Reproducibility of Quantification for Diffusion Values in Lumbar Spinal Nerves Using Diffusion Tensor Imaging

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Introduction Diffusion tensor imaging (DTI) and fiber tractography (FT) have been widely used in the evaluation of the central nervous system. Recently, quantitative diffusion values as the fractional anisotropy (FA) and the apparent diffusion coefficient (ADC) values have been reported as potential tools for diagnosis of lumbar nerve entrapment.[1-3] However, these values are known to be affected by various factors as the measurement method and the partial volume effects. The purpose of this study was to provide a reliable way of obtaining these values using DTI and FT of the human lumbar spinal nerve with a 3.0-T MR scanner.

Materials and Methods The lumbar spinal nerves were examined in 6 healthy male volunteers (mean age, 35 years, range, 32-43 years) with no experiences of sciatica, with DTI and FT using a 3.0-T MR unit (Achieva; Philips Healthcare, Best, The Netherlands) using a five-element phased-array surface coil. DTI was performed with the following imaging parameters: 11084.6/73.7 ms for TR/TE, respectively; flip angle, 90º; field of view, 280mm; b-value,800 s/mm^2; MPG, 33 directions; slice thickness/gap, 1.5 mm; number of slice, 60; actual voxel size, 1.49X2.98X1.50 mm^3; and total scan time of 7 minutes and 35 seconds. Mean FA and ADC values at all consecutive points along the L4, L5 and S1 nerves were quantified by two orthopaedic surgeons with two methods, as follows: direct measurement of FA and ADC placing a region of interest (ROI) in expected axial DTI without fiber tracking (*ROI method*), and with fiber tracking (*FT method*). All measurements were performed on PC workstations using the imaging software Achieva 3T TX system, Release 3.2. On the *ROI method*, to minimize partial volume effects, we set 4 voxels as a ROI in the lumbar spinal nerve.[4] While, on the *FT method*, we confirmed that the fibers passing through the target nerve only by using displays of the coronal- and sagittal- view images. The thresholds for tracking termination were 0.1 for FA, 27º for the angle, 3mm for minimum fiber length. All FA and ADC values (n=754/each method) were analyzed by Pearson's Correlation analysis to detect their concordance rates between the two methods. We measured concordance correlation coefficient values (CCC) for all values to define inter- and intra-rater reproducibility by Pearson's Correlation analysis. Each CCC of all 36 nerve roots was evaluated as follows: Excellent (0.9≤CCC), Good (0.75≤CCC<0.9), Poor (CCC<0.75).[5]

Results Concordance rates of the two methods are 0.528 on FA values, and 0.822 on ADC values (Figure 1,2). Table 1 shows the results of inter- and intra-rater reproducibility on each nerve root. The reproducibility varied according to the nerve root, with the highest of the S1 nerve. *FT method* had a statistically significant excellent/good inter-rater reproducibility (FA: 100%, ADC: 97.2%) compared with *ROI method* (FA: 63.9%, ADC: 75.0%) on both FA and ADC values (Table 2). Also, *FT method* had a statistically significant excellent/good intra-rater reliability (FA: 91.7%, ADC: 97.2%) compared with *ROI method* (FA: 69.4%, ADC: 83.3%) on both FA and ADC values (Table 2).

Table 1
Inter-rater and Intra-rater Reliability of Concordance Correlation Coefficient for FA & ADC Measurements

		Inter-rater		Intra-rater	
		FT	ROI	FT	ROI
L4 (N=103)	FA R/L	0.89/0.89	**0.68/0.54**	0.79/0.83	0.78/0.78
	ADC R/L	0.96/0.93	0.85/0.85	0.87/0.93	0.96/0.86
L5 (N=127)	FA R/L	0.96/0.95	**0.65**/0.77	0.93/0.93	**0.69**/0.79
	ADC R/L	0.96/0.96	0.82/0.93	0.96/0.95	0.88/0.90
S1 (N=135)	FA R/L	0.96/0.98	0.85/0.90	0.96/0.95	0.77/0.87
	ADC R/L	0.96/0.93	0.92/0.95	0.98/0.98	0.97/0.96

Table 2
Summary of data on Inter- and Intra-rater Reproducibility

		FA		ADC	
		ROI method	FT method	ROI method	FT method
Inter-rater Reproducibility	Excellent/ Good	23 (63.9%)	36 (100%) *	27 (75.0%)	35 (97.2%) *
	Poor	13 (36.1%)	0 (0%)	9 (25.0%)	1 (2.8%)
Intra-rater Reproducibility	Excellent/ Good	25 (69.4%)	33 (91.7%) *	30 (83.3%)	35 (97.2%) *
	Poor	11 (30.6%)	3 (8.3%)	6 (16.7%)	1 (2.8%)

Concordance Correlation Coefficient : CCC,

Excellent : 0.90=CCC
Good: 0.75 =CCC<0.90
Poor: CCC<0.75

Chi-squire test, * p<0.05

Discussion Our study demonstrated that FA values measured with two methods were inconsistent (r=0.528), while ADC values had a relatively good consistency (r=0.822). However, both FA and ADC values measured with *FT method* had significantly better reproducibility. *FT method* includes mainly two advantages over *ROI method* for measurements of FA and ADC values. One advantage is a reduction of time to draw ROIs at each level, and the other advantage is its reproducibility as shown in this study. Although we set small ROIs over the lumbar spinal nerve to minimize partial volume effects in the *ROI method*, the results in this study demonstrated low reproducibility with this method. Recent studies have reported that FA and ADC values could be a potential tool to present the severity of nerve entrapment.[1-3] We suggest the *FT method* is a reliable method to measure FA and ADC values for future clinical application.

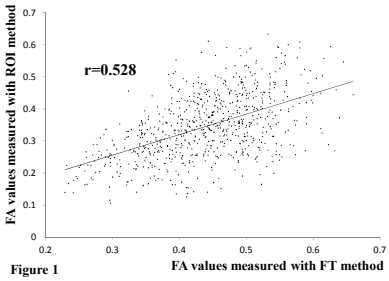

Figure 1

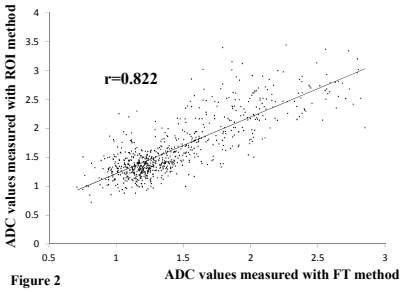

Figure 2

References

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