DTI in neonates: data corruption due to motion

Anneriet M. Heemskerk[1,2], Annemarie Plaisier[2], Irwin Reiss[2], Maarten H. Lequin[1], Alexander Leemans[3], and Jeroen Dudink[1,2]

[1]Radiology, Erasmus MC University Medical Center, Rotterdam, Netherlands, [2]Pediatrics, Erasmus MC University Medical Center, Rotterdam, Netherlands, [3]Image Sciences Institute, University Medical Center Utrecht, Utrecht, Netherlands

Introduction

Motion is a major concern for neonatal imaging as the neonates have high expectancy of movement. Especially for diffusion tensor imaging (DTI) intra-slice motion by a sudden shake of the head, results in a corrupted image (loss of signal intensity), which in turn can result in miscalculation of the DTI estimates (e.g. ADC and FA). Several studies report a rejection of 15-40% of the subjects due to severe artifacts[1,2] and we expect the incidence of less severe artifacts to be even larger. However, no study has quantified the rate of motion artifacts in neonates. Therefore, the aim of our study was to investigate the number of outliers as a method to detect corrupted slices in neonates. We also evaluated the results of different tensor estimation methods and the effectiveness of motion correction.

Material and methods

Subjects: we prospectively investigated a subpopulation of 27 preterms who were born <29 weeks gestational age (GA) and were scanned for routine clinical care between 29^{+3} and 30^{+4} week GA. The preterms had no evidence of white matter injury, were stable at the time of acquisition, not sedated during scanning and placed in an MRI compatible incubator. The study was approved by our local ethical review board.

MRI: The preterms underwent a clinical MRI scan including a DTI acquisition. Parameters were: TR=11725 ms, TE=85.6-88.6 ms, FOV=17-20 cm, matrix 64*128, b=750 s/mm^2, and 25 directions.

Processing: Data processing was performed using ExploreDTI[3]. Eddy currents and motion correction was applied using affine registration. The tensor was estimated using ordinary least squares (OLS), weighted least squares (WLLS) and RESTORE[4]. For each image containing more than 1000 voxels, the % outliers were calculated. An average of 521 images was analyzed per subject. The number of slices per subject with >10% outliers (O_{10}), >30% (O_{30}), and >50% (O_{50}) were determined and reported for the non-motion corrected WLLS datasets to give an indication of the underlying data.

Results

Typically, the child is unsettled for a short time resulting in motion related outliers present within a fraction of the imaging acquisition, thereby corrupting a limited number of gradient directions (fig 1). The occurrence of outliers (Table) shows that 60% of the subjects had data that were corrupted (O_{30}). Ten subjects had more than 10 heavily corrupted slices (O_{50}) which will dramatically impact the ADC and FA maps if the data processing is not performed carefully (Fig 2).

Motion corrupted slices can lead to affine registration problems, such as erroneous stretches and shears, producing extra corrupted data. Additionally, outliers are handled differently by each tensor estimation method, Fig 2.

Discussion

The number of outliers is high for the neonatal datasets and presses the need for careful data inclusion and processing. The impact of outliers on the resulting ADC and FA maps depends on the number and location of corrupted images and the tensor estimation method. OLS is typically used for tensor estimation by MRI vendors and processing tools such as FSL, however, it is insufficient with corrupted data. Advanced methods (RESTORE or DROP-R[1]) have longer processing times but are more consistent. Additional research is ongoing to quantify the effects of motion on the reliability and to determine objective measures for data quality.

Conclusions

Motion corrupted slices are a major problem in neonatal DTI as 40% of the subjects show a limited number of slices with a large % of outliers. Targeted acquisition, processing and quality assessment is needed in this population to obtain reliable tensor estimates.

	O10	O30	O50
# subjects >10 sl	27	15	10
# subjects > 20 slices	26	10	1
Mean # 0x	50	15	9
Range # Ox	17-79	1-38	0-24
Mean % of Ox	9.5	2.9	1.7
Range of % Ox	3.3-15.7	0.2-7.0	0.0-4.4

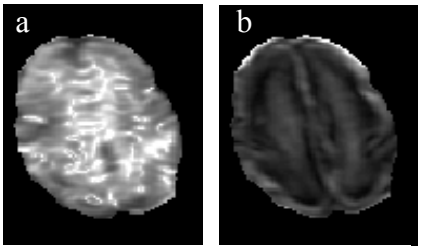

Fig 2 FA map with a) OLS and b) WLLS tensor estimation for data with corrupted slices. FA 0-1

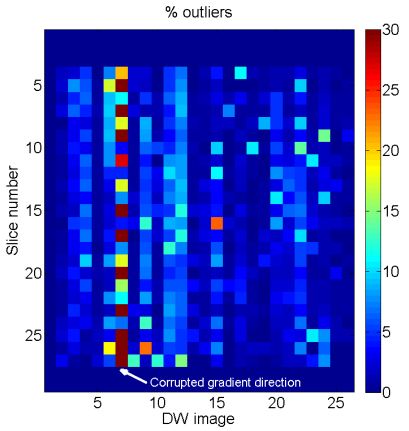

Fig 1 Outlier profile for 1 subject (slices: 39 O_{10}, 10 O_{30} and 3 O_{50}). Only 1 gradient direction is heavily affected.

References: [1] Morris D., MRM (2007) 66:92-101; [2] Dudink J., Ped Rad (2007) 37:1216-23; [3] www.ExporeDTI.com; [4] Chang L, MRM (2005) 53:1088-1095