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The role of diffusion weighted magnetic resonance imaging in assessment of normal myelination in infantile brain

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KEYWORDS

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Abstract *Background:* Myelination is a dynamic process starting during fetal life and proceeds predominantly after birth in a well-defined, predetermined manner. MR techniques such as diffusion-weighted images and the measurement of the apparent diffusion coefficient (ADC) have been applied to the study of normal brain development.
Aim of the work: To demonstrate the role of Diffusion Weighted Imaging and ADC maps in assessing normal progression of the infantile brain myelination.
Patients and methods: The present work included 30 infants with normal MRI study of the brain, normal psychomotor development and normal neurological examination. Conventional MRI, DWI and ADC maps were done for all the infants, the average ADC values were calculated in selected areas in white matter.
Results: The age of studied children ranged from 1 month to 3 years, 13 males (43.3%) and 17 females (56.7%). In each of the selected areas of the white matter of the brain, examined ADC showed the highest values at birth and there was a significant decrease with age ($p < 0.05$).
Conclusion: ADC values decrease with progressive increase of age. Using ADC values is useful in assessment of normal myelination development in the infantile brain and matches the results of conventional MRI.

1. Background

Myelination is a dynamic process that starts during fetal life and proceeds predominantly after birth, at least until the end of the third year in a well-defined predetermined manner.[1]

It is useful to characterize myelination evolution in normal brain development in order to allow assessment of neurodevelopment that can enhance our understanding of early brain

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growth changes during both normal and abnormal brain development.[2]

MR imaging is a safe, noninvasive method for evaluating the development of myelination in infants. Diffusion weighted MRI and ADC maps depend on the fact that as the formation of myelin by the oligodendrocytes proceeds, an increase in brain cholesterol and glycolipids concentration and a decrease in water content take place. This results in a change of white matter diffusion properties.[3]

Myelination begins at around 20 weeks gestational age (GA) and continues up to around 2 years of age. As myelination precedes, the water content of white matter (WM) decreases, causing a reduction in signal intensity (SI) on T2 weighted imaging. There is a corresponding increase in glycolipids, cholesterol and proteins, which causes an increase in SI on T1 weighted imaging. Changes in the SI of WM due to myelination are demonstrated at different ages on T1 and T2 weighted imaging. T1 weighted imaging is better at demonstrating myelination in the first 6–8 months after birth and T2 weighted imaging is better between 6 and 18 months.[4]

The water content of the brain tissues declines between 24 weeks and term. Myelin is seen in many gray matter nuclei and white matter tracts of the brainstem and cerebellum around 28 weeks of gestational age. However, new myelin is not seen between 28 and 36 weeks gestational age.[5]

During the first year of life, myelin spreads throughout the brain according to a predetermined scheme of chronological and topographic sequences. It proceeds centrifugally, from inferior to superior and from posterior to anterior. In the brain-stem, myelination proceeds from the dorsal to the ventral areas. In the cerebral hemispheres, it proceeds from the central sulcus toward the pole and from the occipital and parietal lobes toward the frontal and temporal lobes. Sensory fibers myelinate before motor fibers, and projection pathways earlier than association pathways; sensitive, visual, and auditory tracts are already myelinated at birth.[3]

Diffusion magnetic resonance imaging (DWI) studies the diffusivity of water, i.e. the random microscopic movement of water molecules, or Brownian motion, induced by thermal energy. The movement of water molecules is affected by various tissue components (cell walls, membranes, intracellular organs, macromolecules).[6–8]

MR measurement of the Brownian movement of water molecules can be applied at different, increasingly complex levels: DWI, ADC maps, DTI and Tractography.[9]

2. Aim of the work

The aim of the work is to demonstrate the role of Diffusion Weighted Imaging and ADC maps in assessing normal progression of the infantile brain myelination.

3. Patients and methods

The present work included 30 infants with the following inclusion criteria:

1. Normal MRI study of the brain.
2. Normal psychomotor development.
3. Normal by neurological examination.

All infants included in the study underwent the following:

1. Full history taking.
2. Thorough clinical examination.
3. All the infants were sedated and no discomfort or complications were found by care takers.
4. Conventional Magnetic Resonance Imaging including T1 WI, and T2 WI were done and they were essentially normal.
5. Diffusion Weighted Imaging and ADC maps were done for all the infants, the average ADC values were calculated in selected areas in the white matter as follows:

Supra tentorial region (7 sites)	• Genu and splenium of the corpus callosum. • Anterior and posterior limb of the internal capsule. • Corona radiata. • Centrum semiovale (pre and post central gyrus).
Infra tentorial region (3 sites)	• Middle cerebellar peduncle. • Ventral aspects of the brain stem at the level of the pons. • Dorsal aspects of the brain stem at the level of the pons.

6. Regions of interest of five pixels were outlined manually in these areas by using a combination of the image with a *b* value of 0 images and ADC maps to help identify relevant anatomy.
7. Data from the medical ethics were considered, the infant's parents were aware of examination, informed consent was obtained.

4. Imaging parameters

MR imaging performed at 1.5 T was done for all patients using both conventional and DW sequences. DW imaging was performed with a maximum diffusion-sensitizing gradient of a b value of 1000 s/mm^2 in three orthogonal planes. By using an echo-planar technique, transverse images were obtained, both with and without the diffusion gradient: 6500/101 (repetition time msec/echo time msec); section thickness, 5 mm; intersection gap, 2.5 mm; field of view, 20 cm; matrix size, 128_128; one signal acquired. Conventional MR sequences comprised transverse (480/16) and sagittal (450/8) T1-weighted sequences and transverse T2-weighted sequences (3000/30–90).

5. Statistical analysis

Statistical analysis was performed. A general linear regression model was used to examine the relationship between ADC and subject age.

6. Results

The present work included 30 children with their ages ranging from 1 month to 3 years, they were 13 males and 17 females (Table 1). Nineteen of them had ophthalmological