Delineation of Cerebellar Fiber Tracts on Anatomically Aligned Planes with ViPAR, a Novel MRI Visualization and Manipulation Tool

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Objective

The cerebellum is heavily involved in motor control and coordination, and the cerebellar peduncles establish its connectivity to the cerebrum and other supratentorial structures through the brainstem. These peduncles demonstrate atrophy in many diseases, including ataxia and stroke, and their sizes may be a useful surrogate measure for disease.

Previous methods for peduncle assessment rely on measuring these structures on planes aligned with the cardinal directions (x,y,z) in a reference coordinate system. With these methods, the fiber orientation may be oblique to the acquired slices. Thus, the measured diameters or cross-sectional areas could be erroneously increased, and measurement errors would be subject-specific due to different trajectories relative to the fixed reference coordinates.

Our protocol measures cross-sectional area *perpendicular* to local fiber orientation. We present ViPAR (Visualization, Paint, And Rotation, **Fig. 1**) a novel MRI visualization and manipulation tool that enables efficient real-time 3D transform and delineation of regions of interest (ROIs).

Methods

We developed ViPAR as a plugin for MIPAV (Medical Image Processing, Analysis, and Visualization), a freely available medical image analysis software package published by the NIH. Since both our plugin and MIPAV are implemented in Java, the system may be used on many common platforms, including Windows, Linux, Macintosh, and Unix.

ROIs were delineated on diffusion tensor colormaps (**Fig. 2**) derived from three acquisitions of 32 diffusion encoding directions and a scanner average of five minimally weighted volumes on a 3T MR scanner (Intera, Philips Medical Systems, The Netherlands). Written informed consent was obtained. A multi slice, spin echo, single-shot EPI sequence (SENSE = 2.0) was used to achieve whole brain coverage (212x212 mm FOV, 96x96 acquisition matrix, 256x256 reconstruction, 2.2 mm slice thickness, no slice gap).

To assess the intra- and inter-rater reliability of the ViPAR method, two blinded raters repeated three measurements of ten ROIs in four subjects. Two subjects were normal controls and two were ataxia patients. To assess the accuracy and reliability differences between the novel method with ViPAR and the conventional legacy method, a single blinded rater used each method to repeat three measurements of four ROIs in four subjects.

Results

Within the peduncles, there were no significant differences between raters with the ViPAR method (mean $0.24\pm3.1mm^2$). Intra-rater reliability depended on the size of the region of interest (**Table 1**), and was approximately 4.7% of the cross-sectional area. No significant subject, disease state, or ROI related differences were observed in the variability measures. Areas delineated with the legacy method areas were consistently ($p<0.001$) larger than the cross-sectional areas found with ViPAR and showed substantial variability in the percentage differences (mean 39±23%), **Table 2**.

Discussion

We present a protocol and software to identify the cerebellar peduncles in cross-section and show that it is reliable within and across raters. The results are as consistent as legacy methods, and based on visual inspection by an expert cerebellar anatomist, the ViPAR measurements are more accurate representations of the cross-sectional areas. This work represents a simple yet important innovation in the quantitative analysis of white matter tracts.

Figure 1. User Interface of the ViPAR Plugin

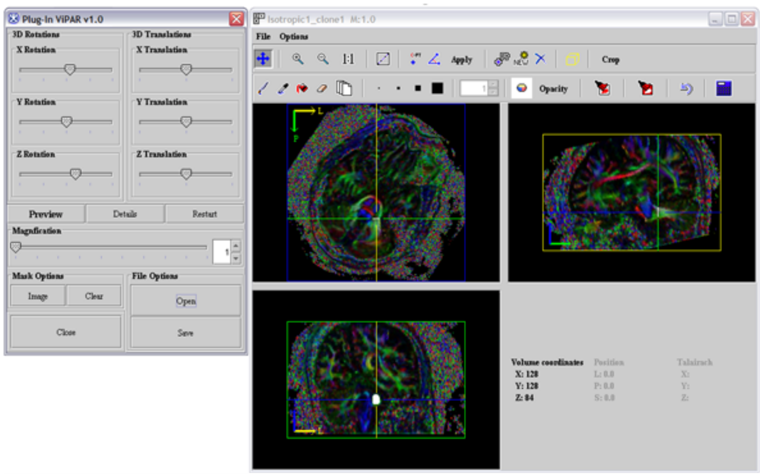
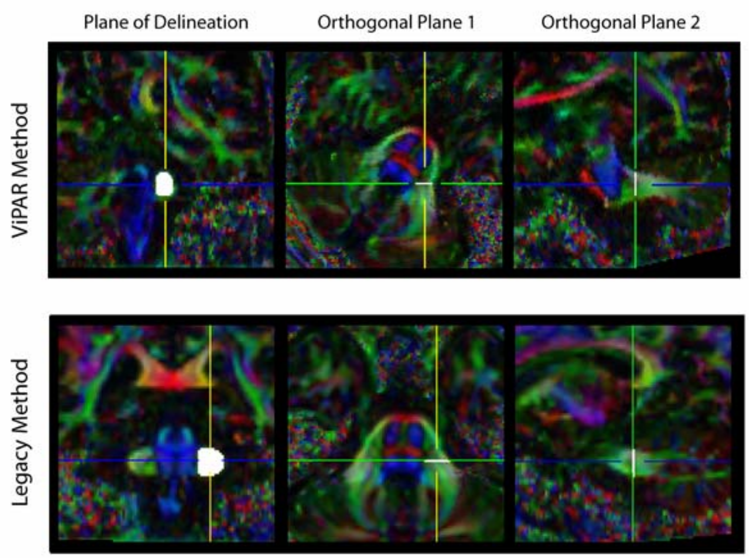


Figure 2. Comparison of ViPAR versus Legacy Method

Cross-Sectional Area of the Left Middle Cerebellar Peduncle



Regions of interest are delineated in white and indicated by crosshairs.

Table 1:

Descriptive Comparison of Intra- and Inter-Rater Accuracy and Reliability

Cerebellar Peduncle		#*	Rater 1 Mean	Rater 1 St.Dev **	Rater 2 Mean	Rater 2 St.Dev
Inferior	L	1	8.23	0.67	8.34	1.07
	R	1	8.97	0.60	8.80	0.78
Middle	L	2	95.67	7.23	94.92	5.38
	R	2	100.3	8.92	100.78	4.51
Superior	L	2	11.77	0.76	11.29	1.49
	R	2	11.77	1.01	11.34	1.49

* # denotes number of ROIs within a peduncle. Each ROI measurement was repeated 3 times on 4 subjects. ** St. Dev. indicates standard deviation of repeated measurements around subject specific mean. All measurements are in mm^2.

Table 2:

Descriptive Comparison of Legacy and ViPAR Methods

Region of Interest	Legacy Method Mean	Legacy Method St.Dev.	ViPAR Method Mean	ViPAR Method St.Dev.
Cerebrospinal Tract	81.40	3.26	69.82	5.94
Inferior Cerebellar Peduncle	12.23	0.24	8.23	0.79
Middle Cerebellar Peduncle	130.35	1.86	95.98	7.46
Superior Cerebellar Peduncle	18.12	1.95	12.17	0.74

* Each ROI measurement was repeated 3 times on 4 subjects. ** St. Dev. indicates standard deviation of repeated measurements around subject specific mean. All measurements are in mm^2.