The role of NMR and other techniques in neonatal imaging

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1 Introduction

Nuclear magnetic resonance (NMR) is a recent addition to the imaging techniques available to the neonatologist evaluating disease in the newborn. Reports of this new modality are at present few and the role for NMR imaging (NMRI) is not yet clear but we have encouraging indications of the direction that further research may pursue. The aim of this review article is to consider the potential advantages of NMRI over other imaging techniques and to discuss how NMRI may contribute to evaluation of neurological disorders in the infant.

The main advantage of NMR computerized X-ray tomography (CT) is in its safety and the facility for multiple scanning planes. There is no known biological hazard of NMR and it is considered to be a safe imaging technique. Previously recommended contraindications including epilepsy, cardiac arrhythmias and pregnancy are no longer considered to be potentially dangerous. It is possible to make NMR images in coronal, sagittal, axial, or oblique planes, and this is a major advance over CT. The main disadvantage is in the instrumentation of NMR. Nuclear magnetic resonance imaging requires a large cylindrical magnet in which the patient lies. The room in which the magnet is housed must be screened from extraneous radiowaves, consequently the patient must be brought to the NMR unit, thus limiting its value in the examination of critically ill neonates. In addition the scanning times of currently available NMR units are slow (minimum of several minutes) and sedation of young children is usually necessary.

Almost all the published reports on NMRI in children refer to head scanning and the majority of this review will deal with this aspect. It is however worth mentioning that there is some promising data on the use of NMR to detect serious chest infection; NMR abnormalities in children have been detected which were not apparent on chest X-ray [15]. Pelvic organs are very well seen and NMR examination of the

Curriculum vitae

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neonatal hips in cases of suspected dysplasia may become particularly important as X-ray does not reveal the unossified hip joint. Recent reports of real-time NMR imaging in delineating cardiac anatomy in children [11] may reduce the need for cardiac catheterization in infants with suspected heart disease.

The technique of image production by NMR is complicated and has been well reviewed elsewhere [10]. NMR images may be derived in several ways depending on the strength and duration of proton stimulation. Scans are referred to as proton density, inversion recovery (IR), and spinecho (SE) sequences.

In cerebral imaging the proton density scan, as its name suggests, reflects the compactness of the protons within the brain and usually gives a representation of cerebral anatomy. On this scan the brain has a relatively featureless appearance. The IR scan is largely T1 dependent and as white matter behaves differently from grey matter (the former has a shorter T1), clear contrast between grey and white matter is seen. The SE scan produces T2 dependent images. The ventricular system is clearly seen but does not discriminate grey from white matter. Pathology usually shows well on the SE sequences.

Because of the physical differences between grey and white matter they are clearly distinguished from each other on NMR inversion recovery scans and progress in myelination of the child's brain can be observed (Figs. 1 and 2). No other imaging technique provides this ability. In addition bone produces a very poor paramagnetic signal and does not show well.

Fig. 1. An axial IR scan from a normal infant aged six months at the mid-thalamic level. There is a white region (short T1) corresponding to myelination in the region of the thalami and this extends posteriorly as the thalamo-occipital radition. (Reproduced by courtesy of the Editor, British Medical Journal).

Fig. 2. An axial IR scan from an infant aged 17 months. The slightly dilated lateral ventricles are clearly seen. When compared with Fig. 1 there is much more extensive apparent myelination (short T1) including thalamus, forceps major and minor, as well as the external capsule. (Reproduced by courtesy of the Editor, British Medical Journal).
Levene, NMR-techniques

This is used to advantage as the skull does not obscure structures close to it when viewed on NMR scans. This is of particular importance when examining the posterior fossa.

2 Intracranial hemorrhage

Intraventricular hemorrhage (IVH) is the commonest cause of intracranial hemorrhage in the premature newborn and approximately 50 percent of all infants born at a gestational age of 30 weeks and below will sustain this lesion. Computerized X-ray tomography has been used to diagnose IVH and appears to be an accurate method but real-time ultrasound is convenient, safe and probably more reliable than CT. Preliminary data with NMR reveals that hemorrhages both intraparenchymal and confined to the ventricles have been diagnosed by this technique [5]. In another report, NMR could not confirm the presence of a small IVH seen on ultrasound examination in one infant [7]. It is possible that the small lesion was missed by taking too few axial scans through the head of the caudate nucleus. Small subdural and subarachnoid hemorrhages may be missed in the newborn infant examined by ultrasound, and NMR may be more successful in detecting these than other techniques. For the present and probably the near future real-time ultrasound is likely to remain the best method for detecting intracranial pathology.

3 Ventricular dilatation

This may prove to be one of the most important applications for NMRI. A major concern to neonatologists is the distinction between cerebral atrophy and post-hemorrhagic ventricular dilatation in order to know which infants require ventriculo-peritoneal shunting. Neither CT nor ultrasound provide adequate information to distinguish these conditions. NMRI clearly delineates ventricular size and shape (Fig. 2) and in addition preliminary studies suggest that transependymal fluid may be clearly seen [5, 6, 7]. This was present on SE scans as areas of prolonged T2 surrounding the ventricles. In one infant with acute shunt blockage this appearance was clearly seen before replacement of the shunt, and this abnormality subsequently disappeared after appropriate surgery (Fig. 3).

Fig. 3. An axial SE scan from an infant of 11 months. The child with a ventriculo-atrial shunt presented with irritability and vomiting and a shunt blockage was suspected. NMR scan at that time shows lighter regions (increased T2) at the margin of the dilated lateral ventricles, best seen around the occipital horns. The rest of the brain and ventricular system looks relatively featureless. (Reproduced by courtesy of the Editor, British Medical Journal).

4 Asphyxia

Perinatal asphyxia is a common and important cause of neurological abnormality in the newborn infant and in some cases leads to permanent neurodevelopmental abnormalities.
CT reveals areas of parenchymal hypodensity thought to be due to cerebral edema in full-term infants with hypoxic-ischemic encephalopathy [4]. Real-time ultrasound is much less reliable in the detection of this condition and although abnormalities have been reported with ultrasound [8, 12], these are not consistently seen.

There have been several case reports of NMR abnormalities in infants with symptomatic cerebral asphyxic injury [5, 6, 7]. Two infants demonstrated long T2 in the periventricular region on SE scan which was not present in normal newborn infants (Fig. 4). In addition long T1 was also seen on IR scans in a similar distribution. It is not certain at present how specific these abnormalities are and how they correlate with CT or autopsy findings. Nevertheless there is some promise that NMRI may be able to follow the progression of cerebral edema in asphyxiated infants.

5 Ischemia

Ischemic lesions in the newborn may take the form of periventricular leukomalacia (PVL) in premature infants, or cerebral artery (or venous) infarction in both preterm and mature newborns. Periventricular leukomalacia can be diagnosed by real-time ultrasound and appears to show a characteristic hyperechoic pattern which in some cases resolves to leave echofree cystic lesions in the periventricular white matter [8, 9]. CT may detect cystic degeneration if severe but ultrasound is certainly more sensitive to this abnormality. Hypodense areas in the periventricular area seen on CT are probably normal in the premature infant and are unhelpful in diagnosing PVL. There is only one report of cystic PVL diagnosed by NMR and much further data must be collected before the role for NMRI in diagnosing PVL is clear.

In adults there is evidence that NMRI detects cerebral ischemic lesions [3, 4] and at least in some cases at a considerably earlier stage than CT. Animal experiments show NMR abnormalities within two hours of the ischemic lesion and these correspond to areas of ischemia found on pathological examination [2]. These encouraging reports suggest that NMRI may be of considerable value in diagnosing these important lesions [14] in the newborn period.

6 Posterior fossa lesions

As mentioned above, the skull containing the posterior fossa may cause considerable interference in detecting pathology in this region. In the newborn, hemorrhage associated with tentorial tears and intra-cerebellar hemorrhages are relevant in this context. Ultrasound is far from reliable in detecting these abnormalities.
There are no reports in the literature of the NMRI diagnosis of either of these conditions but in the adult it has proved to give information not detected on CT scanning [3]. Further reports are awaited in this area.

7 Congenital abnormalities

Both ultrasound and CT detect most significant congenital intra-cranial abnormalities and initial evidence that NMRI is also effective in this area [5, 6]. It is unlikely that NMR will contribute significantly more in the diagnosis of congenital abnormality than does ultrasound.

8 Abnormalities in myelination

This is probably the most important role for NMRI in pediatric practice. Delay in myelination can be readily diagnosed and has been seen following IVH, probable rubella embryopathy and in infants with cerebral palsy and in one child with a neurodegenerative disorder [5]. In a study reporting follow-up of infants with IVH and related disorders, gross delay in myelination was seen in three children [7] and all had significant neurological problems or developmental delay. Two other children with spastic hemiplegia, however, showed no apparent delay in myelination.

9 Conclusion

NMRI shows promise in making further progress in our knowledge of neonatal cerebral pathology and in predicting outcome. Thus far, too few studies have been performed to be able to predict the precise role for this new imaging technique but intracerebral edema, and assessment of ventricular dilatation are particularly important. No imaging technique other than NMR offers the prospect of observing myelination in vivo.

Currently real-time ultrasound must be the technique of choice in imaging the brain of the newborn and infant, and NMR may then be indicated in some abnormalities particularly if ischemia, edema or increased ventricular pressure is suspected. It is likely that in the future NMR may take over completely from X-ray CT in imaging of the child's brain.

The prospects of improving NMR with faster imaging times, contrast studies [1] and even assessment of cerebral blood flow [13] make NMR one of the most exciting developments in medicine for several years.

Keywords: Brain, hemorrhage, hydrocephalus, newborn, NMR.

Zusammenfassung

Bedeutung der Kernspintomographie und anderer bildgebender Verfahren in der Neonatologie

Die Kernspintomographie (NMR) ist ein neues Verfahren, mit dem wichtige Informationen, die andere bildgebende Techniken nicht liefern, erhalten werden können. Wie beim Ultraschall oder Computertomogramm werden die anatomischen Strukturen, das Ausmaß von Hämorrhagien und die Ventrikelgröße deutlich dargestellt.

Schlüsselwörter: Blutung, Gehirn, Hydrocephalus, Neugeborenes, NMR.

Résumé

Rôle de la RMN et des autres techniques dans l'imagerie néo-natale

L'imagerie par résonance magnétique nucléaire (IRMN) est une nouvelle technique fascinante qui a déjà fourni d'importantes informations qui n'étaient pas disponibles par les autres méthodes. L'IRMN trace clairement les limites anatomiques, démontre l'étendue d'une hémorragie et révèle la taille des ventricules au même temps.
Levene, NMR-techniques

titre que les ultrasons et le scanner. Toutefois, l'IRMN
donner en complément des informations sur la myélinisa-
tion cérébrale et sur l'eau intra-cérébrale, ce qui n'est
pas obtenu par les autres méthodes. Des développements

Mots-clés: Cerveau, hémorragie, hydrocéphalie, nouveau-né, RMN.

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