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Evaluation of White Matter and Cerebellum Structures of Essential Tremor and Parkinson's Patients by Diffusion Tensor Imaging and Volbrain Method

Esansiyel Tremor ve Parkinson Hastalarında Beyaz Cevher ve Serebellum Yapılarının Difüzyon Tensör Görüntüleme ve Volbrain Yöntemi ile Değerlendirilmesi

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ABSTRACT

Essential tremor (ET) and Parkinson's disease (PD) are the two most commonly encountered tremor disorders in movement disorders. Diffusion tensor imaging (DTI) is one of the best in vivo ways of mapping white matter pathways in the human brain. The aim of our study was to investigate diffusion variables and cerebellum volume in ET and PD using parcellation methods. Our study included 20 ET, 20 PD and 20 healthy controls. Fraction Anisotropy (FA) and Mean Diffusivity (MD) values were obtained with DTI, while the volume of each lobe of the cerebellum was obtained with T1 images. One-way ANOVA was used for intergroup analysis and Scheffe test was used for post-hoc analysis. Significant differences were found in the diffusion values of the pedunculus cerebellaris, fornix stria, superior longitudinal fasciculus, sagittal stratum, cerebral pedunculus, tapatum and thalamus of ET and PD. Lobule V, Lobule IX, Lobule X volumes of the cerebellum showed significant differences between the groups. Stria thermialis shows involvement of mesolimbic dopaminergic system in PD and it is thought that disruption of strial networks leads to changes in the activity of cerebellar networks and reveals the role of the cerebellum in tremor. It is obvious that cerebellar thalamocortical pathways are affected in Parkinson's disease. In Parkinson's disease, patients should be evaluated for visual processing, conceptualisation, postural instability and gait disturbance to clarify the diagnosis or to differentiate from essential tremor.

Keywords: Diffusion Tensor Imaging, Essential Tremor, Parkinson Disease, Volbrain

ÖZ

Esansiyel tremor (ET) ve Parkinson hastalığı (PH) hareket bozuklukları içinde en sık karşılaşılan iki tremor bozukluğudur. Difüzyon tensör görüntüleme (DTI), insan beynindeki beyaz madde yollarını haritalamanın en iyi in vivo yollarından biridir. Çalışmamızın amacı ET ve PH'da parselasyon yöntemlerini kullanarak difüzyon değişkenlerini ve serebellum hacmini araştırmaktır. Çalışmamıza 20 ET, 20 PH ve 20 sağlıklı kontrol dahil edildi. Fraksiyon Anizotropi (FA) ve Ortalama Difüzivite (MD) değerleri DTI ile elde edilirken, serebellumun her bir lobunun hacmi T1 görüntüleri ile elde edildi. Gruplar arası analiz için tek yönlü ANOVA ve post-hoc analiz için Scheffe testi kullanıldı. ET ve PD'de pedunculus cerebellaris, fornix stria, superior longitudinal fasciculus, sagittal stratum, serebral pedunculus, tapatum ve talamusun difüzyon değerlerinde anlamlı farklılıklar bulundu. Serebellumun Lobül V, Lobül IX, Lobül X hacimleri gruplar arasında anlamlı farklılıklar gösterdi. Stria thermialis, PH'da mezolimbik dopaminerjik sistemin tutulumunu gösterir ve strial ağların bozulmasının serebellar ağların aktivitesinde değişikliklere yol açtığı ve serebellumun tremordaki rolünü ortaya koyduğu düşünülmektedir. Parkinson hastalığında serebellar talamokortikal yolakların etkilendiği aşikardır. Parkinson hastalığında, tanıyı netleştirmek veya esansiyel tremordan ayırmak için hastalar görsel işleme, kavramsallaştırma, postüral instabilite ve yürüme bozukluğu açısından değerlendirilmelidir.

Anahtar Kelimeler: Difüzyon Tensor Görüntüleme, Esansiyel Tremor, Parkinson Hastalığı, Volbrain

Permissions to complete the study were granted by the relevant ethics committee in Turkey (Karadeniz Technical University Faculty of Medicine Scientific Research Ethics Committee date, 30/09/2022 no. 24237859-565).

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INTRODUCTION

Essential tremor (ET) is a neurological disease characterized by postural and action tremor. Parkinson's disease (PD), on the other hand, is a disease with rest tremor and slowly progressive over time.[1] A neurodegenerative process is involved in the pathophysiology of both these diseases.[2] In ET and PH, clinical findings may be mixed in some cases. There are opinions suggesting that the transformation of some ET cases to PH may occur coincidentally due to the high incidence of both clinical syndromes. In the diagnosis of ET, it is important to distinguish it from other specific types of tremor because it includes the tremor of PD. Clinical, physiological studies, and imaging studies indicate involvement of the cerebellum and/or cerebellothalamocortical circuits in the pathophysiology of the disease.[3]

The tremor of Parkinson's disease does not involve any voluntary muscle contraction, voluntary movement attempt, or the influence of gravity in the affected area. Both essential tremor and Parkinson's tremor can include postural, kinetic, and resting tremor components. However, Parkinson's tremor is traditionally resting tremor that is relieved by action, while ET is kinetic/postural tremor that is relieved by rest. The diagnosis of ET and PH is made mainly by a detailed history and neurological examination. In typical cases, imaging methods are not needed however, radiological methods can be used in cases with atypical and diagnostic difficulties.[4-6]

Diffusion tensor imaging (DTİ) method is one of the best in vivo methods of mapping white matter pathways in the human brain.[7] Advances in this method facilitate the detection of pathology-specific details such as microstructural changes in the axons and myelin of the brain white matter.[8, 9]

To determine the similarities and differences of the diseases by examining the diffusion variables of the white matter pathways of ET and PD, and the gray matter volumes of each lobe of the cerebellum with DTİ and automatic segmentation method.

MATERIALS AND METHODS

Our study included 20 ETs (13F-8M) with a disease duration of at least 3 years and no head and neck tremor, 20 idiopathic PD (9F-11M) (no dementia or cognitive impairment), and 20 healthy controls (HC) wıth transıent neurologıcal symptoms (headache, dızzıness vs.) and no pathologıcal fındıngs (10F-10M) admitted to Karadeniz Technical University Neurology Clinic. Participants were over 18 years of age. The images were obtained with a 3 T MR machine (Siemens Magnetom Skyra, Netherlands) at Karadeniz Technical University, Department of Radiology. DTI sequence was a twice-refocused spin-echo sequence based on single-shot echo-planar acquisition. Diffusion sensitizing gradients were applied along 20 orthogonal directions using two b values (0 and 1000 s/mm2). DTI and T1 image parameters are as follows.

1. T1-weighted MPRAGE sequence: sagittal, Repetition time (TR)=1900ms, Echo Time (TE)=2.67ms, FOV=250mm, Matrix:256x256, Slice Thickness=1mm.

2. 2. DTI: axial, TR=3500 ms, TE=83 ms, number of slices=20, FOV=230mm, matrix:128x128, slice thickness=5mm, averages=3

The DTI data in our study were obtained using cloud-based MriCloud software (http://www.braingps.mricloud.org) and ROIEditor (https://MriStudio.org) image processing software. The CERES pipeline, an automatic segmentation of the cerebellum, was used to obtain the volume of each lobe of the cerebellum.

Data Processing

In order to use the MriCloud software, you must first register and log in at "https://MriStudio.org". After registration, you need to download the ROIeditor programme suitable for your computer's

operating system. The DTIs of the groups were used to obtain FA and MD values and the results were obtained.

To use the Volbraine method, you need to register by creating a registration at https://www.volbrain.upv.es/. After registration, you need to download the dcm2nii programme from https://www.nitrc.org/projects/mricron and convert the images in the dicom files to niftii format.[10, 11] Volume results were obtained by using T1 images to obtain the volume of each lobe of the cerebellum with the Volbrain method.

Statistical Analysis

The data obtained in the study were analysed using SPSS (Statistical Package for Social Sciences) for Windows 22.0 software. Number, percentage, mean, standard deviation were used as descriptive statistical methods in the evaluation of the data. Differences between the rates of categorical variables in independent groups were analysed with Chi-Square and Fisher exact tests. The t-test was used to compare quantitative continuous data between two independent groups, and the One way Anova test was used to compare quantitative continuous data between more than two independent groups. Scheffe test was used as a complementary post-hoc analysis to determine the differences after the ANOVA test.

Ethical Aspect of Research

This study was carried out using MR images obtained with the approval of the scientific research ethics committee of the Karadeniz Technical University Faculty of Medicine. Participants were asked to sign an informed consent form before the MRI scan

RESULTS AND DISCUSSION

When the patient groups were analysed according to gender, age and disease duration, gender and disease duration did not show a significant difference, while age showed a significant difference (Table 1-2).

Table 1. Average Age According to Groups

Groups	PD	ET	HC	F	p	Post hoc analysis
	X±sd	X±sd	X±sd			
Age	58.950±11,799	45.450±18.757	49.850±10.017	4.809	**0.012**	**p=0.004; 1>2** **p=0.045; 1>3**

1: It shows a statistically significant difference when compared with the Parkinson Disease ($p < 0.05$).
2: It shows a statistically significant difference when compared with the Esential Tremor ($p < 0.05$).
3: It shows a statistically significant difference when compared with the Healty Control ($p < 0.05$).
X: mean sd: standard deviation

Table 2. Mean Disease Duration According to Patient Groups

Groups	PD (n=20)	ET (n=20)	t	sd	p
	X±sd	X±sd			
Disease Duration(year)	6.800±4.008	7.300±5.564	-0.326	38	0.746

X: mean. sd: standard deviation

Differentiation of FA Values of Patient Groups According to Groups

According to the patient groups; the FA values of the left pedunculus cerebellaris inferior, left fornix stria terminalis and (right-left) fasciculus longitudinalis superior were significantly decreased in the Parkinson's patient group compared to ET and HC. A significant decrease was found in FA values of right pedunculus cerebellaris inferior, right pedunculus cerebellaris superior, right pedunculus cerebri, right sagittal stratum,

right tapatum and right thalamus of Parkinson's disease group compared to

healthy controls. There is a decrease in the FA of the right pedunculus cerebellaris inferior in the essential tremor patient group compared to healthy controls and in the FA of the right fasciculus longitudinalis superior in the Parkinson's patient group compared to the essential tremor group (Table 3).

Table 3. Differentiation of FA Measurements According to Groups

Grups	PD	ET	HC	F	p	Post hoc analysis	
	X±sd	X±sd	X±sd				
Corticospinal Tract - L	0.528±0.055	0.510±0.041	0.537±0.040	1.929	0.155		
Inferior cerebellar peduncle- L	0.490±0.061	0.525±0.045	0.529±0.040	3.864	**0.027**	**p=0.026** **p=0.015**	**2>1** **3>1**
Süperior cerebellar peduncle- L	0.562±0.060	0.559±0.049	0.583±0.027	1.493	0.233		
Cerebral peduncle- L	0.607±0.057	0.628±0.040	0.629±0.023	1.630	0.205		
Fornixstria terminalis- L	0.383±0.061	0.415±0.054	0.427±0.036	4.043	**0.023**	**p=0.049** **p=0.008**	**2>1** **3>1**
Süperior longitudinal fasciculus- L	0.346±0.040	0.371±0.039	0.379±0.024	4.959	**0.010**	**p=0.028** **p=0.004**	**2>1** **3>1**
Inferior fronto-occipital fasciculus- L	0.400±0.056	0.414±0.029	0.429±0.028	2.654	0.079		
Sagittal stratum - L	0.398±0.047	0.414±0.036	0.427±0.020	3.222	**0.047**	**p=0.014**	**3>1**
Pontine Crossing Tract - l	0.450±0.027	0.455±0.039	0.468±0.033	1.509	0.230		
Middle cerebellar peduncle- L	0.475±0.050	0.467±0.040	0.484±0.025	0.911	0.408		
Tapetum - L	0.541±0.058	0.542±0.041	0.547±0.057	0.079	0.924		
Caudate nucleus - L	0.220±0.020	0.217±0.018	0.220±0.016	0.256	0.775		
Putamen- L	0.184±0.024	0.184±0.031	0.180±0.015	0.230	0.795		
Thalamus- L	0.330±0.029	0.335±0.014	0.337±0.011	0.733	0.485		
Globus pallidus- L	0.259±0.028	0.275±0.026	0.273±0.029	1.855	0.166		
Corticospinal Tract- R	0.513±0.038	0.510±0.026	0.527±0.035	1.446	0.244		
Inferior Cerebellar Peduncle- R	0.479±0.053	0.482±0.034	0.517±0.032	5.547	**0.006**	**p=0.004** **p=0.008**	**3>1** **3>2**
Süperior Cerebellar Peduncle- R	0.553±0.088	0.575±0.062	0.608±0.034	3.560	**0.035**	**p=0.010**	**3>1**
Cerebral Peduncle-R	0.585±0.047	0.602±0.028	0.616±0.027	3.730	**0.030**	**p=0.009**	**3>1**
Fornixstria terminalis - R	0.412±0.053	0.429±0.047	0.432±0.035	1.136	0.328		
Süperior Longitudinal Fasciculus- R	0.361±0.040	0.387±0.043	0.401±0.021	6.463	**0.003**	**p=0.026** **p=0.001**	**2>1** **3>1**
Inferior Fronto-occipital Fasciculus- R	0.414±0.048	0.420±0.026	0.430±0.026	1.131	0.330		
Sagittal Stratum-R	0.400±0.047	0.416±0.034	0.433±0.023	4.149	**0.021**	**p=0.006**	**3>1**
Pontine Crossing Tract- R	0.421±0.033	0.427±0.040	0.437±0.029	1.132	0.329		
Middle Cerebellar Peduncle- R	0.476±0.040	0.480±0.035	0.495±0.020	2.006	0.144		
Tapatum - R	0.445±0.101	0.489±0.059	0.530±0.066	5.892	**0.005**	**p=0.001**	**3>1**
Caudate Nucleus - R	0.188±0.022	0.188±0.015	0.195±0.015	0.927	0.402		
Putamen - R	0.210±0.034	0.202±0.031	0.199±0.015	0.856	0.430		
Thalamus - R	0.316±0.027	0.323±0.016	0.332±0.012	3.395	**0.040**	**p=0.012**	**3>1**
Globus pallidus - R	0.285±0.038	0.293±0.041	0.291±0.020	0.266	0.768		

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3: It shows a statistically significant difference when compared with the Healty Control ($p<0.05$)
X: mean. sd: standard deviation. L: left. R: right

Differentiation Status of MD Values of Patient Groups According to Groups

According to the patient groups; there is a significant increase in the MD value of the left fornix stria terminalis in Parkinson's patients compared to essential tremor and healthy controls. There is an increase in the MD value of the right nucleus caudatus and right globus pallidus between the Parkinson's patient group and healthy controls (Table 4).

Table 4. Differentiation of MD Measurements According to Groups

Grups	PD	ET	HC	F	p	Post hoc analysis
	X±sd	X±sd	X±sd			
Corticospinal Tract - L	0.789±0.252	0.752±0.043	0.744±0.018	0.528	0.593	
Inferior cerebellar peduncle- L	0.982±0.357	0.827±0.297	0.905±0.060	1.651	0.201	
Süperior cerebellar peduncle- L	0.997±0.130	0.996±0.119	0.943±0.083	1.495	0.233	
Cerebral peduncle- L	0.923±0.186	0.889±0.061	0.859±0.053	1.495	0.233	
Fornixstria terminalis- L	0.935±0.090	0.888±0.042	0.868±0.044	5.951	**0.004**	**p=0.021; 1>2** **p=0.001; 1>3**
Süperior longitudinal fasciculus- L	0.798±0.084	0.768±0.058	0.754±0.021	2.774	0.071	
Inferior fronto-occipital fasciculus- L	0.829±0.089	0.812±0.040	0.790±0.020	2.300	0.109	
Sagittal stratum - L	0.884±0.079	0.862±0.066	0.842±0.039	2.247	0.115	
Pontine Crossing Tract - l	0.795±0.175	0.772±0.049	0.749±0.024	0.978	0.382	
Middle cerebellar peduncle- L	0.773±0.185	0.734±0.025	0.719±0.021	1.292	0.283	
Tapetum - L	0.948±0.469	0.842±0.311	0.956±0.132	0.730	0.486	
Caudate nucleus - L	0.836±0.075	0.845±0.077	0.812±0.031	1.455	0.242	
Putamen- L	0.780±0.067	0.773±0.046	0.765±0.023	0.459	0.634	
Thalamus- L	0.869±0.086	0.846±0.053	0.828±0.029	2.361	0.103	
Globus pallidus- L	0.855±0.099	0.842±0.050	0.834±0.033	0.502	0.608	
Corticospinal Tract- R	0.787±0.259	0.735±0.037	0.733±0.029	0.816	0.447	
Inferior Cerebellar Peduncle- R	0.939±0.174	0.866±0.225	0.867±0.061	1.240	0.297	
Süperior Cerebellar Peduncle- R	1.032±0.121	1.040±0.145	0.979±0.101	1.448	0.244	
Cerebral Peduncle-R	0.895±0.188	0.848±0.069	0.823±0.037	1.924	0.155	
Fornixstria terminalis - R	0.924±0.102	0.894±0.108	0.912±0.087	0.449	0.640	
Süperior Longitudinal Fasciculus- R	0.778±0.082	0.757±0.057	0.743±0.029	1.776	0.178	
Inferior Fronto-occipital Fasciculus- R	0.804±0.083	0.802±0.033	0.781±0.026	1.172	0.317	
Sagittal Stratum-R	0.894±0.086	0.873±0.069	0.845±0.032	2.764	0.071	
Pontine Crossing Tract- R	0.828±0.200	0.779±0.043	0.775±0.033	1.202	0.308	
Middle Cerebellar Peduncle- R	0.755±0.104	0.736±0.026	0.712±0.020	2.408	0.099	
Tapatum - R	1.276±0.367	1.178±0.160	1.095±0.141	2.735	0.073	
Caudate Nucleus - R	0.969±0.125	0.908±0.134	0.876±0.071	3.494	**0.037**	**p=0.012; 1>3**
Putamen - R	0.743±0.070	0.756±0.035	0.748±0.019	0.409	0.666	
Thalamus - R	0.924±0.106	0.891±0.079	0.855±0.037	3.878	**0.026**	**p=0.007; 1>3**
Globus pallidus - R	0.814±0.092	0.803±0.048	0.803±0.032	0.202	0.818	

1: It shows a statistically significant difference when compared with the Parkinson Disease ($p < 0.05$).
2: It shows a statistically significant difference when compared with the Esential Tremor. ($p < 0.05$).
3: It shows a statistically significant difference when compared with the Healty Control ($p<0.05$)
X: mean. sd: standard deviation. L: left. R: right

Table 5. Volume Values of Cerebellum Structures According to Groups

Grups	PD	ET	HC	F	p	Post hoc analysis	
	X±sd	X±sd	X±sd				
Cerebellum total cm3	123.991±13.270	129.032±15.324	131.136±8.709	1.662	0.199		
Cerebellum right cm3	61.954±6.284	64.820±7.684	65.820±4.418	2.047	0.139		
Cerebellum left cm3	62.078±7.070	64.221±7.698	65.316±4.401	1.265	0.290		
I-II total cm3	0.121±0.030	0.120±0.033	0.121±0.041	0.000	1.000		
I-II right cm3	0.061±0.016	0.062±0.017	0.058±0.021	0.201	0.819		
I-II left cm3	0.059±0.015	0.059±0.017	0.062±0.021	0.222	0.801		
III total cm3	1.319±0.262	1.406±0.239	1.373±0.282	0.557	0.576		
III right cm3	0.658±0.140	0.740±0.125	0.674±0.152	1.933	0.154		
III left cm3	0.632±0.138	0.675±0.120	0.664±0.143	0.566	0.571		
IV total cm3	4.302±0.480	4.739±0.905	4.335±0.731	2.243	0.115		
IV right cm3	2.301±0.332	2.314±0.455	2.147±0.406	1.078	0.347		
IV left cm3	2.182±0.332	2.381±0.488	2.189±0.374	1.563	0.218		
V total cm3	7.321±1.604	8.089±1.745	7.776±1.207	1.265	0.290		
V right cm3	3.834±0.482	4.247±0.617	3.841±0.647	3.247	**0.046**	**p=0.030** **p=0.033**	**2>1** **2>3**
V left cm3	4.064±0.597	4.385±0.568	3.955±0.614	2.845	0.066		
VI total cm3	17.344±2.128	18.493±2.950	17.935±2.735	0.958	0.390		
VI right cm3	8.673±1.128	9.140±1.469	9.001±1.310	0.671	0.515		
VI left cm3	8.685±1.094	9.354±1.584	8.934±1.470	1.169	0.318		
Crus I total cm3	24.538±3.045	26.392±5.361	27.032±3.291	2.061	0.137		
Crus I right cm3	12.338±1.685	13.702±2.780	13.879±1.739	3.141	0.051		
Crus I left cm3	16.128±16.498	21.371±25.614	13.172±1.723	1.111	0.336		
Crus II total cm3	15.809±3.072	16.379±2.602	16.365±2.012	0.313	0.733		
Crus II right cm3	7.774±2.052	7.400±2.402	8.390±1.176	1.319	0.275		
Crus II left cm3	7.165±2.122	7.439±1.864	7.990±0.974	1.187	0.313		
VIIB total cm3	9.442±1.719	9.171±2.346	9.129±2.130	0.133	0.875		
VIIB right cm3	4.814±0.895	4.910±0.688	4.792±0.732	0.130	0.878		
VIIB left cm3	4.616±1.207	4.802±0.776	4.874±0.605	0.440	0.646		
VIIIA total cm3	12.082±1.616	12.097±1.805	12.995±2.083	1.606	0.210		
VIIIA right cm3	5.838±0.944	5.850±1.030	6.502±1.079	2.785	0.070		
VIIIA left cm3	6.244±0.887	6.179±1.044	6.492±1.088	0.535	0.589		
VIIIB total cm3	7.384±1.743	7.792±1.169	8.277±1.243	2.018	0.142		
VIIIB right cm3	3.810±0.708	3.799±0.557	3.951±0.615	0.364	0.696		
VIIIB left cm3	4.081±0.520	3.994±0.653	4.326±0.827	1.289	0.283		
IX total cm3	6.544±1.200	6.789±1.311	7.525±1.020	3.729	**0.030**	**p=0.011**	**3>1**
IX right cm3	3.303±0.600	3.440±0.669	3.851±0.550	4.399	**0.017**	**p=0.006** **p=0.037**	**3>1** **3>2**
IX left cm3	3.241±0.632	3.327±0.726	3.757±0.523	3.819	**0.028**	**p=0.013** **p=0.036**	**3>1** **3>2**
X total cm3	2.915±4.178	1.357±0.200	1.330±0.154	2.821	0.068		
X right cm3	0.625±0.070	0.689±0.101	0.672±0.088	2.854	0.066		
X left cm3	0.604±0.077	0.668±0.102	0.658±0.073	3.219	**0.047**	**p=0.021**	**2>1**
Cerebellum mean cortical thickness	4.521±0.146	4.393±0.543	4.516±0.150	0.936	0.398		
Cerebellum right cortical thickness	4.541±0.146	4.398±0.539	4.491±0.170	0.930	0.400		
Cerebellum left cortical thickness	4.500±0.163	4.387±0.551	4.541±0.156	1.070	0.350		

1: It shows a statistically significant difference when compared with the Parkinson Disease ($p < 0.05$).
2: It shows a statistically significant difference when compared with the Esential Tremor. ($p < 0.05$).
3: It shows a statistically significant difference when compared with the Healty Control ($p<0.05$)
X: mean. sd: standard deviation. L: left. R: right

Differences in Cerebellum Volumes of Patient Groups According to Groups

An increase in the lobule V volume of the cerebellum was found in the ET patient group compared to Parkinson's disease and healthy controls. There is a volumetric decrease in lobus IX (Total, rıght, Left) volumes of Parkinson's patients compared to healthy controls. When the lobus IX volumes of essential tremor and healthy controls were analysed, there was a significant decrease in the lobus IX (right and left) volumes of patients with essential tremor. There is a decrease in the volume of lobus X (left) in Parkinson's patients compared to the essential tremor patient group (Table 5).

The brain structures of ETs and PDs were analysed by DTI method and FA and MD values were obtained. Differences in the white matter structures of the brain in ET and PD are instructive in the identification of the diseases. The DTI method is used as a fire to reveal these differences. When the literature is analysed; the superior longitudinal fasciculus consists of 4 axon bundles connecting many prefrontal and frontal regions with parietal and superior temporal areas. As a result of structural heterogeneity, it is associated with a range of premotor, motor, visuospatial and auditory functions. Decreased FA in the superior longitudinal fasciculus is probably associated with degeneration of temporal and parietal cortical regions. In some studies, it was found that Parkinson's patients had a low FA value of the superior longitudinal fasciculus.[12-15] In our study, a significant decrease in FA value was found in the süperior longitudinal fasciculus (left and right) regions of PDs compared to ET and HC groups. There is no significant decrease in FA in the süperior longitudinal fasciculus (left and right) regions between ET and HC groups. This suggests the presence of degeneration of the süperior longitudinal fasciculus in PD.

It is not surprising to find abnormal DTI changes in the thalamus, as the high sensitivity of the thalamus to PD is consistent with neuropathological reports. Decreased FA in the thalamus has been reported in many studies. In our study, the MD value in the right thalamus increased and the FA value decreased significantly compared to healthy controls.[16, 17] Our study supports the literature. An important neuropathological feature of PD is the loss of dopamine neurons in the substantia nigra and midbrain, and degeneration in the striatal and basal ganglia-thalamocortical pathways affecting the thalamus. In their study.[18] Min Wang et al. reported an increase in the MD value of the cerebral peduncle. In our study, there was no increase in the MD value of the right cerebral peduncle, but there was a significant decrease in the FA value. The primary motor cortex of the peduncle projects to other motor areas and nuclei of the thalamus. Cerebral peduncles have functions such as the transmission of impulses and the formation of reflex movements. Investigation of the relationship between cerebral peduncle and the presence of findings such as postural instability and gait disturbance in Parkinson's disease may be useful for the literature. FA and MD values of fornix stria terminalis structures of PHs were analysed and differences were determined. In our study, FA decreased and MD increased in the fornix stria terminalis region of PDs compared to ETs and HCs.[19, 20] Our study, which is similar to the literature, suggests that disruption of strial networks in Parkinson's disease leads to changes in the activity of cerebellar networks. Fornix stria terminalis and thalamus region are neuropathologically important in PD and microstructural changes in thalamus may be an indicator of cognitive decline in PD.

The sagittal stratum is a large cortico-subcortical white matter bundle that carries fibres from parietal, occipital, cingulate and temporal regions to subcortical locations in the thalamus, pons nuclei and other brainstem structures. In the literature, FA and MD values of sagittal stratum structures in PD and ET were analysed and different results were obtained.[14, 21, 22] In our study, there was a significant decrease in the FA value of the sagittal stratum only in the Parkinson's patient group. Considering that the sagittal stratum is responsible for visual

processing and conceptualisation, Parkinson's patients should be evaluated in terms of visual processing and conceptualisation.

They analysed FA and MD values of the cerebellar peduncles of ET patients and reported significantly decreased FA and increased MD values in the right and left inferior cerebellar peduncle.[23] In another study, they compared Parkinson's disease patients with healthy controls and reported white matter abnormalities in the cerebellar peduncles.[24-27] In our study, we found a significant decrease in the FA value of the right inferior cerebellar peduncle in ET patients compared to healthy controls, but there was no significance in our MD value. At the same time, the FA value of the right inferior cerebellar peduncle was found to be lower in PD compared to SC. The significant decrease in the FA of the pedunculus cerebellaris inferior in both ET and PD compared to healthy controls supports the role of the cerebellum in tremor formation.

Lobules IV, V, VI and VIII are sensorimotor lobules of the cerebellum. Cerebellum volumes of Parkinson and essential tremor patients were analysed and different results were obtained.[28-32] In one study, it was reported that lobule V is related to the tremor symptom and lobule IX has a potential role in ET disease.[33] In our study, lobule V volumes of ET patients were significantly larger than PH and HC. The lobule IX volumes of ET and PD patients were significantly decreased compared to healthy controls, which is similar to this study. In line with our findings, it is thought that tremor assessment may reveal the difference between ET and PD.

CONCLUSION AND RECOMMENDATIONS

Stria thermialis indicates involvement of mesolimbic dopaminergic system in PD and it is thought that disruption of strial networks leads to changes in the activity of cerebellar networks. It reveals the role of the cerebellum and its connections in tremor. It is obvious that cerebellar thalamocortical pathways are affected in Parkinson's disease. In Parkinson's disease, patients should be assessed for visual processing, conceptualisation, postural instability and gait disturbance to clarify the diagnosis or to differentiate from essential tremor. In ET and PD, FA and MD values can be used as biomarkers with the DTG method, but attention should be paid to the formation of homogeneous patient groups in the results and the statistical analysis methods used we also believe that effective. results will be obtained with more participants to clarify the relationship between DTG measurements and diseases.

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