

# Evaluation of relationship between middle cerebellar peduncle asymmetry and dominant hand by diffusion tensor imaging

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**Background:** The aim of the study was to evaluate middle cerebellar peduncle (MCP) asymmetry by diffusion tensor imaging (DTI) according to the dominant hand.

**Materials and methods:** Sixty-four volunteers who met the exclusion and inclusion criteria were prospectively evaluated by DTI. Circular voxels of interest were drawn at the right and left MCP levels for all volunteers. The software automatically calculated the median values of fractional anisotropy (FA), mean diffusivity (MD), and number of fibres (NF). The volunteers were categorised as the right-handed ( $n = 44$ ) and left-handed ( $n = 20$ ) groups using the Dellatolas test. The mean values of FA, MD and NF were statistically compared between the two sides and the two groups.

**Results:** In both groups, the mean value of FA for the right MCP was significantly higher than the left MCP ( $p = 0.0016$  and  $p = 0.0032$  for the right- and left-handed groups, respectively). In both groups, no significant difference was observed between the right and left MCPs in terms of MD and NF ( $p = 0.75$ ,  $p = 0.69$  and  $p = 0.96$ ,  $p = 0.46$ , respectively). There was also no statistically significant difference between the groups for the mean values of FA, MD and NF of each MCP ( $p = 0.74$ ,  $p = 0.26$  and  $p = 0.26$ , respectively for the right MCP and  $p = 0.78$ ,  $p = 0.37$  and  $p = 0.54$ , respectively for the left MCP).

**Conclusions:** There is an asymmetry between the mean FA values of the right and left MCP. However, this asymmetry is independent of the dominant hand. (Folia Morphol 2019; 78, 3: 481–486)

**Key words:** middle cerebellar peduncle, diffusion tensor imaging, fractional anisotropy, dominant hand

## INTRODUCTION

The cerebellum plays a key role in many functions; e.g., supporting cerebral functions in coordination, cognitive and motor skills, and mediating coordination by establishing connections with the cerebral cortex, limbic system, and thalamus [19]. Middle cerebellar peduncle (MCP) is the major input pathway of the cerebellum [14, 19]. Morphological changes in the

cerebellum and pathways are observed in movement disorders, such as Parkinson's disease [21]. Studies using diffusion tensor imaging (DTI) have shown fraction anisotropy (FA) changes in these pathways in patients with movement disorders [15]. Therefore, DTI is an important modality for the evaluation of these pathways. It is a powerful technique, especially for studying the microstructure of white matter [19]. DTI examines

the molecular diffusion of water and provides the FA value, which is a quantitative diffusion parameter associated with axonal packing and myelination [19]. Since this axonal packing and myelination is responsible for the neural connection, it contributes greatly to the understanding of the pathways between the brain regions of DTI measurements [19].

In consecutive hand movements, the corticospinal and MCP tracts work in coordination [12, 15, 16]. It has been reported that there are functional and structural differences in the cerebral hemispheres of the right- and left-handed patients [4, 5, 10, 11, 16]. In corticospinal tract evaluation using DTI, asymmetry was observed to be associated with the dominant hand [12, 16]. Similarly, van der Zwaag et al. [18] found that lateralised hand motor movement has a greater impact on the cerebellar lobules 5 and 8 more. This suggests that the dominant hand can affect cerebellar pathways providing motor coordination. However, in the literature, there is no study that used DTI to evaluate the cerebellar pathways coordinating sequential motor activity in relation to the dominant hand. Therefore, in this study, we aimed to evaluate MCP asymmetry by DTI according to the dominant hand.

### Study design

This was a prospective cohort DTI study. All participants provided written informed consent and the study protocol was approved by the institutional Medical Ethics Committee. Eighty-two healthy volunteers aged 15–65 years were enrolled in the study. The individuals were excluded if they reported a neurological disorder ( $n = 3$ ) (stroke, haemorrhage and transient ischaemic attack) or a medical disorder ( $n = 6$ ) (diabetes mellitus, hypertension and other vascular diseases), history of mental retardation ( $n = 1$ ), drug abuse or dependence ( $n = 1$ ), psychiatric illness ( $n = 2$ ), and magnetic resonance imaging (MRI) contraindications ( $n = 5$ ). The remaining 64 volunteers were included in the study. The mean age of the patients was  $38.5 \pm 17.2$  years. Thirty-one volunteers were male and 33 were female. Dominant hand was determined using a test created by Dellatolas et al. [3]. According to the results, 44 volunteers were categorised as right-handed and 20 as left-handed.

### Diffusion tensor imaging

The volunteers were placed on the magnetic resonance (MR) table in a supine position. All MRI studies

were acquired using a 1.5 T MR imaging scanner (Magnetom area; Siemens Healthcare, Berlin, Germany). A three-dimensional T1-weighted magnetisation-prepared rapid gradient echo (MP-RAGE) sequence was used for conventional MRI and a sensitivity-encoded single-shot echo-planar imaging (SENSEPI) sequence was used for DTI. The sequence parameters for MP-RAGE were as follows: voxel size  $1 \times 1 \times 1$  mm, slice thickness 1.15 mm, field-of-view (FOV)  $256 \times 90$ , repetition time/echo time (TR/TE) = 1420/2.98 ms, flip angle 9, and matrix  $186 \times 256$ . The SENSEPI protocol parameters were: TR/TE = 3700/95 ms, FOV  $240 \times 100$ , voxel size  $1.9 \times 1.9 \times 4$  mm, and slice thickness 4 mm. We used 20 directional diffusion-weighted scans with a b-value of  $1000 \text{ s/mm}^2$ .

### Evaluation of DTI data

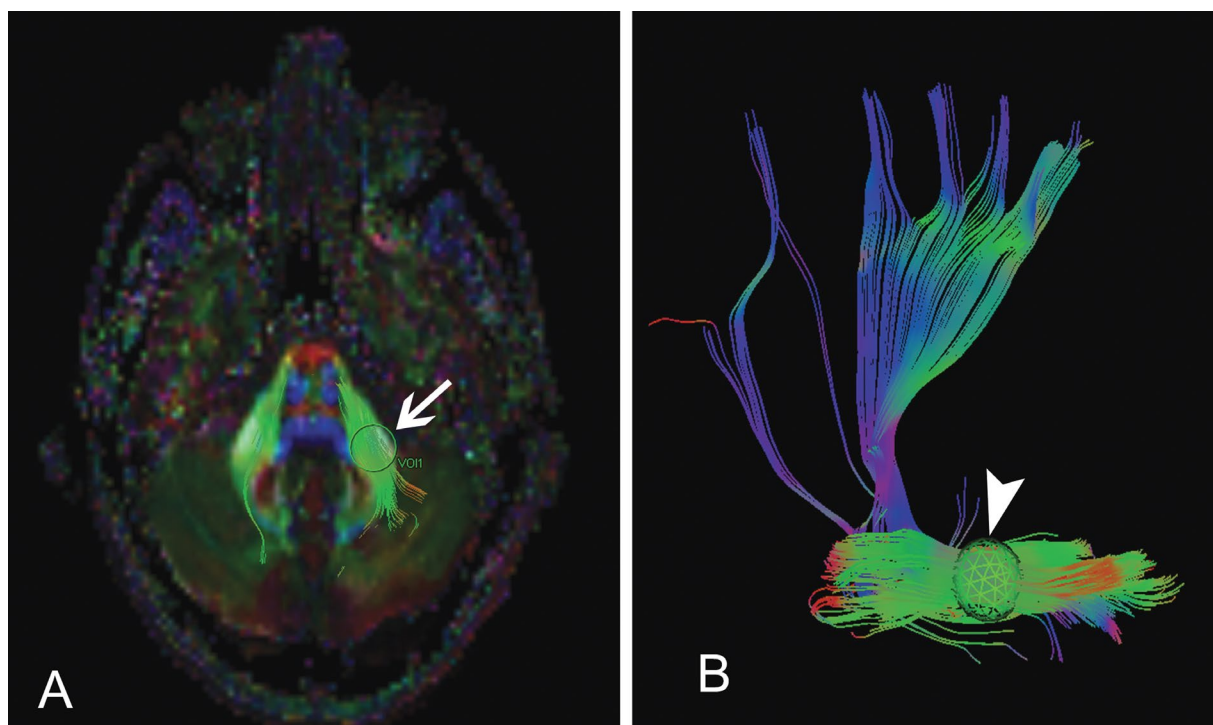
The resulting MRI were assessed on a workstation (Syngo via, Siemens Medical Imaging, Erlangen, Germany). Our offline post-processing system uses deterministic tractography. A radiologist (G.P.) with 7 years of experience evaluated the DTI data. Circular voxels of interest (1 cm radius) were placed on bilateral MCPs to obtain and analyse the DTI values (Fig. 1). The software automatically calculated the median values of FA, mean diffusivity (MD), and number of fibres (NF) of bilateral MCPs. The same radiologist repeated the measurements for each volunteer on 3 different days (minimum interval between each measurement was 1 week). The data were evaluated by calculating the average values.

### Statistical analysis

All statistical analyses were performed using MedCalc software (version 12.2.1.0, Mariakerke, Belgium). Distribution of variables assessed with D'Agostino Pearson test. Comparison between two groups with normal distribution performed with independent t test. Nominal categorical variables were compared using  $\chi^2$  test. In both right-handed and left-handed groups, the statistical significance of the differences between the mean values of FA, MD and NF were assessed by the Mann-Whitney U test. For the right-MCP and left-MCP groups, this evaluation was undertaken using the Wilcoxon test.

## RESULTS

The percentage of men 43.2% ( $n = 19$ ) in the right-handed group and 60% in the left-handed group ( $n = 12$ ) ( $p = 0.96$ ). The mean ages were



**Figure 1.** Diffusion tensor imaging shows right middle cerebellar peduncle (white arrow) in whole tracts (A). In addition, three-dimensional image shows tracts of middle cerebellar peduncle (arrowhead) (B); VOI — voxels of interest.

**Table 1.** Statistical results of right-handed and left-handed groups

	Right-handers			Left-handers			Intergroup comparison (p)
Age	36.7 ± 17.8			42.5 ± 17.05			0.10
Sex (male ratio)	19 (43.2%)			12 (60%)			0.96
	Right MCP	Left MCP	P	Right MCP	Left MCP	P	Right and left
Fractional anisotropy	0.49	0.47	0.0016	0.48	0.47	0.0032	0.74 and 0.78
Mean diffusivity	0.0008	0.0008	0.75	0.0008	0.0008	0.69	0.26 and 0.26
Number of fibres	387	376	0.96	378	365	0.46	0.37 and 0.54

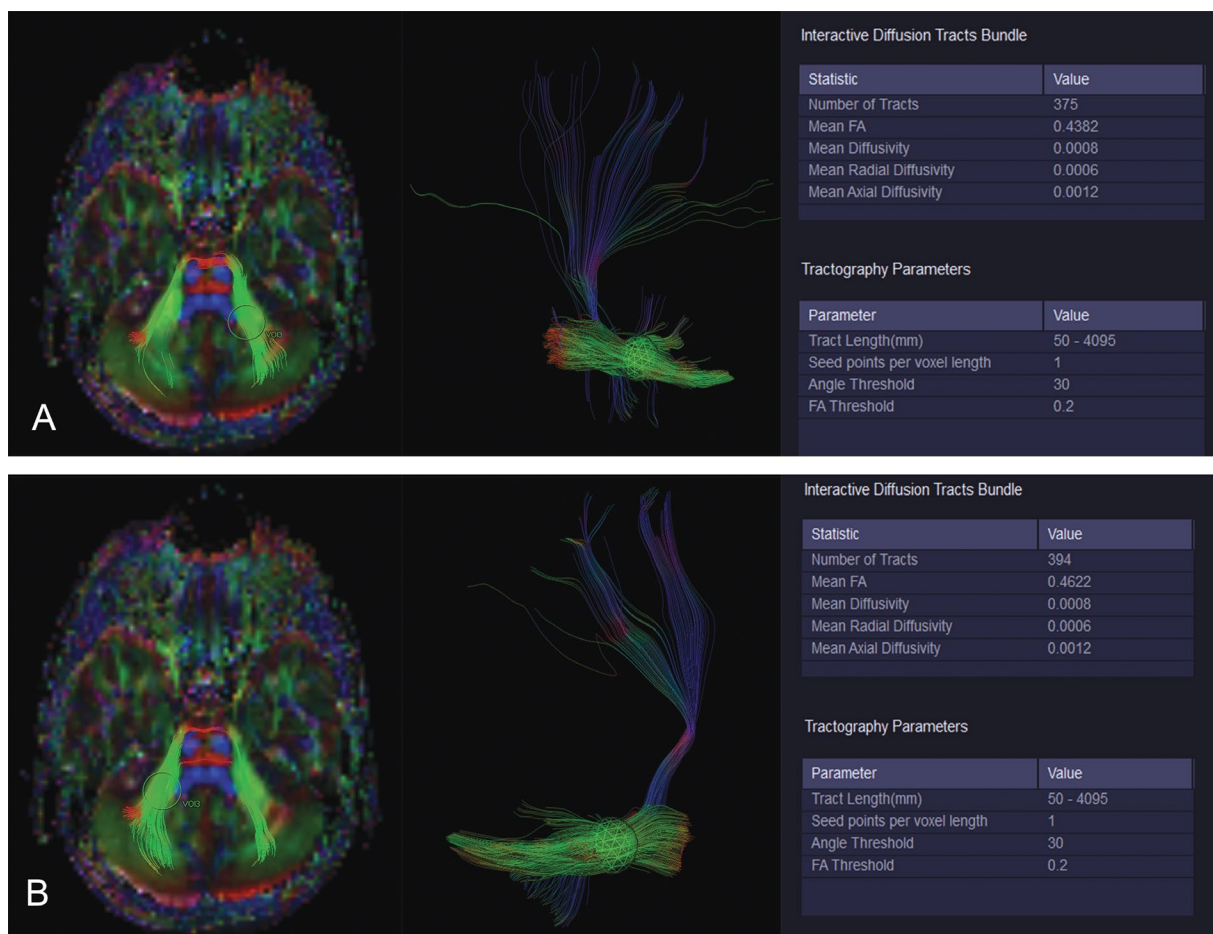
MCP — middle cerebellar peduncle

36.7 ± 17.8 years and 42.5 ± 17.05 years for the right- and left-handed groups, respectively ( $p = 0.10$ ). The data of both groups are shown in Table 1. In both groups, the value of FA in the right MCP was significantly higher compared to the left MCP ( $p = 0.0016$  and  $p = 0.0032$ , respectively) (Figs. 2, 3). However, neither group had any significant difference between the right and left MCPs in terms of MD and NF (Table 1). There was also no significant difference between the right- and left-handed volunteers concerning FA, MD, and NF (Table 1).

## DISCUSSION

This study showed that there was no significant difference between the right- and left-handed indi-

viduals in terms of FA, MD and NF in the MCP motor activity pathway. A few studies have shown functional hemispheric asymmetry between right- and left-handed people [10, 11]. These studies have demonstrated a relationship between handedness and anatomical or functional asymmetry of the brain. Recently, asymmetry between grey and white matter of the encephalic volume was revealed through cross-sectional imaging [6, 13]. In the evaluation of the cerebral hemisphere according to the dominant hand, the differences in FA and MD secondary to asymmetry were revealed on DTI [2, 8, 16, 20]. However, in our study, we found no statistically significant difference between the right- and left-handed groups for the investigated parameters. Seizeur et al. [16] showed that the FA

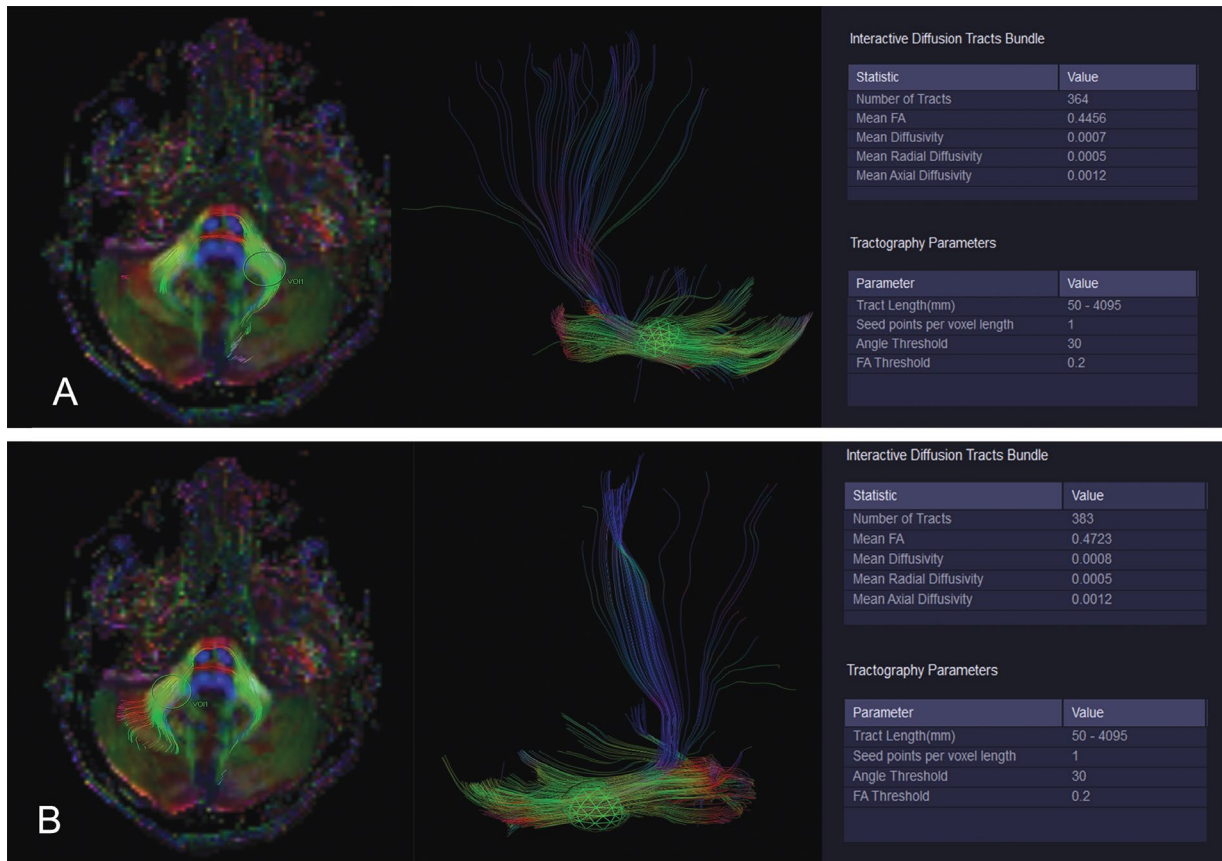


**Figure 2.** Diffusion tensor imaging shows evaluation of left (A) and right (B) middle cerebellar peduncle by voxels of interest in the right-handed volunteer. Right middle cerebellar peduncle fractional anisotropy (FA) is higher than left.

values (right and left corticospinal tract) of the right handers were significantly higher than those of the left handers at the levels of the internal capsule and diencephalon-mesencephalon junction. However, the authors found no significant difference between the two groups for the FA values in the left corticospinal tract at the level of the corona radiata [16]. The current study showed that the FA differences between the dominant and non-dominant hands occurred due to anatomical location. The lack of a lateralisation finding due to anatomic localisation in the corticospinal tracts that conduct and direct motor activation can explain the absence of the same finding in the coordination tracts. Many studies reported that asymmetry due to dominant hand affects anatomic volumes [1, 7, 17]. On the other hand, Kavaklioglu et al. [9] revealed no significant relationship between dominant hand and cerebellar anatomic asymmetry. Similar to the other anatomical studies in the literature, we also did not determine any effect of the

dominant hand on the asymmetry of the cerebellar pathways.

In the current study, it was observed that the FA values in the right MCP were significantly higher than those in the left MCP, regardless of the dominant hand. Re et al. [14] showed significant differences between the right and left MCP motor tracts in terms of FA and NF. However, no significant difference was observed in MCP cognitive tracts [14]. Although their study did not make an evaluation of the dominant hand, it was important in terms of demonstrating the possibility of an asymmetry at the MCP level. In the current study, no significant asymmetry was observed for MD and NF. Re et al. [14] reported no significant difference between the MCP cognitive tracts in terms of NF, but a significant difference was noted for the MCP motor tracts. In the current study, we evaluated the MCP motor and cognitive tracts together considering that motor coordination is the result of the harmony of a system that connects cerebral and cerebellar cortical areas as



**Figure 3.** Diffusion tensor imaging shows evaluation of left (A) and right (B) middle cerebellar peduncle by voxels of interest in the left-handed volunteer. Right middle cerebellar peduncle fractional anisotropy (FA) is higher than left.

a circle [14, 19]. Since we evaluated these pathways together, we may not have observed any asymmetry of the subgroup pathways in terms of MD and NF.

This study had certain limitations. First, we had a relatively low number of volunteers. In addition, we did not make our assessments according to the subgroup pathways. Therefore, we were not able to evaluate the association between asymmetries in the MCP subgroup pathways and dominant hand. Third, we have used standard region of interest for tracking the MCP in all cases. This could cause covering of other fibre groups that are unrelated with MCP, thus lowering the reliability of our results. However, we think that these minor add-ons could not change our significance of comparisons.

### CONCLUSIONS

In conclusion, the asymmetry of FA was observed in cerebellar pathways, which play an effective role in motor coordination. However, the asymmetry of these tracts was independent of dominant hand according to DTI results.

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