Faculty Disclosures
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Off-Label/Investigational Drug Use:
Dr. Ho will discuss the usage of Gd-chelate contrast agents for cardiovascular MRI/MRA which is an “off-label” use.

The opinions or assertions contained herein are the private views of Dr. Ho and are not to be construed as official or reflecting the views of USUHS or the Dept. of Defense.

MR Angiography: Techniques and Pitfalls
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Presentation Objectives
At the end of this presentation, the participant will be able:

• To discuss common MR techniques for vascular evaluation
• To describe common pitfalls of MRA methods

Pros and Cons of MRA
Benefits:
• Does not require iodinated contrast materials
• Fast (especially Gd-enhanced MRA)
• Readily performed on most current scanners
• Does not require ionizing radiation

Disadvantages:
• MRI has contraindications (e.g. pacemakers)
• Stents typically cause artifacts on MRI
• Not necessarily “push button”

MRA Techniques
Time-of-Flight MRA
Phase Contrast MRA
Steady State Free Precession MRA
Gd-Enhanced MRA

Time-Of-Flight MRA
Principle:
• In-Flow Effect (a.k.a. “wash-in” phenomenon or “flow related enhancement”)

Arterial-Venous Segmentation:
• Selective Saturation Band

Concerns:
• Intravoxel Dephasing [Benefit: Flow Jet]
• Saturation Effects (e.g. in-plane flow)
• Pulsatility Artifacts
**Time-of-Flight MRA**

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**TOF Pitfall: Spin Saturation**

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Phase Contrast MRA

Principle:
- Phase Shifts

Arterial-Venous Segmentation:
- Velocity and Direction Prescription
- Phase Map Data

Concerns:
- Intravoxel Dephasing [*Benefit: Flow Jet*]
- Pulsatility Artifacts
- Velocity and Direction Prescription
- Time

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**Phase Contrast MRA**

Principle:
- Phase Shifts

Arterial-Venous Segmentation:
- Velocity and Direction Prescription
- Phase Map Data

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Bipolar Flow Encoded Gradients
**PC Data**

- **Speed Phase Map**
- **Magnitude**
- Dilated Azygous Vein

**Phase Contrast MRA**

**Principle:**
- Phase Shifts

**Arterial-Venous Segmentation:**
- Velocity and Direction Prescription
- Phase Map Data

**Concerns:**
- Pulsatility Artifacts
- Intravoxel Dephasing [Benefit: Flow Jet]
- Velocity and Direction Prescription
- Time

**Phase Contrast MRA**

**Axial Post Gd 3D MRA**

**Axial non-Gd 3D PC MRA**

**Rt. Renal Artery Stenosis**

**Gd improves PC MRA!**

**Concerns:**
- Pulsatility Artifacts
- Intravoxel Dephasing [Benefit: Flow Jet]
- Velocity and Direction Prescription
- Time

**Steady State Free Precession (SSFP, TrueFISP, BaFFE, FIESTA)**

**Principle:**
- T2/T1 ratio (and some “in-flow”)

**Arterial-Venous Segmentation:**
- Anatomic segmentation by operator

**Concerns:**
- $B_0$ Homogeneity
- Specific Absorption Rate (SAR)
- “Contamination” by adjacent structures with high T2 (e.g. biliary tree and gallbladder)

**3D SSFP Coronary MRA**

- RCA and LM
- LAD
- RCA
- LCx

**Gd-Enhanced 3D MRA**

- Vascular imaging relies on the T1-shortening of blood by circulating Gd-chelate contrast media
- Imaging during arterial transit (arterial phase) of the bolus affords preferential arterial illustration

**Number of RF pulses**

- **Gd-enhancement ($T1 = 100$ msec)
- Muscle ($T1 = 600$ msec)
- Blood ($T1 = 1200$ msec)

**CNR**
Gd-enhanced 3D MRA

Principle:
• Synchronization of imaging (center of k-space) for peak vascular contrast enhancement

Arterial-Venous Segmentation:
• Timing (e.g. arterial phase)

Concerns:
• Patient Preparation
• Timing
• “Ringing Artifact”

Gadolinium-Enhanced MRA

Arterial depiction relies on the synchronization of imaging with the arterial phase of the Gd bolus

Gd-Enhanced MRA: Timing

Gd-Enhanced MRA: K-space

Timing of Gd-MRA depends on the MRA k-space scheme

K-Space Scheme

Convention Acquisition (Sequential or Linear)
K-Space Scheme

Conventional Centric Acquisition (Sequential)

K-space Trajectory: From center to next closest radial point to center
Result: Compact acquisition of central k-space data

Conventional Partial-Fourier Acquisition ("0.5 NEX")

Partial-Fourier Reverse Sequential Acquisition

Gd-Enhanced MRA: K-space
Timing of Gd-MRA depends on the MRA k-space scheme

Gd-MRA: Timing
Timing Scan
Real-Time Triggering
MR Fluoroscopy
MR SmartPrep
Multi-Phase Imaging

Timing Scan
Real-Time Triggering
MR Fluoroscopy
MR SmartPrep
Multi-Phase Imaging

**Gd-MRA: Timing**

Axial Timing Run
Apply Inferior and Superior Sat Bands

**Test Bolus**

Prescription: Place monitoring slice over the target vessel
Pulse sequence: axial FMPSPGR, S/I sat, TR 20 msec, TE min, FA 60 degrees, 31.5 kHz bandwidth, 256x128, 1 NEX
...1 image/1-2 sec
Injection: 1-2 mL @ 2 mL/sec followed by 25 mL saline flush via MR-compatible injector

**Test Bolus for Gd-MRA Timing**

\[ Ts = Td + \frac{Tg}{2} - \frac{Ta}{2} \]


**Test Bolus for Gd-MRA Timing**

\[ Ts = Td + 2 \text{ sec} \]

**Gd-MRA: Timing**

Axial Timing Run
Apply Inferior and Superior Sat Bands

**Gd-MRA: Timing**

Detect Gd

Gd-MRA (centric)
### Gd-MRA: Timing

<table>
<thead>
<tr>
<th>Timing Scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-Time Triggering</td>
</tr>
<tr>
<td>MR Fluoroscopy</td>
</tr>
<tr>
<td>MR SmartPrep</td>
</tr>
<tr>
<td>Multi-Phase Imaging</td>
</tr>
</tbody>
</table>

**Multi-Phase 3D MRA**

### Contrast Administration

- **Right antecubital IV (at least 22G)**
- **Match bolus duration with at least half that of the imaging time, namely central k-space**
- **Contrast Dose:** 20 to 30 mL @ 2 mL/sec

Hany et al (ISMRM 1998, 768) estimated that need AT LEAST 0.12 mmol/kg

- **Saline Flush:** 30 mL @ 2 mL/sec

### Imaging Parameters

- **Shortest possible TR and TE**
- **Optimize spatial resolution vs. time (e.g. 2-3 mm for aorta; ≤ 2 mm for renal arteries)**
  
  **Examples:** 0.75 FOV, 0.5 NEX, +64 kHz
- **ZIP (a.k.a. zero filling) … improves MIP (NOTE: spatial resolution not really better)**
- **Centric (or elliptical centric) k-space phase ordering…partial Fourier using reverse sequential**
- **Parallel Imaging (a.k.a. SENSE, ASSET)**

### Patient Preparation

- **Test BH capacity and instruct patient**
- **Respiratory bellows**
- **Cardiac gating ( cine MR)**
- **Oxygen and hyperventilation**
- **Patient positioning**
- **Coil selection**
- **Surgical history (e.g. extra-anatomic shunt, stents)**
- **Right antecubital IV**

### Left Sided Venous Injection

**T2* artifact caused by the high concentration of Gd during the initial “pass” through the left brachiocephalic vein**

**Solution:**
- **Right antecubital injection and multiphase (delayed phase) imaging**

**Arterial Phase**

**Delayed Phase**

### Gd-MRA: K-space Scheme

Timing of Gd-MRA depends on the MRA k-space scheme

- **Conventional Sequential**
- **Sequential Centric**
- **Elliptical Centric**
- **Partial Fourier Reverse Sequential**

Gd-MRA: K-space Scheme

Timing of Gd-MRA depends on the MRA k-space scheme

“Ringing Artifact” on Gd-MRA

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