MR Protocol Review
Clinical Opportunities for Physicists

Anshuman Panda, Ph.D.

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

“Imitation is the sincerest form of flattery”

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

Level 1
• Required for accreditation under mandatory physicist supervision

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

Level 3

ACR Clinical Image Quality

MRI Accreditation Program
Clinical Image Quality Guide

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

ACR Radiology
1801 Preston White Drive
Ranson, WV 25438

SUBMITTED DATA REPORT
Submitted on: 07/21/2013

Magnetic Resonance Imaging #00557-04
Mayo Clinic Hospital

ACR MR Accreditation – Clinical Modules

Examination choices for MR Accreditation by module (repetitive examinations counted by patient)†

Table

- Brain for transient ischemic attack (TIA)
- Internal auditory canal (AC/eromporal bone) for hearing loss
- Brain for suspected demyelinating disease
- Pituitary with dynamic contrast enhancement
- Odds for weight loss

Body
- Spine
  - Lumbar Spine
  - Thoracic Spine
  - Cervical Spine†
  - Concept (spine with contrast for intramedullary disease)

- Head
  - Brain
  - Cardiac
  - Thoracic aorta
  - Distal peripheral runoff
  - High resolution arm and carotids
- Abdomen for renal artery stenosis

NKA
- Black Blood
- Basic
- Delayed enhanced cine 1
- Delayed enhanced cine 2
- Delayed enhanced cine + Black Blood

ACR Cervical Spine Requirements

ACR Cervical Spine Datasheet
**Physicist QC Check - ACR Cervical Spine**

<table>
<thead>
<tr>
<th>Sagittal dark fluid</th>
<th>Sagittal bright fluid</th>
<th>Axial bright fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Nice thickness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.5 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>Gap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.5 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Axial plane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.5 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pass</td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>Pulb area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.5 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

**ACR Cardiac Delayed Enhanced**

**MR Protocol Review**

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- **Level 3**: Level 2 + additional requirements

**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 Advisor
  - Biotronik Entovo
  - 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 Viva AF
- CRT-Ds
  - Biotronik Iperia HF-T
  - Biotronik Inventra HF-T
  - Medtronic Ampla Quad
  - Medtronic Compa Quad
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

MR Artifacts – Protocol Optimization

- Ghosting (Motion)
- Susceptibility (Metal)
- Gibbs Ringing (Truncation)
- Wrap-around (Aliasing)
- Inhomogeneous B₀ or B₁ field

Fat Suppression Techniques

<table>
<thead>
<tr>
<th>Name of Technique</th>
<th>Method</th>
<th>Time</th>
<th>SAR</th>
<th>Sens.</th>
<th>Sens.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHESS/Fat-Sat</td>
<td>Chemical Shift</td>
<td>Small</td>
<td>Med</td>
<td>High</td>
<td>High</td>
<td>Most popular &amp; versatile technique; works best at high fields (≥3-T) (CT); cannot use at fields ≤3-T; poor at incomplete suppression near metal</td>
</tr>
<tr>
<td>Dixon</td>
<td>Chemical Shift</td>
<td>Large</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>3 pt &amp; 3 pt method: generate 8 images (in phase, out of phase, water only, and fat only), commercial implementations. GE (SIGNA, Hitachi, Philips (Endura), Siemens (MAGNETOM); Philips (Polaris), Toshiba (Vantage)</td>
</tr>
<tr>
<td>Water excitation</td>
<td>Chemical Shift</td>
<td>Small</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Commercial use of 3 pt Method, most widely used in MRI, good method for multi-field (≥3-T, ≤1-T) commercial implementations: GE (SIGNA), Siemens (MAGNETOM), Philips (Polaris), Toshiba (Vantage)</td>
</tr>
<tr>
<td>STIR</td>
<td>T1</td>
<td>Large</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Used with w/afield strengths; reduction of 3 pt, sensitivity, non-specific suppression of all other T₁ materials (fat, water, blood) cannot use post-pulse: images are T₂-weighted</td>
</tr>
<tr>
<td>SPIR</td>
<td>Hybrid</td>
<td>Med</td>
<td>Med</td>
<td>High</td>
<td>High</td>
<td>Combination of CHESS/STIR spectrally selective RF echo-sets with fat sat, signal generated after T₁-weight images retain T₁-weighting and can be used post-pulse, cannot use at low fields (≤3-T) or poorly shimmed magnetic, commercial implementations: GE (SIGNA), Siemens (MAGNETOM), Philips (Polaris), Toshiba (Vantage)</td>
</tr>
<tr>
<td>SPAIR</td>
<td>Hybrid</td>
<td>Large</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Same as SPIR but uses adiabatic inverting pulse that increases sensitivity to B₀, usually useful in abdominal/breast field studies</td>
</tr>
</tbody>
</table>

Inhomogeneous Field - Fat Suppression

Axial T2-weighted Thigh MRI

Chemically selective saturation (CHESS)

SPectral Attenuated Inversion Recovery (SPAIR)

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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 Vender Collaborations

MSK

Nursing

GE

SE

Rad Onc

Neurology

Urology

WIP

Neurosurgery

Body GI

Body GU

Body GYN

Breast

IRB

Research

*Meets twice a week

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Level 3+
- Bonus Material

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 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 Scanner Protocol Tree Standardization

Protocol Naming Process

Protocol Standardization

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

DICOM

DICOM is a set of standards used to transfer medical images and diagnostic information between different devices and software systems. It allows for the exchange, storage, management, and sharing of digital medical images and other medical data.
DICOM Mining Infrastructure

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  • Operations Analytics: Consistency, Efficiency
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- **Level 3+**: Beyond clinical
  - Operations Analytics: Consistency, Efficiency

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

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Antelope Canyon
Page, Arizona