Tips and Tricks in Pediatric Body MR Imaging

Important Points To Remember While Imaging

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Instructions...

- 4 important points to remember while imaging any region are given on 2 slides that can be accessed through main menu.
- Once you have seen the region, the relevant box on the main menu is highlighted.
- You can also see slides in continuation by using arrows/Page up-down keys on the key board.

- Sequence acronyms can be found by clicking *Sequence Acronyms*.
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**Sequence Acronyms**
1. **Body part that needs to be imaged should be positioned in anatomic position as much as possible.**
   - This saves time and effort when planning subsequent multi-planar sequences.

2. **Surface and phased-array coils have better SNR and spatial resolution than volume coils.**

   Large malignant peripheral nerve sheath tumor (thin arrows) in a 10-yr-old girl with NF1. Image acquired with torso coil (A) shows overall uniform signal. Image with spine coil (B) has better resolution for intraspinal component (thick arrow) but loses signal anteriorly.
Patient positioning and coil selection

3. *Smallest coil that fits the anatomic region should be used.*

- Smaller coils permit use of smaller FOVs and better resolution. The noise detected by the coil and SAR increases with coil size. Infants and neonates can be imaged in a quadrature knee coil, head coil or even flexible surface coils. Older children are usually imaged with phased-array torso coils.

4. *Patient comfort should always be taken care of!*

- Serious motion artifact in an image can eliminate any of the gains in image quality achieved through optimal coil selection and positioning.
Imaging Parameters

1. **Signal-to noise ratio (SNR)**
   - Most important imaging parameter. An image with high SNR is less grainy and has more details. It improves with signal averages, surface coils, high field strength & particular sequences. Decreases with matrix size and bandwidth.

2. **Spatial Resolution**
   - Ability to discern two points as distinct and separate. Smaller the points that are seen separately better is the resolution. Improves with matrix size.

A) has less SNR (more grainy) and less spatial resolution (compare branching structure in Rt caudate nucleus-arrow) as compared to B)

D) has less SNR but better contrast resolution (compare corticomedullary diff in kidneys) as compared to C)
3. *Contrast-noise ratio (CNR).*
   - Contrast is the signal intensity difference between adjacent structures. CNR is SNR difference between adjacent structures. CNR depends on SNR, spatial resolution and relaxation times (T1, T2) of the tissues.

4. *Scanning Time*
   - Scanning time = Repetition time (TR) x phase matrix x number of signal averages
   - Scanning time decreases with decreasing matrix, signal averages, number of slices and TR, and with increasing echo train length and parallel imaging acceleration factor.
Moving Child

1. **Distraction**
   - Music, movie goggles help to distract children and help them remain still in the magnet bore. Parents holding the hand is another useful way that may work!

2. **Single shot (SS) sequence**
   - SS-FSE can be a good alternative sequence to acquire artifact-free T2-weighted images in short time in almost all body parts and can salvage the examination. However, the sequence has a low SNR and resolution compared with T2-FSE sequence.

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*T2 fast spin echo image is degraded by respiratory motion. Image quality is improved on single shot FSE image.*
3. **Balanced SSFP sequence**
   - Gross anatomic information and vascular anatomy can be obtained by this quick (approx 15-20 sec) sequence that is intrinsically motion insensitive. It lacks spatial resolution and affected by susceptibility artifacts.

4. **T1-w Gradient echo sequence**
   - T1-w TFE/FLASH/SPGR/VIBE sequences can acquire post contrast images in as short as 15-20 sec. They can be used in multiphase study and if child is moving after injection of gadolinium.

**Axial balanced SSFP image of the abdomen shows good anatomic delineation of abdominal organs.**

**Axial T1-turbo field echo (TFE), a gradient-echo, sequence after contrast injection.**
Liver Imaging

1. *In and Out-of-phase imaging*
   - In and out-of-phase T1-GRE sequence is helpful in evaluating liver parenchyma for fat infiltration and characterization of focal liver lesions.

2. *Respiratory motion compensation*
   - Triggering on respiratory tracings from bellows or diaphragmatic Navigator pulses works well when breathing is regular.
   - Breath-hold in older kids.

*Round lesion (arrow) on (A, In-phase, TE-4.6ms) image turns dark on (B, Out-phase, TE-2.3ms) image suggesting its fat content. This was a hepatic adenoma in a child with glycogen storage disorder. Note flow artifact from aorta (arrowhead).*

*Respiratory tracings are obtained by placing Navigator over diaphragm and images are acquired in the same phase with every cycle.*
3. **Dynamic post-contrast imaging**

- Gradient-echo T1-w sequences like FLASH/VIBE, LAVA/SPGR, THRIVE can be acquired in single breath-hold. 4-5 acquisitions starting with injection of contrast help to characterize lesion depending on their pattern of enhancement.

4. **Reconstruction from dynamic images may give some idea about the status of portal vein.**

VIBE axial images of the liver in a 17-yrs-old girl with a *focal nodular hyperplasia* (arrows) show peripheral rim enhancement in arterial phase and delayed central scar enhancement with prolonged contrast retention.
Pancreato-biliary Imaging

1. 3D T2-fast spin-echo MRCP sequence

   - This respiratory triggered sequence should be acquired in all MRCP. It provides good quality 3D data that can be reformatted in any plane and thickness. However, quality is limited if breathing is not regular.

2. Single-shot radial slabs in MRCP

   - SS-FSE sequence with high TE (600-1100 ms) can be acquired in slabs of varying thickness and planes in less than 1 second. Helpful when breathing is not regular.

MIP image from 3D T2-FSE data in a 9-yr-old girl with Proteus syndrome and tuberous sclerosis. Cystic dilatations of central bile ducts (medium arrows) and dilatation of CBD (short arrow) and PD (thin arrow) was thought to be developmental anomaly.

Normal thick slab (25mm) single-shot MRCP in a 7-yr-old girl with TE = 900 ms. Short arrow-CBD, thin arrows-pancreatic duct, dd-duodenum, GB-gall bladder

MAI N MENU
3. **Thin contiguous sections of SSFSE sequence**

- Thin sections should be acquired in axial plane for suspected CBD stones, and in axial & coronal planes for pancreatobiliary junction anomalies.

4. **T1-w fat suppressed gradient echo sequence for pancreas**

- FLASH/VIBE/SPGR/T1-TFE sequences show pancreatic parenchyma very well and they can be acquired in 15-20 seconds.

Axial fat saturated THRIVE (T1-w gradient-echo) images show normal high signal intensity pancreas (arrows).
1. **Oblique coronal and sagittal planes**

   - Oblique coronal and sagittal images along long axis of the kidneys may help increase assessment and should be acquired in addition to axial plane. STIR images show renal cortico-medullary differentiation very well!

2. **Renal cyst in suspected renal carcinoma should always be enhanced**

   - Septa may only be seen on post contrast images.

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16-yr-old girl with *von-Hippel-Lindau* syndrome and Rt renal cyst (thick arrow). An enhancing septa is seen on post contrast images (arrow). This turned out renal cell carcinoma on pathology.
3. *MR Urography*

- Non-functioning dilated systems or multicystic dysplastic kidneys can be imaged with T2-FSE or SSFSE sequence while the non-dilated collecting system is best imaged with gadolinium-enhanced T1-w sequences.

4. *If kidneys are the only region of interest they can be imaged with spine coil.*

MIP of 3D T2 fast spin-echo MR Urography. Right ureter is dilated and tortuous (arrows). It was ectopically opening in the posterior urethra.

Axial T1-w image of the spine with spine coil shows kidneys well. Signal is poor in anterior part of abdomen.
1. Thin sections in all three planes for anatomy
   - Both T1 and T2-w thin images in 3 planes are helpful in evaluation of Mullerian, urethral, gonadal or genital abnormalities. They are also useful in perianal fistulas.

2. Field of view should include top of the iliac crest up to the perineal region including external genitalia in boys.

Axial T2-w (A-C), Sag T1-w (D) & Cor T2 fat sat (E) images show Uterine didelphys with two hemivaginas. The left hemivagina is obstructed. Rt-right, Lt-left, Ov-ovary, Ut-uterus, V-vagina, UB-bladder.
3. **Perianal fistula in Crohn’s disease**

- T1-w fat sat images acquired pre and post contrast may be helpful for looking true enhancement & non-enhancing collection in the fistulous tract.

4. **Sagittal thin T2-w images of the pelvis without fat sat show anatomy better than fat saturated images.**

- Fat sat images may not show perineal anatomy well because of loss of fat planes around structures and overall signal loss.

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**Pre** (A) & post contrast (B) axial fat sat T1-w images of the perianal fistula (arrows) show non-enhancing linear fluid component in the center on post contrast (B) image.

**Fat sat** (C) & non-fat sat (D) T2-w sag images of pelvis in a 2-yr-old girl with cloacal anomaly show dilated vagina (arrow). Note signal loss in perineum on fat saturated (C) image (thick arrow). The common outlet (thin arrow) from vagina, rectum and urethra & perineal muscles are better seen on (D).
1. **Both T1-w and STIR images are required for evaluation of bone marrow**

2. **STIR images can suppress fat more uniformly than T2-w fat sat images especially at curved anatomic surfaces**
   - However, STIR has less SNR than T2-w fat sat images.

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**Coronal STIR (A) & T1-w (B) images in a case of left femur osteomyelitis. Marrow changes (arrows) are better seen on the T1-w image.**

**STIR (C) & T2-w fat sat (D) images of the pelvis. An area of incomplete fat saturation is seen in the pubic region (arrow) on (D) while on (C) fat signal is homogeneous.**
3. Thin axial sections in the region of high signals in suspected cases of osteomyelitis can show cortical break.

Coronal T2-w fat sat (A) image shows signal abnormality in distal metaphysis in this child with osteomyelitis. STIR (B) and post-contrast T1-w (C) axial thin sections in this region show cortical break with a tract (arrows).

4. Bone tumor imaging should include the entire involved bone and joints above and below.
   - This is essential for surgical planning and for looking skip lesions in the bone.
MSK Imaging - Joints

1. **T2-w gradient echo images form essential part of joint imaging.**
   - MPGR/DESS/T2-FFE sequences show articular cartilage better. Also helpful in loose bodies, and hemosiderin deposition in hemophilic arthropathy and PVNS.

2. **Sagittal sections are essential in hip MRI.**
   - Sagittal images show femoral head better and demonstrate femoral head collapse often better than coronal images in osteonecrosis.

Coronal (A) & sagittal (B) T1-w images show post traumatic avascular necrosis of left femoral head. Sagittal image shows more irregularity of epiphysis circumference.

Coronal T2 FFE image shows normal intermediate intensity articular cartilage (arrows) contrasted by dark bones from increased susceptibility and bright joint fluid on this T2-w gradient-echo image.
MSK Imaging- Joints

3. **Shoulder joint coronal image should be along the scapula and sagittal image perpendicular to it.**
   - Gleno-humeral joint and rotator cuff are best seen on these views.

   Left shoulder images in a 10-yrs-old with synovial osteochondromatosis. Note calcified bodies (thin arrows) and erosions of humeral epiphysis (thick arrow).

4. **Small joints.**
   - A greater number of signal averages are required in small joint imaging to support higher matrix and thin sections for small FOV. This increases scanning time.

**MAI N MENU**

- Normal wrist joint
- Coronal T2 fs
- Coronal T1
- Sag T2 fs
- Axial MEDIC
- Coronal T1
1. **Maximum intensity projection (MIP) images can overestimate or falsely show stenosis.**
   - Source images should be carefully reviewed before calling vascular stenosis on MR Angiography.

2. **3T is superior in MRA.**
   - Because of more increase in T1 relaxation time of stationary tissues as compared to blood at 3T, stronger time-of-flight effects are seen. Relative contrast enhancement at 3T also improves contrast-enhanced MRA.

**MIP from CE-MRA (A) shows apparent narrowing of right renal artery just before hilum (arrow). (B) Conventional angiogram showed normal right renal artery.**

**Contrast-enhanced MR Angiogram at 3T in a 16-yrs-old girl with Takayasu’s arteritis shows complete occlusion of left subclavian artery (arrow) with collaterals.**
3. Vascular malformations protocol
   - It should include gradient-echo images, such as MPGR/T2-FFE that can show blood products and possible phleboliths and MR Venography that can show prominent draining veins in venous malformations and AVM.

4. Balanced-SSFP sequence is a quick and easy way to look at the vessels.
   - However, all the vessels (artery+ vein) as well as fluid structures are bright and it may be difficult to differentiate.
### Sequence Acronyms

**Table 4.1: Summary of sequences**

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<tr>
<th>Sequence</th>
<th>Siemens*</th>
<th>GE*</th>
<th>Philips*</th>
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<tbody>
<tr>
<td>1. Spin Echo sequence</td>
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<tr>
<td>Conventional SE (90-180 RF pulses)</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
</tr>
<tr>
<td>Double SE (90 followed by two 180</td>
<td>PD/T2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF pulses)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi SE (90 followed by multiple</td>
<td>Turbo</td>
<td>Fast</td>
<td>Turbo</td>
</tr>
<tr>
<td>180 RF pulses)</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
</tr>
<tr>
<td>Single shot Multi SE</td>
<td>HASTE</td>
<td>Single shot</td>
<td>Ultrafast SE</td>
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<td>(Multi SE with half k-space filling)</td>
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<tr>
<td>2. Inversion Recovery Sequence</td>
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<td>Short TI (80-150 ms) e.g. STIR</td>
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<td>Medium TI (200-800 ms) e.g. MPRAGE</td>
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<td>Long TI (1500-2500 ms) e.g. FLAIR</td>
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<td>3. Gradient Echo Sequence</td>
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<tr>
<td>A. Incoherent spoiled TM</td>
<td>FLASH</td>
<td>SPGR</td>
<td>T1-FFE</td>
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<tr>
<td>B. Coherent/Rephased TM</td>
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<td></td>
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<tr>
<td>1. Post excitation refocused</td>
<td>FISP</td>
<td>GRASS</td>
<td>FFE</td>
</tr>
<tr>
<td>(FID sampled)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. Pre-excitation refocused</td>
<td>PSIF</td>
<td>SSFP</td>
<td>T2-FFE</td>
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<tr>
<td>(Spin echo sampled)</td>
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<td></td>
<td></td>
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<tr>
<td>3. Fully refocused</td>
<td>True</td>
<td>FIESTA Balanced</td>
<td>FFE</td>
</tr>
<tr>
<td>(both FID and spin echo sampled)</td>
<td>FISP</td>
<td></td>
<td></td>
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<tr>
<td>4. Hybrid</td>
<td></td>
<td></td>
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<tr>
<td>Combination of SE and GRE</td>
<td>TGSE</td>
<td>GRASE</td>
<td>GRASE</td>
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<tr>
<td>5. EPI</td>
<td></td>
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<tr>
<td>Single shot</td>
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<tr>
<td>Multishot-segmented</td>
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Sequences Acronyms

- **LAVA (GE)/ VIBE (SIEMENS)/ THIRVE (PHILIPS):** T1-w GRE sequences that are used for dynamic imaging since they can be acquired in a single breath-hold.
- **DESS:** Double echo steady-state
- **EPI:** Echo planar imaging;
- **ETL:** echo train length;
- **FFE:** Fast Field Echo;
- **FIESTA:** Fast Imaging Employing Steady-state Acquisition;
- **FI SP:** Fast Imaging at Steady Precession;
- **FLASH:** Fast low angle shot;
- **FRFSE:** fast recovery fast spin-echo;
- **FSE:** Fast spin-echo;
- **GRASS:** Gradient Recalled Acquisition at Steady-state;
- **GRE:** Gradient echo;
- **HASTE:** half-Fourier single shot turbo spin-echo;
- **MEDI C:** Multi-echo data image combination (T2-w GRE, Siemens)
- **MPGR:** Multiplanar gradient recalled sequence
- **SPGR:** SPoiled Gradient Recalled;
- **SSFP:** Steady-State Free Precession
- **SSFSE:** single shot fast spin-echo;
- **STIR:** short TI (tau) inversion recovery;

**MAIN MENU**