Abdominal MRI Techniques in Pediatric Oncology

Jonathan R. Dillman, M.D.

Assistant Professor
Departments of Radiology & Urology
Section of Pediatric Radiology
C.S. Mott Children’s Hospital
Disclosures

• No relevant conflicts of interest

• Will discuss non-FDA-approved use of gadolinium-based contrast agents
Objectives

• Present state-of-the-art clinical MRI protocols and techniques for the performance of high-quality pediatric abdominopelvic tumor imaging
  – Coil selection
  – Pulse sequence options
  – Motion artifact reduction
  – Advanced MRI techniques
  – Contrast agent selection
(Receive) Coil Selection

- Receive coil (= antenna) → wire loop that detects RF signal and induces current (Faraday’s law) → amplified/digitized
- Prefer multi-element surface or volume coil → ↑ signal-to noise ratio allows improved spatial resolution and/or faster imaging
- Coil choice depends on scanner type, child size, and anatomy of interest
- Avoid built-in “body coil”

http://mri-q.com/
(Receive) Coil Selection

- **Key Points:**
  - Coil should match FOV/anatomy of interest
    - Babies: flex, knee, head/neck coils, etc.
    - Older children: array torso coil
    - Some venders have dedicated pediatric coils
  - Confirm SAR estimation for given coil is accurate re: patient/body part imaged
    - e.g., some scanners/software versions allow babies to be scanned in knee coil – others do not!
Pulse Sequence Selection

• What combination of pulse sequences is necessary for pediatric tumor imaging?

• Options:
  – T2W imaging: SSFSE, FSE (2D or 3D), STIR
  – T1W imaging: FSE, GRE
  – Postcontrast imaging: FSE, GRE (?2D, 3D, dynamic)
    • Dynamic – liver, renal, other arterially-enhancing neoplasms (e.g., pancreatic neuroendocrine tumors)
  – DWI useful?
Pediatric “Abdominal Mass” Generic Protocol

• Coronal and/or axial SSFSE
• Axial T2W FSE fat-sat ± coronal STIR
• Coronal and/or axial T1W FSE
  – Optional T1W GRE IP/OP
• Axial DWI
• Precontrast 3D GRE
• Postcontrast 3D GRE (3 planes)
Pediatric Liver Tumor Protocol

- Coronal SSFSE
- Axial T2W FSE fat-sat
- Axial T1W GRE in/opposed-phase (IP/OP)
- Axial DWI
- Dynamic postcontrast 3D GRE (LAVA/VIBE/eTHRIVE)
  - Precontrast and minimum of three postcontrast phases
- Delayed postcontrast 3D GRE (10-20 min if Eovist)
Liver Mass Protocol – Precontrast

11 year-old girl with liver mass

- SSFSE
- T2W FSE fat-sat
- DWI (b=800)
- T1W GRE (IP/OP)
Liver Mass Protocol – Postcontrast

11 year-old girl with liver mass

3D T1W GRE (Eovist, 20 min)
Motion Artifact Reduction & FSE

- Possible solutions:
  - Change to SSFSE/HASTE
  - Respiratory-triggering (belt/bellows)
  - Navigator echo (extra RF pulse tracks diaphragm motion)
  - Increase NSA
  - Swap phase/frequency directions
  - Alternative approaches to filling k-space
Alternative Approach to Filling k-space

• BLADE/PROPELLER/MULTIVANE:
  – Variation on radial k-space sampling
  – “Blade” = 8-32 parallel phase-encoded lines, per single-shot
    • Rotate 10-20°, repeat
  – Oversamples k-space center
    • Improves signal & contrast-to-noise ratios
    • Minimizes artifacts from X-, Y-, Z-axis rotation/translation

http://mri-q.com/
16 year-old girl with pheochromocytoma

T2W FSE Fat-Sat Multivane XD
14 year-old girl with tuberous sclerosis

T1W FSE BLADE without / with Fat-Sat (case courtesy of Geetika Khanna)
Advanced MRI Techniques: DWI

• Image contrast based on Brownian motion of water molecules

• Tumors commonly restrict water movement = signal hyperintensity
  – ↑ b-value (>500-1000 sec/mm²) → ↑ lesion conspicuity

• Practical uses:
  – Detection of metastatic disease (liver, peritoneal cavity)
  – Subjective assessment of treatment response
15 year-old boy with metastatic nasopharyngeal carcinoma
15 year-old girl with metastatic PEComa
Advanced MRI Techniques: Chemical Shift Imaging

• Water and fat in same voxel cause signal loss due to phase cancellation at certain echo times (TE)

• Acquire 2 GRE images with different TE at same level
  – IP/OP (2.2/4.4 msec at 1.5 Tesla)

• Lipid-containing lesions lose signal on OP imaging
  – Certain liver, renal, adrenal lesions

• Black line at fat-water interfaces (India ink artifact)
Advanced MRI Techniques: Chemical Shift Imaging

10 year-old girl with Alagille syndrome & adenoma

T1W+ Arterial

T1W OP

T1W IP
Advanced MRI Techniques: Chemical Shift Imaging

12 year-old boy with adrenal teratoma & India ink artifact
Advanced MRI Techniques:
Dixon Imaging

• Proposed by Dixon (1984) → variation of chemical shift imaging

• Multiple echoes (e.g., 3) used to create IP, OP, fat only, and water only (fat-sat) images
  – $\frac{1}{2} \left[ \text{IP} + \text{OP} \right] = \text{Water only image}$
  – $\frac{1}{2} \left[ \text{IP} - \text{OP} \right] = \text{Fat only image}$

• Uses:
  – Homogeneous fat-saturation
  – Lesion characterization (i.e., does lesion contain fat?)
Advanced MRI Techniques: Dixon Imaging

15 year-old with tuberous sclerosis & many AMLs
Contrast Agent Selection

• Most often use conventional GBCM for tumor imaging
  – Standard dosing (0.1 mmol/kg)

• Exceptions:
  – Impaired renal function – no contrast?
  – Liver tumors – hepatocyte-specific contrast agent
Contrast Agent Selection

• Available hepatocyte-specific contrast agents:
  – Eovist (gadoxetate disodium) → 50% biliary excretion
  – MultiHance (gadobenate dimeglumine) → 10% biliary excretion

• When do they help?
  – Arterially-enhancing lesions – FNH vs. hepatocellular neoplasm (HCC, adenoma)
  – Detection of metastatic disease
  – Children with countless liver lesions
Hepatocyte-Specific Contrast: Arterially-Enhancing Lesions

11 year-old girl with large FNH
Hepatocyte-Specific Contrast: Arterially-Enhancing Lesions

12 year-old girl with hepatic adenoma
Hepatocyte-Specific Contrast: Multiple Arterially-Enhancing Lesions

12 year-old girl with Abernethy syndrome & HCC
Hepatocyte-Specific Contrast: Metastatic Disease

12 year-old girl with metastatic sarcoma
Hepatocyte-Specific Contrast: Benign & Hypointense

4 month-old girl with neuroblastoma & infantile hemangiomas
Hepatocyte-Specific Contrast: Benign & Hypointense

9 year-old boy with chronic granulomatous disease & liver abscess

T1W+ 20 min
Conclusions

• MRI is increasingly important in pediatric oncologic imaging

• High-quality, added-value MRI requires proper:
  – Coil selection and placement
  – Pulse sequence choices (including DWI, Dixon imaging, etc.)
  – Motion artifact minimization
  – Contrast agent usage