Diffusion-weighted imaging (DWI) can readily be performed in the neonate, although currently studies remain a few years behind those carried out on adults. DWI relies on the random diffusion of water molecules. As for the adult population, a pulsed gradient spin echo sequence (PGSE) with cardiac gating can be used to exploit the effect of diffusion on image contrast and to determine the apparent diffusion coefficient (D*) for tissues or fluids. Anisotropic properties caused by the restriction of the movement of water molecules may be demonstrated. In the neonatal brain restricted motion can be detected in both myelinated and unmyelinated white matter tracts. DWI has been used to study changes in global and focal ischaemic injury to the neonatal brain. A decreased D* may be documented after an ischaemic insult followed by a gradual increase. These changes are consistent with animal data but show a slower time course. Intervention following perinatal ischaemic injury must be started within hours. DWI detects early ischaemic injury and may therefore be a useful tool for identifying those infants who could benefit from intervention.

Keywords Magnetic resonance · Diffusion-weighted imaging · Neonate · Brain · Ischaemia

Introduction

Although paediatric diffusion-weighted imaging was performed soon after adult studies began [9, 10], there have been relatively few studies performed over the last decade, and only now is the subject receiving significant attention [1, 2, 3, 4, 5, 6, 7, 8].

In this paper we describe the techniques we have used in studies performed over the last 10 years. Normal features, changes seen in hypoxic-ischaemic injury and neonatal infarction are described, and other conditions are briefly mentioned.

Techniques

Two MR systems were used in these studies. One was a Picker prototype which was operated at 0.15 T. The other was a standard Picker HPQ system operating at 1.0 T. On the 0.15-T system a whole-body gradient coil set of 490 mm internal diameter was used for most studies, and provided a gradient strength of up to 16 mT/m. Quasispherical head receiver coils were used for all studies in this system, with the addition of padded foam to increase patient comfort and a plastic bag containing polystyrene beads, which was evacuated to assist with head fixation. The receiver coils were supported so that rocking motion with respiration was reduced. The same general type of fixation was used on the 1.0-T system.

Cardiac gating on alternate beats (or every fourth beat for rapid pulse rates) with a delay of 200–700 ms from the R wave was employed to time the pulse sequences into mid and late diastole. Images were of 128×256 matrix size except where specifically labelled 256×256. Two of four excitations were used in each study, with a slice thickness of 4–8 mm.
A pulsed gradient spin echo (PGSE) pulse sequence was used. TE values of 130 or 200 ms were used with the conventional whole-body gradient coils. We used b values of 550 or 600 mm$^2$/s (TE = 130 and 200 ms) as well as 1100 mm$^2$/s (TE = 200 ms) and 1510 mm$^2$/s (TE = 200 ms).

First-order gradient moment nulling was implemented in the z axis in the coronal, sagittal and transverse planes. A purpose-designed small gradient coil set of 300 mm internal diameter was employed for some head studies. This set provided approximately four times the gradient strength of the standard set. With this system, it was possible to obtain b values of 550 mm$^2$/s with a TE of 80 ms and a diffusion time of 27 ms. The gradient set was only suitable for imaging heads and limbs in adults, although whole-body examinations of infants are possible with this system.

Unsensitised control sequences that were comparable in all respects except for the additional diffusion sensitising gradients were available to match all PGSE sequences.

**Normal features**

These are illustrated in Fig. 1. Anisotropic changes can be seen in the varying signal intensity in white matter. This applies both to the white matter which is myelinated and to the premyelinated areas [11].

**Hypoxic-ischaemic injury**

In hypoxic-ischaemic injury (HII) damage is more generalised than in focal infarction. The symptomatology of these two conditions can overlap, and both may evolve over several days, making early diagnosis and clinical grading difficult. Focal infarction generally has a good prognosis, whilst the more severe forms of HII have a very poor outcome. Cranial ultrasound and X-ray computed tomography are generally not diagnostic of either condition in the first few days of life, and conventional T1- and T2-weighted MR imaging studies have not been performed in the very early neonatal period. The need for early and accurate diagnosis in these conditions has increased, because new forms of therapy may soon be available for HII, and these are likely to require administration within 6–8 h of birth before the...