Pediatric DTI Database for Characterization of Normal Brain Development and for Radiological Diagnosis of Anatomical Abnormalities

L. Hermoye[1], C. Saint-Martin[1], S. Mori[2], S. Wakana[2], R. Menten[1], S-K. Lee[3], J. Kim[3], P. Clapuyt[1], G. Cosnard[1]

[1]Diagnostic Radiology Unit, Universite Catholique de Louvain, Brussels, Belgium, [2]Department of Radiology and Radiological Science, Johns Hopkins University, Baltimore, Maryland, United States, [3]Department of Radiology, Yonsei University, Seoul, Korea, Republic of

Introduction

Diffusion tensor imaging (DTI) is a promising technique for the characterization of pediatric neurological disorders. However, its clinical use is hampered by the lack of a reference standard. Although atlases of the normal fibers topology have been created in adults (1), their pediatric equivalent cannot be found in the literature. To fill in this gap, we started a multi-institutional effort to create a database of the DTI color maps in children between 0 and 1 years.

Materials and methods

Five normal neonates and 13 pediatric patients (age range 0-1 years) were scanned with a SENSE head-coil on a 1.5 Tesla whole-body MR scanner (Intera, Philips Medical Systems, Best, The Netherlands) fitted with explorer gradients (60 mT/m). The pediatric patients had clinical indications of neural abnormalities and were anesthetized. Only the patients whose brain anatomy, as depicted on a T2-weighted sequence, turned out to be normal were included. Five normal adult volunteers were also scanned. The agreement of our Institutional Review Board was obtained and an informed consent form was signed by the children's parents.

All participating sites used a common protocol. For the DTI acquisitions, a single-shot spin echo - echo planar sequence (SE-EPI) was used, with diffusion gradients applied in 32 non-collinear directions. Fifty axial slices were acquired, parallel to the AC-PC line. The imaging parameters were: FOV = 220mm, slice thickness/gap = 2.3 mm/0.0 mm, acquisition matrix = 96*96, reconstruction matrix = 256*256, TR = 7859 ms, TE = 80 ms, diffusion b-value = 700 s/mm^2, SENSE reduction factor = 2.5.

The fiber direction was assumed to be indicated by the eigenvector corresponding to the tensor's main eigenvalue. This direction was color-coded (blue for superior-inferior, green for anterior-posterior, and red for left-right) with a brightness weighed by the fractional anisotropy, yielding a cartography of the tracts' location, direction, and anisotropy.

The main developmental changes were described by a group of four observers. To illustrate our findings, representatives cases were chosen amongst the newborns, the 1-year-old children, and the adult subjects at four representative sections.

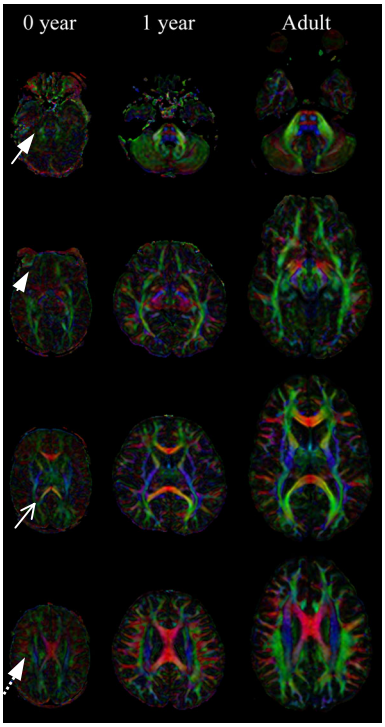

Figure 1: Representative color maps in newborns, 1-year-old children and adults

Results

Anatomical changes delineated by color maps are shown in figure 1. As the tracts' brightness is weighted by their fractional anisotropy, an appreciable increase of the image brightness was observed between 0 and 1 years. Almost all the tracts could be observed from birth. Tract size increased progressively with the age. The four anatomical structures whose evolution is the most definite are:

- The middle cerebellar peduncles (filled arrow) which were short and dark in the newborns but developed rapidly during the first year
- Association fibers such as the inferior fronto-occipital , uncinate fasciculi (arrowhead), and superior longitudinal fasciculus (dotted arrow), were poorly visible in the newborns, thickened during the first year but acquired their final size only later
- The forceps major (open arrow) which was thin and inverse V-shaped in the newborns but grew and became inverse U-shaped during the first year
- The corpus callosum in the medial regions and the internal capsule which are fibers that can be most distinctively identifiable in the early phase of the development.

Discussion

Before the advent of modern imaging techniques, post-mortem dissections were the only way to study the brain maturation (2). The observation of the gray-white matter contrast on anatomical MR sequences was a great step forward (3), but DTI offers even greater perspectives. The possibility to localize the tracts individually, to analyze their shape, their direction and their anisotropy could indeed improve the characterization of the pediatric neurological disorders. The ability of color maps to reveal the white matter anatomy is clear in Fig. 1 (4,5). For the future use of this modality for diagnostic radiology, it is imperative to understand the normal time course of anatomical changes, especially during the first year of life, in which drastic anatomical changes occur. In this abstract, we report our effort to create a database of normal brain development revealed by DTI.

One limitation of our study is that most of our subjects were not normal volunteers. Although the inclusion criteria were limited to pathologies that are not known to alter the white matter maturation, this database should be used only for characterization of significant brain abnormalities and not for control data of quantitative studies of subtle diseases. It is our future effort to confirm the lack of neurological disorders in the participants. We are also working to make the database available as a public resource for normal references.

References

1) Wakana S. et al., *Radiology*, 230: 77-87, 2004
2) Brody,B.A., *J Neuropathol Exp Neurol*, 46 : 283-301, 1987
3) Barkovich A.J. et al, *Radiology*, 166: 173-180, 1988
4) Neil J. et al, *NMR Biomed*, 15:543-552,2002
5) Mukherjee P. et al, *Radiology*, 221:349-358, 2001