointed medical physicist, or qualified expert must perform the acceptance testing.

1.2.2B The system parameters must be compared to the manufacturer's system specifications or industry standards and reviewed by appropriate staff. Acceptance testing must include (where applicable to the scanner):

1.2.2.1B magnetic field homogeneity;

1.2.2.2B gradient and RF calibration;

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Level 1	• Required for accreditation under mandatory physicist supervision
Level 2	• Structured, accreditation or pt care, medical physicists involvement not required
Level 3	

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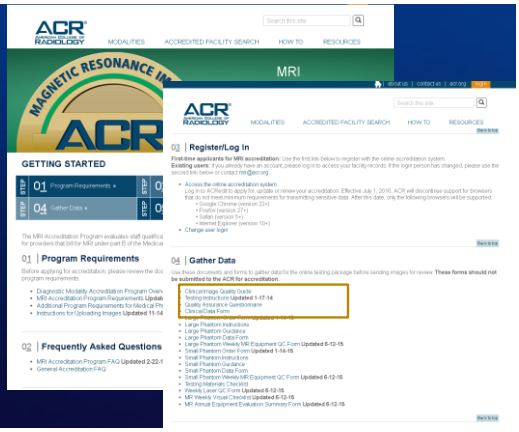
ACR Clinical Image Quality



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ACR Clinical Image Quality

MRI Accreditation Program
Clinical Image Quality Guide

Submitted Data Report

THIS INFORMATION IS FOR INTERNAL FACILITY REVIEW ONLY.
DO NOT SUBMIT THIS PRINTOUT TO THE ACR.

ACR®
AMERICAN COLLEGE OF RADIOLOGY
1891 Preston White Drive
Reston, VA 20191

SUBMITTED DATA REPORT

Submitted on : 07/21/2013

Magnetic Resonance Imaging #00557-04
Mayo Clinic Hospital

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ACR MR Accreditation – Clinical Modules

Examination choices for MR Accreditation by module (specialty examinations denoted by asterisk*)		
Head/Neck	**Spine**	**MSK**
• 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*	• Lumbar Spine • Thoracic Spine • Cervical Spine* • Cervical Spine with contrast for intramedullary disease*	• 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	**MRA**	**Cardiac**
• Male pelvis such as for prostate cancer • Renal • Hepatobiliary to Include MRCP* • Female pelvis such as for uterine or adnexal disease*	• Brain • Carotid • Thoracic aorta • Distal peripheral runoff • High resolution arch and carotid* • Abdomen for renal artery stenosis *	• Black blood • Basic • Delayed enhanced cine 1 • Delayed enhanced cine 2 • Delayed enhanced cine + black blood*

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ACR Cervical Spine Requirements

Cervical Spine * - maximum examination time ≤ 35 minutes			
Required Sequences	**Category A: Pulse Sequence and Image Contrast**	**Category C: Anatomic coverage and imaging planes** *Failure to meet these specifications will result in failure.*	**Category D: Spatial Resolution**
Sagittal dark fluid	• Should not have non-anatomic heterogeneous signal intensity of the cord. • CSF must be hypointense to the cord/nerve roots so that cord/nerve roots are clearly defined. • Fat must not be so intense that it masks the fat/muscle plane. • Must show good contrast between the cord and CSF. • T1 FLAIR is acceptable for this sequence	• Must cover foramen magnum to T1. • Must cover laterally through the neural foramina.	Slice thickness ≤ 3.0 mm Gap ≤ 1.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.0 mm Pixel area ≤ 1.0 mm²
Sagittal bright fluid	• Should not have non-anatomic heterogeneous signal intensity of the cord. • CSF must be hyperintense to the cord/nerve roots so that cord/nerve roots are clearly defined. • Fat must not be so intense that it masks the fat/muscle plane. • Must show good contrast between the cord and CSF.	• Must cover foramen magnum to T1. • Must cover laterally through the neural foramina.	Slice thickness ≤ 3.0 mm Gap ≤ 1.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.0 mm Pixel area ≤ 1.0 mm²
Axial bright fluid	• Should not have non-anatomic heterogeneous signal intensity of the cord. • CSF must be hyperintense to the cord/nerve roots so that cord/nerve roots are clearly defined. • Fat must not be so intense that it masks the fat/muscle plane. • Must show good contrast between the cord and CSF.	Must cover contiguously from C3 to T1.	Slice thickness ≤ 3.0 mm Gap ≤ 1.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.0 mm Pixel area ≤ 1.0 mm²

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ACR Cervical Spine Datasheet

CLINICAL TEST IMAGE DATASHEET (CERVICAL SPINE)

1. Scanner Serial number:	45327
2. Manufacturer:	Siemens
3. Model name:	MAGNETOM SKYRA 3T
4. Year manufactured:	2012
Type of exam:	Cervical Spine
Date of exam:	06/04/2013
Reason for exam:	Pain Neck
Age of patient:	53
Approximate weight of patient, if applicable (kg):	77.0

Parameter	Sagittal dark fluid	Sagittal bright fluid	Axial bright fluid
Sequence name/type	T1 TSE	T2 TSER	T2 TSER
Sequence #	3	2	5
Orientation	Sagittal	Sagittal	Axial
Slice thickness (mm)	3.0	3.0	3.0
Gap (mm)	0.45	0.45	0.00
FOVp (mm)	200.0	200.0	160.0
FOVf (mm)	200.0	200.0	160.0
Np (acquisition phase matrix)	320.0	384.0	256.0
Nf (acquisition frequency matrix)	256.0	288.0	192.0
Np (reconstruction phase matrix)	320.0	384.0	256.0
Nf (reconstruction frequency matrix)	320.0	384.0	256.0
Np (display phase matrix)	320.0	384.0	256.0
Nf (display frequency matrix)	320.0	384.0	256.0
# Acquisitions	2.000	2.000	2.000
TR (ms)	500.0000	4070.0000	6520.0000
TE (ms)	9.7	108	84
Flip Angle	140	150	160
TI	0	0	0

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Physicist QC Check - ACR Cervical Spine

Accession: **FAILED**

	Sagittal dark fluid	Sagittal bright fluid	Axial bright fluid
Slice thickness (≤ 3.0 mm)	Pass	Pass	Pass
Gap (≤ 1.0 mm)	Pass	Fail	Pass
In plane pixel(read) (≤ 1.0 mm)	Pass	Pass	Pass
In plane pixel(phase) (≤ 1.0 mm)	Pass	Pass	Fail
Pixel area (≤ 1.0 mm2)	Fail	Pass	Pass

ACR Cardiac Delayed Enhanced

Delayed Enhanced Cine with Black Blood*

Required Sequences	Category A: Pulse Sequence and Image Contrast	Category C: Anatomic coverage and imaging planes *Failure to meet these specifications will result in failure.*	Category D: Spatial Resolution
BLACK BLOOD - Axial	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Must be T1 (1 R-R/short TE) or proton density weighted (2 R-R/short TE) • Must be in the axial plane • Must have good myocardium discrimination (including good blood suppression) • TE can be optimized for your system, but should be proton density/ T1 -weighted (less than approximately 45 msec) **This sequence may be from a different patient from the other sequences.** **Note that single shot (e.g., "HASTE", " SSFSE" or "SSTSE") imaging technique is not acceptable.**	Must cover from aortic root to diaphragm (axial)	Slice thickness ≤ 8.0 mm Gap ≤ 4 mm In plane pixel (read) ≤ 1.6 mm In plane pixel (phase) ≤ 2.5 mm Pixel area ≤ 4.0 mm²
SHORT AXIS CINE	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Real time cine images are not acceptable • Must show entire systolic cycle • Must have good myocardium discrimination (including good blood suppression) • Must image end systole and end diastole • Steady State free precession technique is preferred, but fast gradient echo is allowed	Must cover entire left ventricle from base to apex	Slice thickness ≤ 8.0 mm In plane pixel (read) ≤ 1.6 mm In plane pixel (phase) ≤ 2.5 mm Pixel area ≤ 4.0 mm² Temporal resolution ≤80 msec (without view sharing)
LONG AXIS CINE 2 Chamber	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Real time cine images are not acceptable • Must show entire systolic cycle • Must have good myocardium discrimination (including good blood suppression) • Must image end systole and end diastole • Steady State free precession technique is preferred, but fast gradient echo is allowed	Single slice oriented vertically through the middle portion of the left atrium and the middle portion of the left ventricle	Slice thickness ≤ 8.0 mm In plane pixel (read) ≤ 1.6 mm In plane pixel (phase) ≤ 2.5 mm Pixel area ≤ 4.0 mm² Temporal resolution ≤80 msec (without view sharing)
LONG AXIS CINE 4 Chamber	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Real time cine images are not acceptable • Must show entire systolic cycle • Must have good myocardium discrimination (including good blood suppression) • Must image end systole and end diastole • Steady State free precession technique is preferred, but fast gradient echo is allowed	Single slice oriented vertically through the middle portion of the left atrium and the middle portion of the left ventricle	Slice thickness ≤ 8.0 mm In plane pixel (read) ≤ 1.6 mm In plane pixel (phase) ≤ 2.5 mm Pixel area ≤ 4.0 mm² Temporal resolution ≤80 msec (without view sharing)
LONG AXIS CINE Aortic Outflow Tract	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Real time cine images are not acceptable • Must show entire systolic cycle • Must have good myocardium discrimination (including good blood suppression) • Must image end systole and end diastole • Steady State free precession technique is preferred, but fast gradient echo is allowed	Single slice oriented vertically through the middle portion of the left atrium and the middle portion of the left ventricle	Slice thickness ≤ 8.0 mm In plane pixel (read) ≤ 1.6 mm In plane pixel (phase) ≤ 2.5 mm Pixel area ≤ 4.0 mm² Temporal resolution ≤80 msec (without view sharing)
DELAYED GADOLINIUM ENHANCED	• Must be gated to the cardiac cycle • Must have no significant arrhythmia during the MRI cardiac cycle • Must be in the short axis plane in patients with prior myocardial infarction • Inversion prepared gradient echo pulse sequence • Must choose TI so that there is good suppression of normal myocardium • Must show sufficient contrast between normal myocardium and scar	Must cover entire left ventricle from base to apex in the short axis	Slice thickness ≤ 10.0 mm Gap ≤ 2.0 mm In plane pixel (read) ≤ 1.9 mm In plane pixel (phase) ≤ 3.1 mm Pixel area ≤ 5.9 mm²

ACR Cardiac Delayed Enhanced

CLINICAL TEST IMAGE DATASHEET (DELAYED ENHANCED CINE WITH BLACK BLOOD)

1. Scanner Serial number:	45327
2. Manufacturer:	Siemens
3. Model name:	MAGNETOM SKYRA 3T
4. Year manufactured:	2012
Type of exam:	Delayed Enhanced Cine With Black Blood
Date of exam:	06/18/2013
Reason for exam:	PALPITATION, CARDIOMYOPATHY, NOS
Age of patient:	31
Approximate weight of patient, if applicable (kg):	56.0

Parameter	Short Axis Cine	Long Axis Cine 2 Chamber	Long Axis Cine 4 Chamber	Long Axis Cine Aortic Outflow Tract	Delayed Gadolinium enhanced	Black Blood Sequence
Sequence name/type	SHORT AXIS STACK TP2D	2CH TP2D	4CH SS TP2D	AO LOC TP2D	TI SAX DELAYS FL	DIR DB TSE
Sequence #	34	31	32	57	86	7
Orientation	Oblique	Oblique	Oblique	Oblique	Oblique	Axial
Slice thickness (mm)	5.0	5.0	5.0	5.0	8.0	5.0
Gap (mm)	0.00	0.00	0.00	0.00	1.60	0.00
FOVp (mm)	270.0	312.0	257.0	312.0	350.0	276.0
FOVf (mm)	340.0	340.0	340.0	340.0	350.0	340.0
Np (acquisition phase matrix)	134.0	154.0	157.0	154.0	164.0	208.0
Nf (acquisition frequency matrix)	224.0	224.0	224.0	224.0	256.0	256.0
Np (reconstruction phase matrix)	178.0	206.0	196.0	206.0	256.0	208.0
Nf (reconstruction frequency matrix)	224.0	224.0	224.0	224.0	256.0	256.0
Np (display phase matrix)	128.0	206.0	196.0	206.0	256.0	208.0
Nf (display frequency matrix)	224.0	224.0	224.0	224.0	256.0	256.0
# Acquisitions	1.000	1.000	1.000	1.000	1.000	1.000
TR (ms)	29.6600	23.6600	29.6600	23.6600	500.0000	954.0000
TE (ms)	1.8	1.5	1.8	2.0	1.6	24
Flip Angle	77	58	76	58	20	180
TI	0	0	0	0	270	0
Temporal resolution (ms)	30	24	30	24	500	
# Views per Segment	7	7	7	7	41	

MR Protocol Review

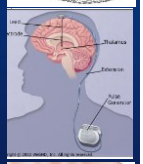
Level 1 • Required for accreditation under mandatory physicist supervision

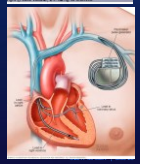
Level 2 • Structured, accreditation or pt care, medical physicists involvement not required

Level 3

Low SAR Protocol Development

- Growing need for low SAR sequences
  - Patients with reduced thermoregulator capacity
    - Cardiac impairment; hypertension; diabetes; obesity; fever
    - Pregnancy (risk for fetal heating)
    - Unconscious, sedated, locally anesthetized
  - Patients with implanted devices
    - Stents, retained leads, wires
    - Neurostimulators: DBS (0.1W/kg), VNS
    - Cardiac Devices: Pacemakers, ICDs, CRT-Ds





FDA MR-Conditional Approvals: 2015 vs 2016

2015

- Pacemakers
  - Medtronic Revo
  - Medtronic Advisa
  - Biotronik Entovis
  - Biotronik Eluna
- ICDs
  - Medtronic Evera

2016

- Pacemakers
  - Boston Scientific Accolade
  - Boston Scientific Essentio
  - Medtronic Micra Pacemaker
- ICDs
  - Boston Scientific Emblem
  - Biotronik Iperia 7 VR-T DX
  - Biotronik Inventra VR-T DX
  - Biotronik Iforia DR-T / VR-T DX
  - Medtronic Visia AF
- CRT-Ds
  - Biotronik Iperia HF-T
  - Biotronik Inventra HF-T
  - Medtronic Amplia Quad
  - Medtronic Compia Quad

SUPERSAR TECHNOLOGIST Pacemaker/ICD SAR Monitoring Sheet

Updated Form on: 4/20/2016

Date:			
SuperSAR Technologist:			
Scanning MR Technologist:			
PACEMAKER/ICD DETAILS			
Is this a Pacemaker or ICD?			
Is this an MR-Conditional device?			*Yes/No*
Is Pacemaker set at MR Compatible Mode; *eg: SureScan?*			*Yes/No*
If MR Conditional ICD, is ICD turned OFF?			*Yes/No*
MR CONDITIONAL Pacemaker/ICD Info:		**MR CONDITIONAL Lead Info:**	
		Atrial Lead	**Ventricular Lead**
Manufacturer:		Manufacturer:	Manufacturer:
Model/Serial		Model/Serial	Model/Serial
Implantation Date:		Implantation Date:	Implantation Date:
MR Conditional:		MR Conditional:	MR Conditional:
SCANNER and PROTOCOL DETAILS			
MR scanner:		**MCH-MR1**	
MR region scanned:			
Coil used:			
Pacemaker protocol used: (Only use Pacemaker Protocols; if no protocol present please contact the on-call physicist before proceeding)			
Scan performed on **1.5T Scanner**			*Yes/No*

SAR Reduction Strategies:		**General Notes:**
STEP 1	Increase TR	
STEP 2	Decrease flip angle	
STEP 3	Decrease # of slices (for 2D scans)	
STEP 4	Reduce echo-train-length for FSE	
STEP 5	**If the strategies don't work, contact on-call Physicist**	
If Physicist Contacted		*Yes/No; Physicist name*

PHYSICIST SECTION:		
Final physicist approval	**Name**	**Date**

SAR Reduction Strategies

- Set RF Type to "Low SAR", "Normal Mode"
- Decrease # of slices (for 2D scans)
- Decrease # of averages
- Eliminate SAT bands and Fat Sat
- Increase TR
- Decrease flip angle
- Reduce echo-train-length for FSE/TSE
  - Gradient echo scans provide less SAR than spin echo
  - Spin echo scans provide less SAR than fast (turbo) spin echo

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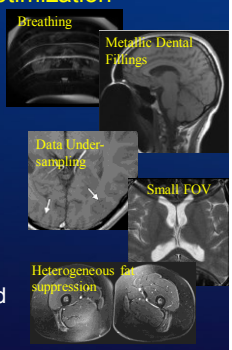
Level 1	• Required for accreditation under mandatory physicist supervision
Level 2	• Structured, accreditation or pt care, medical physicists involvement not required
Level 3	• Neither well defined nor mandated, primarily research and clinical development activities

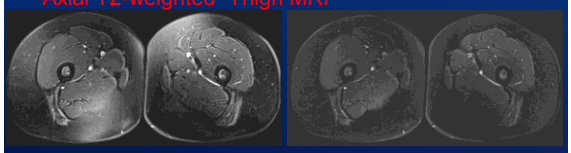
MRI Artifacts – Protocol Optimization

- Ghosting (Motion)
- Susceptibility (Metal)
- Gibbs Ringing (Truncation)
- Wrap-around (Aliasing)
- Inhomogeneous B_0 or B_1 field



Inhomogeneous Field - Fat Suppression

Axial T2-weighted Thigh MRI



Chemically selective saturation (CHESS)

SPectral Attenuated Inversion Recovery (SPAIR)

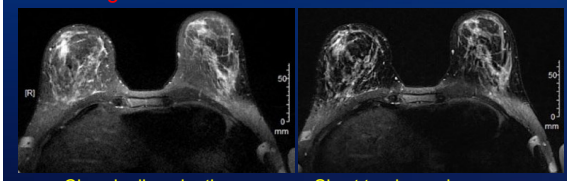
Fat Suppression Techniques

Name of Technique	Method	Time Penalty	SAR	Sens. To B_0	Sens. to B_1	Comments
CHESS/ Fat-Sat	Chemical Shift	Small	Med	High	High	Most popular & versatile technique; works best at high fields (1.5T-3.0T); cannot use at fields <0.3T; poor or incomplete suppression near metal
Dixon	Chemical Shift	Large	Low	Low	Low	2 pt. & 3+ pt. methods; generate 4 images in one acquisition (in-phase, out-of-phase, water only, and fat only); commercial implementations: GE (IDEAL, Flex), Siemens (Dixon), Philips (mDixon), Hitachi (FatSep), Toshiba (WFOP)
Water excitation	Chemical Shift	Small	Low	High	Low	Binomial pulses (1-1, 1-2-1, 1-3-3-1); most widely used in MSK; good method for midfield (0.3-1.0T); commercial implementations: GE (SSRF), Siemens (WE), Philips (ProSet), Toshiba (PASTA, WET)
STIR	T1	Large	High	Low	Low	Widely used; works at all field strengths; tolerant of B_0 and B_1 inhomogeneities; nonspecific suppression of all short T1 materials (fat, protein, blood); cannot use post-Gad; images are T2-weighted
SPIR	Hybrid	Med	Med	High	High	Combination of CHESS+STIR: spectrally selective RF pulse inverts fat only, signal generated after TI delay. Images retain T1-weighting and can be used post Gad; cannot use at low fields (<0.3T) or poorly shimmed magnets; commercial implementations: GE (SPECIAL, SSRF), Philips (SPIR)
SPAIR	Hybird	Large	High	High	Low	Same as SPIR but uses *adiabatic* inverting pulse that minimizes sensitivity to B_1 nonuniformity; useful in abdominal breath-hold studies

mri-q.com – Dr. Elster

Fat Suppression: CHESS vs STIR

T2-weighted Breast MRI

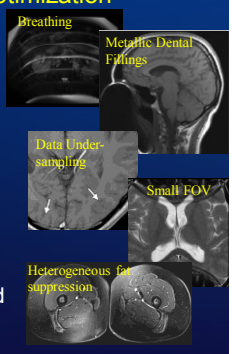


Chemically selective saturation (CHESS) fat suppression

Short tau inversion recovery (STIR) fat suppression

MRI Artifacts – Protocol Optimization

- Ghosting (Motion)
- Susceptibility (Metal)
- Gibbs Ringing (Truncation)
- Wrap-around (Aliasing)
- Inhomogeneous B_0 or B_1 field



MR Protocol Committee

Standardization | Optimization | Training/Education | Vendor Collaborations

MSK, Neuro, Body GI, Cardiac, Body GU, Body GYN, Breast

GE, Siemens, WIP

Rad Onc, Neurology, Urology, Neurosurgery

IRB, Research

*Meets twice a week

MR Protocol Review

Level 1	Required for accreditation under mandatory physicist supervision
Level 2	Structured, needed for accreditation, medical physicists involvement not required
Level 3	Neither well defined nor mandated, primarily research and clinical development activities
Level 3+ Bonus Material	

MR Practice Complexity – Mayo AZ

- 2012 – FIVE Scanners
  - All GE 1.5T
  - All 16x
- 2017 – EIGHT Scanners
  - FIVE GE scanners
    - FOUR 1.5T; ONE 3T
      - 16x (Long Bore)
      - 24x
      - 25x
  - TWO Siemens Skyra
    - Both VE 11
  - 2016 - GE 3.0 T PET/MR

Variability is the enemy of quality

MR Protocol Inconsistency Issues

- MR practice quality issues
  - Protocol inconsistencies
  - Image quality (SE vs FSE)
  - Missing images (sequences per protocol)
  - Hanging protocol mismatch on PACS (sequence order)
- Workflow inefficiencies - Technologists
  - Identifying right protocol
  - Indication, coil, and specialty protocols
  - On-the-fly changes
- Workflow inefficiencies - Radiologists
  - Protocols hanging on PACS
  - Indication based protocoling
  - Interruptions with missed images
- Suboptimal patient care

MR Scanner Protocol Tree Standardization

Protocol Naming Process

NEURO
92
100BRN 010RTN 20CH
100BRN 010RTN 64CH
100BRN 012FST RTN 20CH
100BRN 012FST RTN 64CH
100BRN 013MOTION RTN 20CH

PROTOCOL NAME

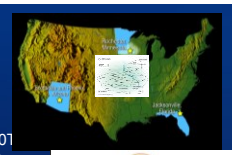
TAG

SPECIALTY	SECTION	SUB SECTION	BODY PART	MODIFIER	CLINICAL PROTOCOLS	TECHNIQUE (section specific)	COILS
PACER	1 NEURO	0 HEAD	0 BRN		010 RTN, 012 FAST RTN, 013 MOTION RTN, 020 METS, 030 ATW, 040 MS, 050 IAC LTD, 050 IAC FULL, 060 TLV, 070 PIT, 075 DYN PIT, 080 POST FOSSA, 090 TRI NERVE, 100 MRA HEAD, 110 MRA ANEURYSM COIL, 120 MRV HEAD, 130 MRA NECK, 140TEMP ARTY	0 NONE, 1 METAL, 2 FAST, 3 MOTION	8CH, HNS, TR COIL, NVII, 20CH, 64CH,
PEDS			1 BRN ADV		010 TBI CONCUSSION, 020 CSF FLOW, 030 STROKE PERF, 040 TUMOR PERF, 050 PERF NO GAD, 060 DTI, 070 SPECT, 080 DBS, 090 STEREOTACTIC, 100 STEALTH, 110 VISUALASE, 120 GRID PLACEMENT, 130 THERAPY PLAN, 140 GLIOMA	0 NONE, 1 METAL, 2 FAST, 3 MOTION	8CH, HNS, TR COIL, NVII, 20CH, 64CH,
PETMR			9 BRN		999 GEN SEQ	0 NONE, 1 METAL, 2 FAST, 3 MOTION	8CH, HNS, TR COIL, NVII, 20CH, 64CH,
RADONC RESEARCH	1 NEURO	1 FACE NECK	0 FACE NECK		010 RTN, 030 THERAPY PLAN	0 NONE, 1 METAL, 2 FAST, 3 MOTION	8CH, HNS, TR COIL, NVII, 20CH, 64CH,
			1 ORBITS		010 RTN	0 NONE, 1 METAL, 2 FAST, 3 MOTION	HNS, NVII, 20CH, 64CH,
			2 PAROTID		010 RTN	0 NONE, 1 METAL, 2 FAST, 3 MOTION	20CH, 64CH
			3 SIALOGRAM		010 RTN	0 NONE, 1 METAL, 2 FAST, 3 MOTION	20CH, 64CH

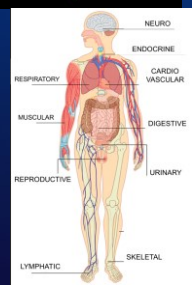
Protocol Standardization

NEURO	MSK	BODY
92	64	126
100BRN 010RTN 20CH	200SHOULDER 010RTN	300LIVER MRCP 010RTN
100BRN 010RTN 64CH	200SHOULDER 010RTN BODY18	300LIVER MRCP 011MED BH
100BRN 012FST RTN 20CH	200SHOULDER 011METAL RTN	300LIVER MRCP 012SHORT BH
100BRN 012FST RTN 64CH	200SHOULDER 012FAST RTN	300LIVER MRCP 013RTN
100BRN 013MOTION RTN 20CH	200SHOULDER 013MOTION RTN	300LIVER MRCP 014LARGE FOV
100BRN 013MOTION RTN 64CH	200SHOULDER 020ARTHRO	300LIVER MRCP AB 010RTN
100BRN 020METS 20CH	201ELBOW 010RTN KNEE COIL	300LIVER MRCP AB 011MED BH
100BRN 020METS 64CH	201ELBOW 010RTN LG FLEX	300LIVER MRCP AB 012SHORT BH
100BRN 030ATW 20CH	201ELBOW 011METAL RTN KNEE COIL	300LIVER MRCP AB 014LARGE FOV
100BRN 030ATW 64CH	201ELBOW 011METAL RTN LG FLEX	301LIVER 010EOVIST
100BRN 040MS 20CH	201ELBOW 020ARTHRO KNEE COIL	301LIVER 020STRICTURE
100BRN 040MS 64CH	201ELBOW SUPINE 010RTN LG FLEX	301LIVER 030SPHINCTER OF ODDI
100BRN 050IAC FULL 20CH	201ELBOW SUPINE 011METAL RTN LG FLEX	301LIVER 040PERF
100BRN 050IAC FULL 64CH	202WRIST 010RTN	301LIVER 060HEMOCHROMATOSIS
100BRN 050IAC LTD 20CH	202WRIST 010RTN SM FLEX	302LIVER MRCP LTD PEL 010RTN
100BRN 050IAC LTD 64CH	202WRIST 011METAL RTN	302LIVER MRCP LTD PEL AB 010RTN
100BRN 060TLV 20CH	202WRIST 011METAL RTN SM FLEX	310ENTERO AB 010RTN
100BRN 060TLV 64CH	202WRIST 020ARTHRO	311APPENDIX 010RTN
100BRN 070DYN PIT 20CH	202WRIST SUPINE 010RTN	312LYMPHANGIOGRAM 010RTN
100BRN 070DYN PIT 64CH	202WRIST SUPINE 010RTN SM FLEX	320KIDNEY 010RTN
100BRN 070PIT 20CH	202WRIST SUPINE 011METAL RTN	321ADRENAL 010RTN
100BRN 070PIT 64CH	202WRIST SUPINE 011METAL RTN SM FLEX	322UROGRAM 010RTN
100BRN 080POST FOSSA 20CH	210HUMERUS 010RTN	322UROGRAM 020NO GAD

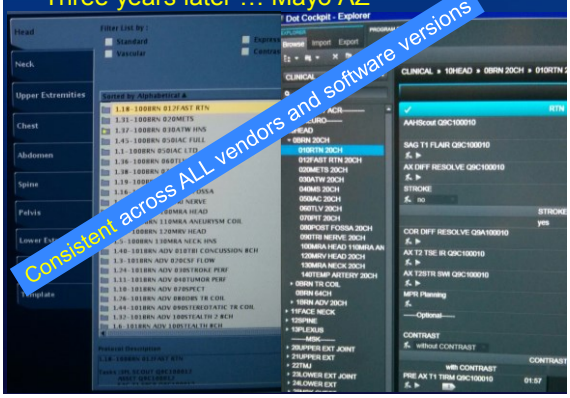
Unique MR Protocols



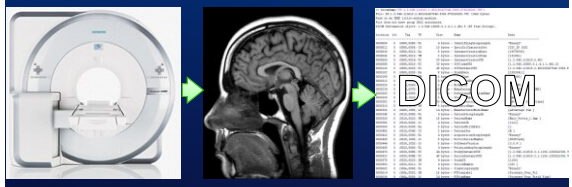
- 60 MRI Scanners
  - Multiple vendors (GE and Siemens)
  - Multiple hardware versions (1.5T, 3.0T
  - Multiple software versions (VE11, 16x, 23x, 25x)
  - 7 unique combination at Mayo Arizona of vendor+hardware+software
- Radiology practice
  - Neuro, Body, MSK, Cardiac, Breast
  - 320 unique protocols at Mayo Arizona
- 2240 unique protocols in Mayo Arizona (~20,000 Mayo Enterprise)

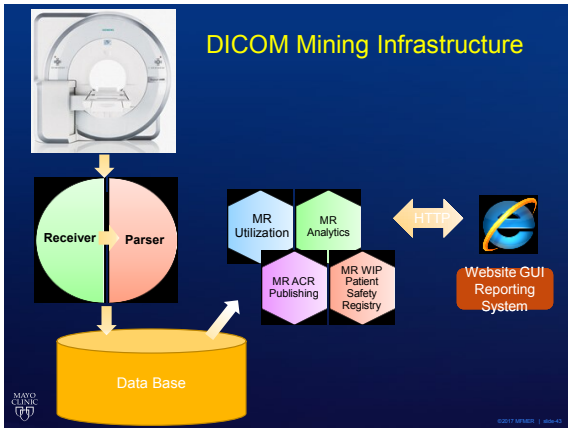


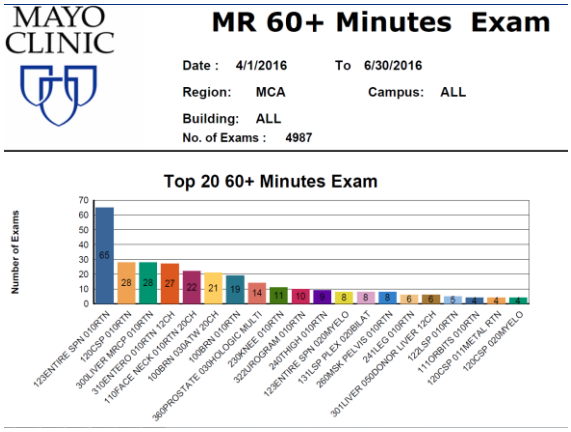
Three years later … Mayo AZ

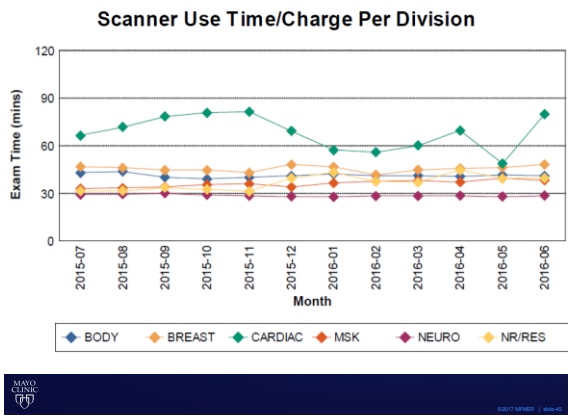


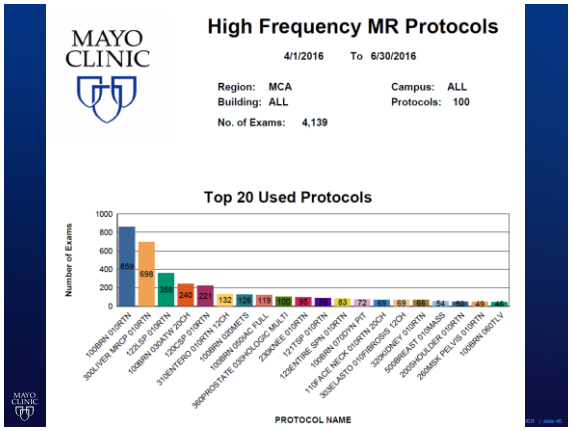
DICOM - Digital Imaging and Communications in Medicine

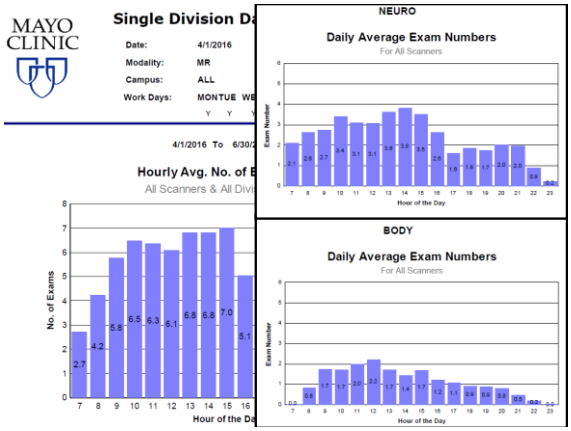












MR Protocol Review - Opportunities

- Level 1: Required for accreditation under mandatory physicist supervision
  - Parameter review for ACR physics phantom QC
  - Annual MR safety survey
    - Acoustic noise – GE Silent, Siemens Quite
- Level 2: Structured, needed for accreditation, medical physicists involvement not required
  - ACR parameter review for clinical MR protocols
  - Low-SAR protocol development- Pacemakers, Neurostimulators
- Level 3: Neither well defined nor mandated, primarily research and clinical development activities
  - Image acquisition optimization – fat sat, metal artifact reduction
  - New sequences, hardware, software
  - Operations Analytics: Consistency, Efficiency

MR Protocol Review

Level 1	• Required for accreditation under mandatory physicist supervision
Level 2	• Structured, needed for accreditation, medical physicists involvement not required
Level 3	• Neither well defined nor mandated, primarily research and clinical development activities
Level 3+	• Beyond clinical • Operations Analytics: Consistency, Efficiency

Medical physicist expertise beyond technical compliance to direct patient care and clinical operations $$

Antelope Canyon
Page, Arizona