Quantitative fiber tracking in the premature at term age shows a correlation with MRI findings, gestational age and head circumference

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Introduction

Premature birth is associated with a high risk of cerebral abnormalities leading to cognitive impairment and long term morbidity [1]. Diffusion Tensor Imaging (DTI) is an MRI method sensitive to white matter maturation [2]. Fiber tracking has been used to detect abnormalities in white matter structures in term newborns [3] and in preterms [4]. We studied preterm infants at term equivalent age in order to investigate whether fiber tracking (FT) parameters display a relation with conventional MRI findings and patient specific factors, like birth weight (BW), gestational age (GA) and head circumference (HC).

Study group and Methods

All preterm infants < 31 weeks with a 3.0T MRI scan at term equivalent age entered the study. Most patients were sedated during scanning. Based on conventional MR findings, patients were divided into three groups: I) children with no and minor MRI abnormalities, II) children with mild ventricular dilatation and III) children with moderate-severe WM abnormalities.

The MRI was performed on a Philips Achieva 3.0T scanner and included at least axial T1, T2 and DTI series, the latter with sense factor 3, b-values: 0-800s/mm^2, 32 directions using single-shot-EPI (50 slices,1.41x1.41x2mm). DTI registration was performed using registration software of the Philips MR workstation. We used a fiber-tracking program [5], based on a line propagation technique, stopping for anisotropy index CI<0.12 and maximum angle α >10º. Two structures were analyzed: the posterior limb of the internal capsule (PLIC) and the corpus callosum (CC). PLIC fibers were generated by fiber tracking starting from all voxels in the brain, using two filtering ROI's on two consecutive axial slices in the PLIC region (Fig.1A). For CC fibers, two sagittal slices were used for filtering (Fig. 1B). Quality of the fiber bundle was assessed visually: if the volume of the artifactual fibers was more than 10% of the total volume of the bundle, the bundle was excluded from further analysis. For the generated fiber bundles, volume V (sum of volume of all pixels through which one or more fibers passed), fractional anisotropy (FA) and apparent diffusion coefficient (ADC) (average value of index of all voxels through which one or more fibers passed) and length L (average length of all fibers in the bundle) were calculated.

Since all FT parameters were influenced by postmenstrual age (PMA) at which the scan was made, all parameters were corrected for PMA using a linear model. Next, in SPSS an univariate General Linear Model (GLM) was used to assess the effects of factor (group) and variables (GA, BW, HC) on the FT parameters. The difference of FT parameters between the MRI groups was further analyzed using a Mann-Whitney test. Furthermore, the differences in FT parameters between left and right PLIC bundle were tested using a Wilcoxon signed rank test.

Results:

Of the 92 patients, fiber tracking was possible in 74 patients (example in Fig.1C), with n=20 in group I, n=20 in II and n=34 in III. 18 patients were excluded due to severe artifacts (motion and sense artifacts). In addition, 10 CC bundles and 2 PLIC bundles were removed from analysis due to artifacts. The FT parameters depended on various variables (Table 1). Only the ADC in the CC and left PLIC displayed a significant relation with the MR group (values in Fig.2). For the CC, volume V, CI and length L depended significantly on GA. For the PLIC, both volume and length of the left and right bundles depended on the head circumference. The results for the PLIC displayed a lower inter-patient variability than the results for the CC (Fig.2). A significantly larger volume V and higher CI was observed in the right PLIC compared to the left PLIC.

Discussion

Quantification for PLIC and CC fibers is possible in the premature brain at term. Compared to PLIC, a larger variation for CC for all FT parameters was observed in this population, likely due to heterogeneity in the brain maturation in this structure, which is also observed visually when fiber tracking. The significant difference in ADC of the CC between the MR-groups suggests that the maturation is delayed in the group with more severe MRI abnormalities (higher ADC). Interestingly, in the CC several FT parameters depended on the GA, suggesting an influence of age at birth on brain maturation.

References

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model	corpus callosum CC					PLIC right					PLIC left				
variable	V	FA	CI	ADC	L	V	FA	CI	ADC	L	V	FA	CI	ADC	L
HC	*					**				**	**				*
BW						*									
GA	*		*		*										
group				*										*	

** = p<0.01; * = p<0.05; HC = head circumference. BW = birhtweight. GA = Gestational age.
V = volume. FA and CI are anisotropy indices. ADC = Apparent Diffusion Coefficient. L = Length of fiber bundle.

Table 1: GLM analysis of effect of variable on dependent FT parameter.

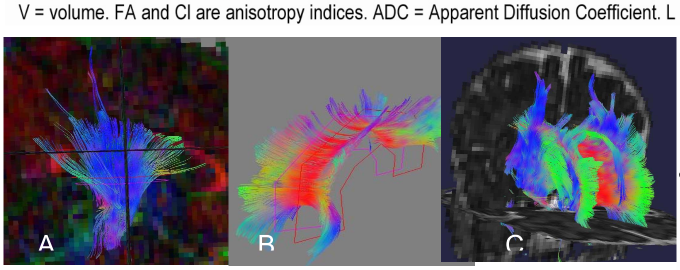

Fig.1. A. PLIC fibers and ROIs. B. CC fibers and ROIs. C. Example of FT in premature brain at term equivalent age.

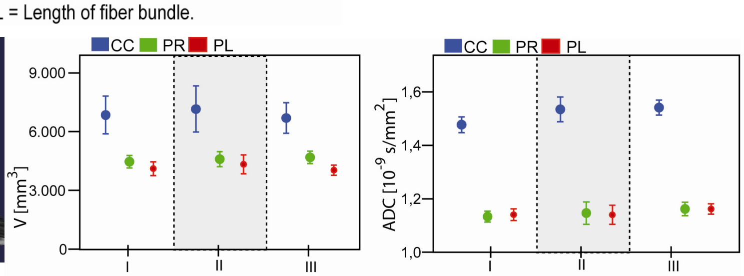

Fig. 2. Volume V and ADC for the 3 patient groups, for the corpus callosum (CC), PLIC-right (PR) and PLIC-left (PL) fiber bundles