BSNR Standards Sub-Committee

Imaging of the Developing Brain

BSNR Guidelines for Pediatric, Neonatal and Fetal brain imaging

Introduction:

There is increasing demand for safe and effective service provision for imaging of the developing brain (both in utero and postnatally). These recommendations are to help guide a uniformity of practice across the UK incorporating the most up to date evidence-based knowledge.

Much of this activity may take place in the district general hospital (DGH) setting where there may be limited access to specialist neuroradiological opinion. This guidance is provided to support neuroradiologists who engage in these practices to deliver services in their regional catchment areas. It is also to inform and advise general radiologists with specialist interest in this area of practice.

Imaging of the developing brain is challenging for a number of reasons; it is a time of rapid change in both anatomical structure and the constituent properties of brain, physical acquisition of the scan can be difficult, motion and other artefacts cause degradation of image quality and imaging changes due to pathology may be subtle. It is hoped that guidance to promote best practice will help to improve imaging in this complex area.

A framework for practice on fetal and neonatal brain magnetic resonance imaging (MRI) has been published through the British Association of Perinatal Medicine (BAPM) and this extensively covers the clinical indications for and evidence base on imaging of the fetal and neonatal brain [1]. The aim of this document is to complement the recommendations from BAPM with some additional guidance on imaging processes and techniques. The practice guidelines produced collaboratively by the American Radiological colleges and societies for the performance and interpretation of MRI of the brain and for the safe and optimal performance of fetal MRI have also been reviewed [2, 3].

It is recognised that some of the content of this document is aspirational and uniform practice may not be widespread or possible at this time in the UK.

Pediatric Neuroimaging:

- The curricula for neuroradiology training and for pediatric radiology training in the UK include specific training and experience in pediatric neuroimaging.
- The radiographic and nursing staff in the scanning centres may also need to have specific training and guidance.
- There should be close collaboration with pediatric clinicians involved in the patient's care and, where required, with the anaesthetic team.

General infrastructure and imaging recommendations:

1. Ultrasound imaging should be provided by practitioners who are trained and maintain their skills in pediatric head and neck ultrasound.
2. CT scanners should be set up to use a pediatric imaging protocol and to carefully monitor and optimise radiation dosage against diagnostic efficacy.
3. MRI scanners should have sequences specifically set up and optimised for the paediatric population. Coils appropriate for pediatric imaging should be available.
4. Imaging modalities will benefit from being situated in a child friendly environment.
5. Patients should be suitably prepared for the examination and this may require play therapy, sedation or general anaesthesia.
6. CT and MRI units need to be supported by a safe and effective pediatric anaesthetic service.
7. CT and MRI units may also be supported by a safe and effective sedation service.
8. The requests for neuroimaging should be vetted by individuals who understand the advantages and limitations of each modality in addressing the clinical question as well as its relative merits against alternative neuroimaging techniques.
9. Enough information should be provided on the imaging request to demonstrate the requirement for the investigation, to facilitate the appropriate protocol to be performed and to allow accurate interpretation of the scan.
10. Standard imaging protocols will help to improve scanning and reporting efficiency, but they may be varied on an individual basis as required. Contrast agents may need to be administered in accordance with the guidance of the manufacturers.
11. For CT, radiation dose should be recorded and regular audit of this should be undertaken to ensure national dose reference levels are not being exceeded. [4, 5]
12. The reporter should have appropriate training and expertise to interpret the scan. If this is not available locally/at the scanning centre, then tertiary review may be required. There is however a shortage of neuroradiologists generally, and paediatric neuroradiologists specifically.
13. Multidisciplinary team (MDT) review is encouraged as it improves communication, encouraging consistency in the information provided, as well as promoting education and training.

Specific recommendations – MRI:

1. This should be the neuroimaging modality of choice in the paediatric population, with CT applied in a supporting role.
2. Basic imaging datasets should include at least two different MRI contrast methods (i.e. T1 and T2), have at least two imaging planes for each contrast type and include all three imaging planes between them [6].
    a. T2-weighted imaging should be optimised for the incompletely myelinated brain in those under the age of 2 years. This may be achieved by increasing the TR and TE or by using a STIR sequence. Many congenital anomalies and pediatric disorders are characterised well with T1-weighted imaging.
    b. Sagittal imaging is useful for brain malformations where midlines structures are involved, but reformatted images from volume datasets can also reliably provide this information.
    c. Diffusion weighted imaging (DWI) with corresponding trace ADC maps are rapid sequences which provide many advantages in characterising lesions.
3. Infants and young children may benefit from applying thinner slices with smaller interslice gaps at the expense of longer imaging times compared to older children and young adults. Suggested imaging protocols are given in the appendix.
4. The examination of small body parts such as the pituitary, IAMs and orbital imaging may benefit from imaging at higher field strength (3 Tesla).
5.

Specific recommendations – CT:

1. The technique should be optimised to minimise the radiation dosage to the patient.
2. Image reconstructions should be performed using pediatric reconstruction kernels for both soft tissue and bone. If spiral volume datasets are used, images may be presented in three orthogonal planes.
3. There are variations in opinion on whether the scanning plane should avoid the eyes. Many neurological diseases for which neuroradiologists are involved include the eyes as part of a brain examination.

Neonatal Neuroimaging:

- Specific radiology training in this field may be sought to support the basic training provided within the neuroradiology or paediatric radiology training curricula.
- The radiographic and nursing staff in the scanning centres may also need to have specific training and guidance.
- Scanning centres should be equipped to manage potentially unstable neonates as well as the handling of transfers to and from Neonatal intensive care or Special Care Baby units (NICU / SCBU). Ideally an MR compatible transport incubator should be available; co-location with the neonatal/SCBU is aspirational.
- There should be close collaboration with paediatric clinicians and neonatologists.

The general observations for infrastructure and imaging recommendations for the paediatric population also apply here. Whilst many centres avoid the use of sedation and general anaesthesia by applying local guidelines for 'feed and wrap' techniques, motion artefacts cause the most significant impact on image quality and are the most challenging aspect of image interpretation.

Specific recommendations – neonatal MRI:

1. Timing of scans.
    a. Many scans are performed for prognostication in hypoxic-ischaemic encephalopathy (HIE). For this indication, and particularly if the imaging is not supported by good quality diffusion imaging, the scans are best performed in the subacute phase following an insult, typically at 10-14 days [7, 8].
    b. DWI can confirm severe HI injury in the first few days of life which may be helpful if consideration is being given to treatment withdrawal [9].
    c. Occasionally scans are performed for diagnostic reasons where the cause of the encephalopathy is uncertain. Such scans may be performed as soon as can be practically arranged.
2. Recommended basic imaging datasets are the same as for infants (see above).
    a. DWI and susceptibility weighted imaging (SWI) are very useful in the acute setting.
    b. More advanced imaging techniques, including MR proton spectroscopy and arterial spin labelling, may be used according to local expertise

Specific recommendations – neonatal CT:

1. CT scanning of the neonatal brain is not routinely recommended, but in the acute setting it can rapidly provide useful information in a sick infant and can help guide early management.
2. The specific recommendations for paediatric CT brain scans apply to neonates, but in addition, soft tissue window settings of the images should be optimised to allow for the increased water content of the neonatal brain [10].

Fetal Neuroimaging

- Ultrasound is the cornerstone of fetal anomaly scanning but the value of MR imaging of the fetal brain is being increasingly recognised [11, 12].
- Antenatal MR scans should be undertaken within the remit of a fetal medicine referral and there should be close collaboration with the fetal medicine team.
- Specific radiologist training may be sought to support any basic training provided within the neuroradiology training curriculum.
- Radiographic staff in the scanning centres require specific training and guidance.
- Scanning centres should be equipped to manage women in early and late stages of pregnancy.
- Where expertise is not available to interpret and report the scan locally, if appropriate processes are in place and there is suitable radiographic experience, the scan may still be performed locally with specialist reporting provided by a tertiary centre.
- Multidisciplinary team (MDT) review is encouraged as it improves communication, encouraging consistency in the information provided, as well as promoting education and training.

Specific recommendations – fetal brain MRI:

1. The scanning protocol should aim to obtain single shot T2-weighted images in the highest possible spatial resolution in all three orthogonal planes. (reference)
2. This should be supplemented with T1-weighted imaging and DWI if possible.

Appendix: Pediatric MR brain scan – suggested basic protocol and sequence parameters

The range of pathologies are expected to be wider than in adults with a relatively greater proportion of congenital malformations, genetic and neurometabolic disorders, many of which are associated with variations in myelin maturation. The proposals below are to provide a general guide and not aimed at being prescriptive:

Neonates and infants, applicable up to age 2* (whilst white matter is mostly immature):

- Axial FSE/TSE T2 or STIR
- Coronal FSE/TSE or STIR (FLAIR considered less useful with immature white matter)
- Sagittal T1
- Coronal T1
- Axial DWI & ADC
- 4mm thick slices or less, with no more than 1mm interslice gaps
- Volume sequences could be considered with appropriate reformats – depending on scanning time

Young children, older children and adolescents* (from age 2 upwards)

- Axial FSE/TSE T2
- Coronal FLAIR
- Sagittal T1
- Coronal T1
- Axial DWI & ADC
- 4 – 5mm thick slices or less, with interslice gaps no more than 20% of slice thickness

NB: T2 gradient echo imaging or SWI are also considered to be useful.

References:

1. Fetal and neonatal brain magnetic resonance imaging: clinical indications, acquisitions and reporting - a framework for practice. British Association of Perinatal Medicine (February 2016). www.bapm.org/publications

2. ACR-ASNR-SPR practice guideline for the performance and interpretation of MRI of the brain (Resolution 6). Revised 2013. www.acr.org/guidelines
(ACR – American college of radiology, ASNR – American society of neuroradiology, SPR – Society for pediatric radiology)

3. ACR-SPR practice parameter for the safe and optimal performance of fetal MRI (Resolution 11). Revised 2015. www.acr.org/guidelines

4. IRMER 2000, no 1059, regulation 7 (optimisation)

5. www.gov.uk/government/publications/diagnostic-radiology-national-diagnostic-reference-levels-ndrls/national-diagnostic-reference-levels-ndrls

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ischemic encephalopathy: a systematic review. *Pediatrics* (2013) 131:88-98

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