

Imaging the Pediatric Patient: Specific Pathologies: Specific Imaging Protocols

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The application of MR imaging in the pediatric patient has increased dramatically in the recent years and undoubtedly, its role will continue to expand.

In this presentation, we will discuss the following aspects of imaging the pediatric patient:

- Sedation
- Specific Imaging protocols which are advantageous for imaging the pediatric patient
- Specific pathologies with focus on oncological imaging, and emerging applications of advanced MR imaging techniques

Sedation (1-9)

- Sedation is generally required for infants and children up to 6-7 years of age.
- Maybe pediatric anesthesiologist-led, radiologist-led or specialist nurse-led.
- Debate between use of general anesthesia and deep sedation:
 - Advantage of GA: less failure rate and therefore faster turn around. Failure rate for deep sedation ranges from 1-7%. ? Safer.
 - Disadvantage of GA: need for dedicated anesthetic equipment and pediatric anesthesiologists.
- Safety guidelines have been issued by the American Society of Anesthesiologists (ASA), American Academy of Pediatrics (AAP) and American College of Radiology (ACR). Deep sedation should be performed by someone:
 - Who is working to an accepted guideline
 - With sole responsibility for the sedation
 - Trained to an acceptable level for life support
 - Familiar with drugs, dosages, monitoring equipment, and requirements of the procedure
 - Support from other skilled staff e.g. pediatric nurse
- Pre-procedural evaluation:
 - Thorough patient assessment, including history and physical examination to screen patients and exclude contraindications to sedation. History taking should include history of respiratory illness, e.g. asthma, obstructive sleep apnea. Physical examination with evaluation of airway, range of neck motion, size of mandible and tongue, any craniofacial abnormalities.
 - Current medication and allergies

- History of sedation or anesthesia
- ASA physical status classification (I-IV). Only Class I and II are suggested candidates for sedation by non-anesthesiologists
- Preparation
 - Informed consent
 - Fasted for 4 hours before sedation
 - Reliable intravenous access
- Monitoring
 - Continuous pulse oximetry (Oxygen saturation >95%)
 - Pulse and respiratory rate.
 - Resuscitation equipment
- Post-procedural evaluation and post-discharge:
 - Continue observations until recovery of consciousness.
 - Child responds to verbal commands appropriately.
 - Found in a study that 48% returned to baseline activity and behavior with 8 hours of procedure and 89% within 24 hours
- Adverse effects of sedation
 - Around 1%
 - Mostly respiratory events, in particular, oxygen desaturation
 - Risk factors were found to be use of multidrug sedation regimes and history of pulmonary disease e.g. asthma, bronchiolitis, pneumonia
 - Delayed adverse effects i.e. after discharge home were found
 - Motor imbalance (31%), gastrointestinal effects (23%), agitation (19%) and restlessness (14%)
- Alternative methods and Aids:
 - “Feed and Wrap” for neonates. However, if failure, sedation must wait for fasting period.
 - Simulation using MR scanner simulator
 - Audio-visual system
 - Behavioral techniques and play specialists

MRI techniques for the Pediatric patient

Parallel Imaging (10-11)

Under-sample k-space and reconstruct missing data either directly in k-space or indirectly in the image domain. Skip phase-encoding steps in conventional Fourier transformation MRI during data collection using a multi-element surface coil. Traverse k-space more rapidly thereby reducing scan time. But, trade off with SNR.

General Advantages:

- Rapid Imaging, Decrease scan time and therefore, decrease motion artifacts. Useful to shorten breath-hold time or for children who cannot breath-hold.
- Enhance spatial resolution, by keeping to the same scan time. Important for resolution of small structures in pediatric patient.
- Decrease blurring in single-shot imaging techniques, such as SSFSE and EPI.
- Reduce SAR (specific absorption rate) by reducing scan time, especially relevant to 3T (high-field) imaging.
- Reduce susceptibility artifacts and eddy-current related distortions, especially for DWI/DTI.
- Coupling with 3T (high-field) imaging is ideal because of loss of SNR in parallel imaging.

Applications:

- Time-resolved contrast enhanced MRA
 - Dynamic contrast-enhanced MRA acquired prior to contrast injection and consecutively for 6-8 dynamics
 - Best arterial and venous phases can be subsequently selected for post-processing.
 - Eliminates the need to time the bolus (especially useful because of rapid circulatory rate and small contrast bolus in children).
 - Reduced image acquisition time such that arterial and venous phases can be separated i.e. no venous contamination.
- Single shot imaging (SSFSE) for e.g. in MRCP
 - Reduce image blurring by decrease in echo-train length and duration of acquisition
 - Decrease motion artifact
 - Decrease echo-train length so that single-shot acquisition can be completed within 1 expiratory phase.
- Respiratory motion artifacts for e.g. in cardiac MR
 - Increase number of signals averaged in the same scan time will minimize motion artifacts

Propeller (periodically rotated overlapping parallel lines with enhanced reconstruction) MR Imaging for the pediatric brain (12-14)

A method for motion correction involving both data collection and reconstruction Based on rotating k-space acquisition, with blades rotating through the center of k-space. Therefore, center of k-space is sampled multiple times improving artifact suppression, and data within the central region can be compared between each blade. If motion has occurred between the acquisitions of each blade, the data can be

transposed and rotated to its estimated stationary position, before final image reconstruction.

- Corrects in-plane motion, but not through-plane motion.
- Can be applied to FSE T2W images, FLAIR and DWI.
- Advantages compared to SS FSE:
 - Better contrast resolution with improvement in gray-white matter differentiation.
- Disadvantages compared to SS FSE:
 - Imaging time slightly longer than SS FSE, but still can be done within 1 min.
 - Susceptibility artifacts more pronounced with PROP
 - Increase in image reconstruction time

MRI in Pediatric Oncology

Advantages:

- Multiplanar
- Superior delineation of soft tissue anatomy and better soft tissue contrast-resolution and tissue characterization compared to CT
- Sensitivity to contrast agents
- Specificity of tumor characterization
- Flow sensitive techniques
- Study of tumor phenotypic characteristics possible i.e. cell density, areas of hypoxia, perfusion, microvascular density

Disadvantages:

- Not sensitive to small calcification
- Longer imaging time i.e. problem with sedation and motion artifacts

Emerging MRI techniques in pediatric oncology

Whole body MRI for Screening and Staging (15-18)

- Whole body staging with a single examination is desirable in pediatric cancer patients.
- Whole body MRI is now possible because of new developments in software (fast scan sequences and parallel imaging) and hardware (rolling table platform).
- No standardized sequence yet, but usually coronal T1-weighted and STIR sequences.
- Examination time: possible in 15-30mins.

- Found to be more sensitive than bone scintigraphy for bone marrow metastases (although ribcage and skull metastases may be missed), and can additionally detect soft tissue, extraskelatal metastases and primary tumor.
- CT still needed for detection of lung metastases
- Some pitfalls compared to adults:
 - Haematopoietic bone marrow is normally low signal on T1-weighted scans and high signal on STIR. Therefore, may obscure lesions
 - High signal on STIR adjacent to the growth plate due to normal proliferative process
 - High STIR signal from subclinical minor bone bruises in the lower limbs.

Dynamic contrast-enhanced MRI (DCE-MRI) for characterization of tumor microvasculature (19, 20)

- Roles in lesion characterization i.e. distinguishing malignant from benign tumors, prognostication, monitoring the effects of or predict responses to treatments and evaluating antiangiogenic and antivascular drug treatments.
- Most studies are in adult malignancies
- Involves quantitation of signal intensity changes observed during dynamic acquisition of T1-weighted images after an i/v bolus of paramagnetic, low-molecular-weight contrast agent (Gd) is delivered.
- Most studies use T1-weighted gradient-echo, saturation recovery/inversion recovery snapshot sequences or echoplanar sequences.
- Tissue T1-relaxation rate is estimated, thus allowing quantification of contrast medium concentration.
- Concentration-time curves are mathematically fitted using a pharmacokinetic model.
- Primary end points include:
 - K^{trans} ; volume transfer constant of the contrast agent, reflects contrast agent delivery (perfusion) and transport across the vascular endothelium (permeability).
 - IAUGC (Initial area under the Gd concentration-time curve). Calculated from the areas under the contrast agent concentration curve up to a specified cutoff time (usually 60s). Does not require curve-fitting, or knowledge of an accurate physiological model.

Multi-voxel proton MR Spectroscopy for brain tumors (21, 22)

- Provides independent non-invasive, biochemical information about brain tumors.
- Role includes differentiation of tumor and tumor recurrence from non-neoplastic processes and post-treatment effects, to predict histological tumor

type and grade, and assist surgical planning by localizing metabolically active areas within brain tumors.

- It has been shown that neoplastic spectra can be distinguished from non-neoplastic spectra with a high degree of accuracy.
- Tumors exhibit reduced NAA, increased Cho, inositols or glycine, enhanced broad mobile lipid resonances and accumulated lactate
- The metabolite ratios of Cho/tCr and Cho/NAA are increased in the solid portions. In the cystic portions, only lipid and lactate peaks are detected
- It has been suggested that increased amounts of Cho, lipids and lactate may be used to predict the aggressiveness of the tumor.

Diffusion tensor MR imaging (DTI) for detection and monitoring of treatment-induced neurotoxicity (23-25)

- Brain tumor patients have improved survivals
- Morbidity from cognitive function deterioration, including memory and attention, are prevalent and severely impact on quality of life
- Risk factors of neurotoxicity include young age at treatment, radiation dose and combined chemo-irradiation.
- Conventional MRI (leucoencephalopathy) is not sensitive.
- Using DTI, we found fractional anisotropy (FA) is reduced in multiple anatomical sites and that the lesions are distributed symmetrically in the periventricular white matter (shown by voxel-based analysis of FA maps)
- We found significant associations of FA with known risk factors of neurotoxicity, including age at irradiation and irradiation dose.
- In a cross-sectional study using normal control data for comparison, differences in FA had a significant effect on full-scale IQ, verbal IQ and performance IQ after adjusting for the effects of age at treatment, irradiation dose and time interval from treatment.
- Our findings suggest that DTI, using FA is a clinically useful biomarker for the assessment of treatment-induced neurotoxicity in childhood cancer survivors and can be used as an adjunct to IQ scores. Need large scale prospective studies for further verification.

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