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Dorsal striatum in obsessive-compulsive disorder: a texture analysis study

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Abstract

Objective: The aim of this study was to examine Magnetic Resonance (MR) images of the dorsal striatum, which is known to play a role in the etiopathogenesis of obsessive-compulsive disorder (OCD), using a texture analysis method.

Methods: Twenty-eight OCD patients with brain MRI images stored in the hospital Picture Archiving and Communication System were included. The control group consisted of 28 healthy individuals. T1 weighted MRI images were obtained with 1.5T systems. All regions of the putamen, and the caudate nucleus were selected individually from the axial images that best represented the anatomy, without exceeding their borders. Symmetrical locations were used as separate samples (56 samples each of the caudate and putamen for both groups).

Results: Most of the parameters for both locations showed statistically significant differences between the patient and controls. ROC curve analysis showed high sensitivity and specificity for the mean values for both nuclei. Logistic regression analyses indicated that the calculated parameters could predict the probability of participants having OCD.

Discussion: The current methodology provided better results compared to structural approaches. It identified the structures that could not be visually assessed based on microstructural information and provided more valuable information when compared to shape-based measurements.

Conclusion: Tissue parameters in the dorsal striatum of OCD patients were found to be different from healthy controls. Thus, tissue analyses can be a useful technique for demonstrating tissue changes in the dorsal striatum using MRI images of OCD patients.

obsessive-compulsive disorder; caudate nucleus; putamen; computer-assisted image processing; magnetic resonance imaging

INTRODUCTION

Obsessive-Compulsive Disorder (OCD) is a chronic disorder that is characterized by thoughts, images or impulses that significantly affect functionality, are involuntary, unfamiliar, disturbing, cannot be voluntarily removed from the mind, and entails the use of involuntary repetitive actions or behaviors for relief or as a coping strategy [1]. OCD is generally char-

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acterized by a long duration between the age of onset of the disease and the start of treatment, which can negatively affect functionality, and has a high incidence in the community. Although significant improvements in the diagnosis of OCD have been made in recent years, its etiology and pathogenesis have not been fully elucidated [2-4]. The frontal lobe, basal ganglia and limbic system are known to be important in the pathophysiology of OCD. Previous brain imaging studies have revealed that differences in brain structures such as the basal ganglia, thalamus, the caudate nuclei and especially the orbitofrontal cortex (OFC) may be implicated in the etiology of the disease [5-8]. However, the outcomes of the studies in the literature examining structural changes in OCD are inconsistent, which may be due to human factors in the method used for measurement. Structural methods generally entail a subjective and technically laborious process for which the operators must be rigorously trained; additionally, the region of interest (ROI) is manually delineated.

Texture analyses evaluate the spatial position and intensity of signal features in imaging, i.e. unique pixels present in digital images. Texture properties are essentially mathematical parameters calculated from the pixel distribution obtained with the tissue type and therefore characterize the basic structure of the objects in the image. By quantitatively assessing the spatial variation and distribution of grayscale levels in the ROI, it provides a more objective and detailed assessment of tissue characteristics compared to visual analyses by human observers [9-12].

Previously, structural studies carried out in the relevant brain regions in psychiatric diseases along with texture analysis (histogram) of the same regions have been reported. Some structural studies did not report any differences in the relevant brain regions of the patients and healthy controls; however, texture analysis (histogram) studies could successfully reveal differences between the brain regions of patients and healthy controls [13-16]. These outcomes suggest that texture analysis (histogram) may be a useful technique for demonstrating tissue changes using magnetic resonance imaging (MRI) images of psychiatric patients.

The aim of the current study was to evaluate MRI images of OCD patients using the texture analysis (histogram) method and thus identify neuroanatomical aspects in the etiology of OCD.

METHODS

The current study was carried out in accordance with the 1983 revised version of the 1975 Declaration of Helsinki. A local Ethics Committee approval was obtained (Session Date: 16 December 2021, Issue: 2021/13-14). Since the study had a retrospective design and included MRI images taken from the Picture Archiving and Communication System (PACS) of the University Hospital, written consent was not obtained from the participants.

Study population

Patients who were diagnosed with OCD in the last five years and were regularly followed-up were screened from the University Hospital Information System (HIS), and 28 cases with brain MRI images available in the PACS were included in the study. The patients were diagnosed according to DSM-5 in the in-patient and outpatient clinics of the Psychiatry Department by senior assistants and specialists. Medical records of the patients were scanned from their follow-up notes, and patients with any other organic disease or psychiatric disease, including substance use disorders, other than OCD were not included in the study. All of the patients included in the study were undergoing pharmacotherapy including antidepressants and low-dose antipsychotics as augmentation therapy; none of the patients were on psychotherapy. The control group included 28 healthy individuals matched for age and gender with the study group and were selected from the HIS and PACS. These individuals had not been diagnosed with any psychiatric, neurological or other organic diseases according to the data available in the HIS. The control group had undergone MRI for reasons such as headaches, with no recorded pathological outcomes. The number of years of formal education, handedness and nicotine use of the participants were evaluated; no other data pertaining to the patients had been recorded in the HIS. Some of the cases whose MRI image

quality was determined to be low by a radiologist with 20 years of experience (M.B.) were excluded from the study.

Table 1. Gender distributions of the study samples.

		Control			Obsessive-Compulsive Disorder			Total		
		Female	Male	Total	Female	Male	Total	Female	Male	Total
Right	Caudate	16	12	28	16	12	28	32	24	56
	Putamen	16	12	28	16	12	28	32	24	56
Left	Caudate	16	12	28	16	12	28	32	24	56
	Putamen	16	12	28	16	12	28	32	24	56
Total	Caudate	32	24	56	32	24	56	64	48	112
	Putamen	32	24	56	32	24	56	64	48	112

Image acquisition and analysis

T1 weighted MRI images were obtained with the 1.5T GE Signa Excite systems (General Electric, Milwaukee, Wisconsin, USA) installed in the hospital Radiology Department. Images were transferred to a Windows 10 (Microsoft Corporation, Seattle, WA, USA) based computer in DICOM format and processed to obtain the final data. The analysis algorithm was applied to all selected images with a software coded in MATLAB (version R2021b; MathWorks, Natick, MA, USA) as described previously [11, 12, 16]. All regions of the putamen and the caudate nucleus were selected individually from the axial images that best represented the anatomy, without exceeding their borders, with an ROI determined by a senior radiologist (M.B.) [17, 18]. The calculation of the histogram values from ROIs has been previously described in the literature [9, 11, 12, 16-19].

Statistical analysis

Data are presented as mean ± standard deviation. The statistical analyses were conducted with IBM SPSS for Windows, version 25.0 (IBM Corporation, Armonk, New York, USA). The normality of the distribution of the data was analyzed with the Kolmogorov–Smirnov test. Based on the test findings, Mann-Whitney U test was used to compare the groups. $p<0.05$ was accepted as statistically significant. Logistic regression and receiver operating characteristic (ROC) curve analysis were carried out to determine the effects of the significant parameters in predicting the presence of OCD.

RESULTS

The study included MRI images of 28 controls and 28 OCD cases (Table 1). The differences in gender (Control/OCD: F/M; 16/12-16/12, $p=1.000$) and age (Control/OCD: 33.86±7.87/33.96±11.31, $p=0.650$) between the two groups did not reach statistical significance. Bilateral locations of the brain structure were used as separate samples (56 each of caudate and putamen samples for both groups). Most of the parameters for both locations showed statistically significant differences between the OCD and control groups. The histogram data is shown in Table 2 for both locations.

Table 2. Distribution of the study samples.

	Caudate					Putamen				
	Control (56)		Obsessive-Compulsive Disorder (56)		p	Control (56)		Obsessive-Compulsive Disorder (56)		p
	Mean	Std. Deviation	Mean	Std. Deviation		Mean	Std. Deviation	Mean	Std. Deviation	
Mean	340.71	140.07	515.77	264.06	<0.001	357.46	147.21	564.77	288.70	<0.001
Standard Deviation	17.33	7.54	28.36	17.90	<0.001	16.00	6.47	24.46	13.83	<0.001
Median	340.60	139.72	515.59	264.53	<0.001	357.66	147.23	565.23	289.22	<0.001
Mean Absolute Deviation	13.49	5.84	21.81	13.47	<0.001	12.72	5.24	19.53	10.77	<0.001
Median Absolute Deviation	10.97	4.56	17.36	10.46	<0.001	10.70	4.57	16.59	8.90	<0.001
Minimum	274.14	119.39	403.16	189.52	<0.001	299.63	133.23	476.73	227.01	<0.001
Maximum	388.52	156.34	599.61	315.33	<0.001	406.41	166.70	639.52	333.79	<0.001
Variance	356.06	353.02	1118.59	2095.94	<0.001	297.00	279.37	786.23	1277.88	<0.001
Covariance	356.06	353.02	1118.59	2095.94	<0.001	297.00	279.37	786.23	1277.88	<0.001
Range	114.38	56.86	196.45	144.28	<0.001	106.79	40.67	162.79	113.95	<0.001
Interquartile Range	22.27	9.67	34.92	20.86	<0.001	21.41	9.22	33.19	17.93	<0.001
Most Frequent Value	340.38	139.40	509.89	257.18	<0.001	359.88	150.22	565.32	287.49	<0.001
Size %L	14.41	2.00	13.83	2.09	0.084	15.57	1.57	16.00	1.36	0.037
Size %M	70.28	3.55	71.44	3.45	0.072	68.75	2.46	68.04	1.97	0.062
Size %U	15.31	2.12	14.73	1.93	0.116	15.68	1.28	15.96	1.11	0.331
Kurtosis	3.93	1.49	4.16	1.42	0.111	3.39	1.16	3.07	0.54	0.020
Skewness	-0.223	0.512	-0.147	0.616	0.361	-0.115	0.335	-0.098	0.183	0.935
Smoothness	0.005	0.003	0.002	0.002	<0.001	0.005	0.003	0.003	0.003	<0.001
Root-Mean-Square Level	341.18	140.22	516.58	264.61	<0.001	357.83	147.33	565.31	289.01	<0.001
Root-Sum-of-Squares Level	8553.50	4153.40	13392.80	8553.24	<0.001	13967.36	6701.91	22616.79	13440.37	<0.001
1st Percentile	296.62	128.02	441.01	217.07	<0.001	319.06	134.84	506.35	253.01	<0.001
3rd Percentile	307.59	129.65	460.79	229.95	<0.001	327.52	136.85	518.46	262.12	<0.001
5th Percentile	312.60	130.50	470.55	236.09	<0.001	331.45	137.94	524.64	267.02	<0.001
10th Percentile	319.73	132.36	482.38	243.47	<0.001	337.28	139.76	533.50	272.55	<0.001
25th Percentile	329.82	135.87	498.57	254.56	<0.001	346.76	142.98	548.31	280.44	<0.001
75th Percentile	352.09	144.17	533.50	274.62	<0.001	368.17	151.18	581.50	297.62	<0.001
90th Percentile	362.62	148.61	550.98	284.84	<0.001	377.73	154.73	595.90	305.31	<0.001
95th Percentile	369.16	151.38	562.51	291.52	<0.001	383.57	156.98	604.03	309.35	<0.001
97th Percentile	373.30	152.51	569.00	295.41	<0.001	387.33	158.34	609.40	311.83	<0.001
99th Percentile	379.79	154.04	582.08	302.88	<0.001	393.84	161.37	619.96	319.08	<0.001

	Caudate					Putamen				
	Control (56)		Obsessive-Compulsive Disorder (56)		p	Control (56)		Obsessive-Compulsive Disorder (56)		p
	Mean	Std. Deviation	Mean	Std. Deviation		Mean	Std. Deviation	Mean	Std. Deviation	
Entropy	3.92	0.42	3.97	0.45	0.692	3.61	0.41	3.51	0.21	0.224
Uniformity	0.385	0.060	0.376	0.078	0.235	0.326	0.068	0.313	0.033	0.789
Mean Local Entropy	2.86	0.36	2.85	0.39	0.658	2.49	0.38	2.37	0.17	0.075
Mean Local Range	83.35	33.28	121.14	55.74	<0.001	61.05	20.50	93.49	45.06	<0.001
Mean Local Standard Deviation	34.27	13.77	49.83	22.44	<0.001	25.27	8.52	39.06	18.38	<0.001
Contrast	202.46	130.38	222.35	78.08	0.002	819.58	392.42	1008.19	355.34	0.005
Correlation	-0.034	0.086	-0.029	0.032	0.912	-0.008	0.060	-0.011	0.050	0.940
Energy	0.002	0.001	0.002	0.000	0.053	0.001	0.000	0.001	0.000	0.123
Homogeneity	0.164	0.025	0.155	0.024	0.008	0.097	0.024	0.090	0.019	0.068

The ROC curve analysis showed high sensitivity and specificity for the mean values calculated for both nuclei (Figures 1, 2). Logistic regression analyses were carried out to determine the effects of the parameters calculated from the caudate nucleus on the likelihood of the participants having OCD (Table 3). The logistic regression models were statistically significant, $\chi^2(34) = 81.841$, $p<0.001$. This model explained 69.1% (Nagelkerke R^2) of the variance, and correctly classified 84.8% of the cases as having OCD. Increasing the maximum (p=0.021) and size %M (p=0.015), and decreasing the most frequent value (p=0.008), root-sum-of-squares level (p=0.049) and 97th percentile (p=0.027) were associated with an increased likelihood of exhibiting OCD.

Table 3. Logistic regression values of the study samples.

Parameter	B	S.E.	Wald	df	Sig.	Exp(B)
Caudate						
Maximum	0.206	0.089	5.319	1	0.021	1.229
Most Frequent Value	-0.248	0.094	7.027	1	0.008	0.780
Size %M	1.143	0.471	5.900	1	0.015	3.137
Root-Sum-of-Squares Level	-0.002	0.001	3.866	1	0.049	0.998
97th Percentile	-0.870	0.393	4.913	1	0.027	0.419
Putamen						
Most Frequent Value	-0.227	0.093	5.952	1	0.015	0.797
Kurtosis	-9.530	4.650	4.200	1	0.040	0.000
Skewness	-18.928	7.997	5.602	1	0.018	0.000
Smoothness	802.960	393.329	4.167	1	0.041	
Energy	-29245.983	13521.891	4.678	1	0.031	0.000

Next, logistic regression analyses were carried out to determine the effect of the calculated parameters from the putamen nucleus on the likelihood of the participants having OCD

(Table 3). The logistic regression models were statistically significant, $\chi^2(34) = 83.888$, $p<0.001$. This model explained 70.3% (Nagelkerke R^2) of the variance, and correctly classified 86.6% of the cases as having OCD. Increasing the smoothness (p=0.041), and decreasing the most frequent value (p=0.015), kurtosis (p=0.040), skewness (p=0.018) and energy (p=0.031) were associated with an increased likelihood of exhibiting OCD.

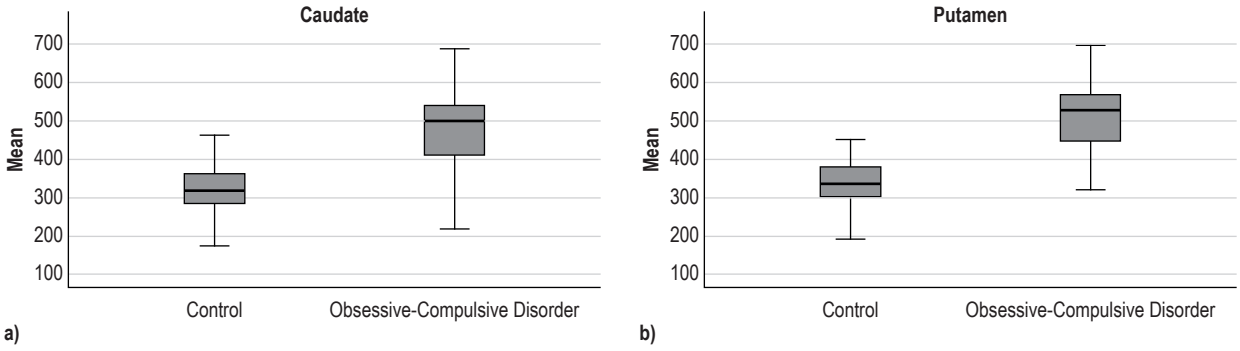

Figure 1. Distributions of the means of the caudate (a) and putamen (b) nuclei.

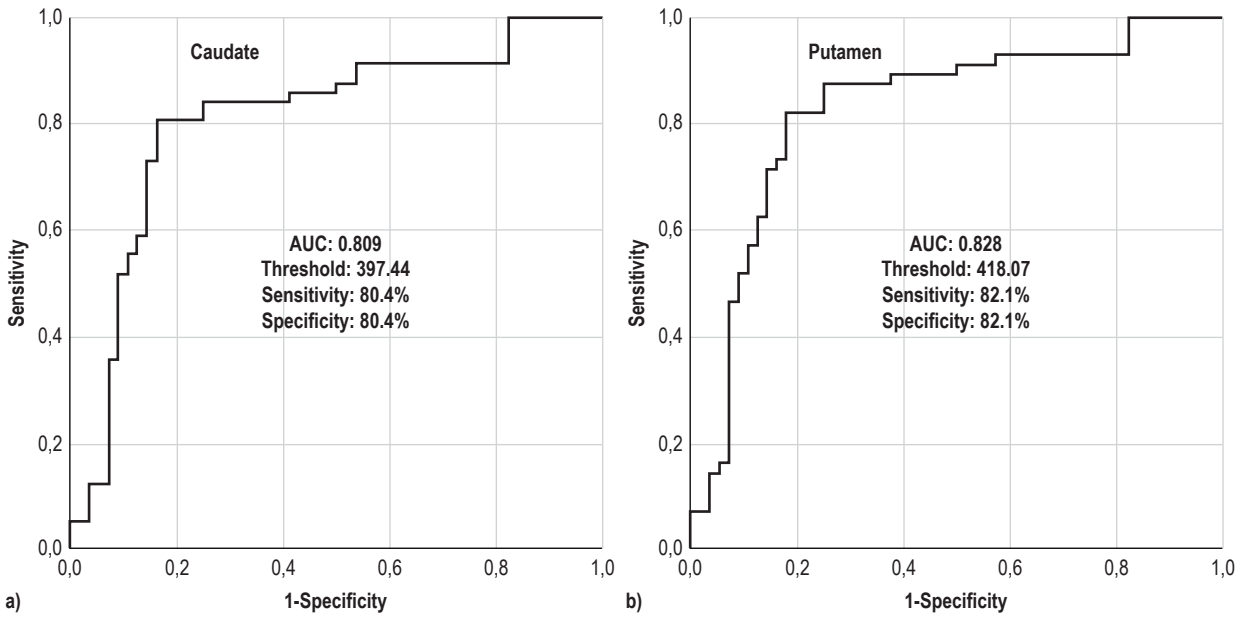

Figure 2. ROC curve of the means of the caudate (a) and putamen (b) nuclei

DISCUSSION

Evidence in support of the orbitofrontal-striatal model of OCD from Positron Emission Tomography (PET) studies has led to extensive research on structural brain abnormalities within these regions. The majority of the studies have utilized a case-control structural approach, which was the main analysis method available until recently. These studies have suggested that structural abnormalities are evident in OCD patients within the affective frontal-striatal loop The most consistent finding has been a decrease in the volume of the OFC [20-23]. In accordance with the orbitofrontal-striatal model of OCD, decreased striatal volumes have been consistently reported [24, 25]. Nonetheless, the direction of the structural findings is not entirely consistent. Thus, some studies have reported increased volume of the head of the right caudate in OCD [26, 27], while others did not report any significant changes in the striatal vol-

ume in OCD patients [28, 29]. A review published in 1996 reported no consistent differences in the caudate volume in patients with OCD [30] while a meta-analysis by Qiuying et al. indicated that OCD patients had abnormal white matter microarchitecture and altered grey matter volume [31]. The inconsistencies in the findings from case-control structural studies leads to questions regarding the methodology. The structural method requires that regions are manually delineated; a subjective and technically laborious process which requires rigorous training of the operator. This has restricted the number of regions and subjects that can be feasibly investigated. Thus, in most cases, one or two regions within a small sample have been analyzed, limiting the statistical power and generalizability of the results. Additionally, the methods for manually defining anatomical landmarks differ between studies, which may lead to inconsistencies in the reported volume changes; and separate analyses of several regions present a multiple comparisons issue which is not always accounted for. A cautious approach is required when developing a hypothesis about which brain regions to select for any volume-based analysis, as this method requires narrowing the field of research and therefore findings elsewhere in the brain can be neglected.

The texture of images refers to the appearance, structure, and arrangement of parts of an object within the image, represented by a set of coordinates in space, and each has a value that represents the gray level intensity of that image. Texture properties are mathematical parameters calculated from the distribution of pixels that characterize the texture type and therefore the most fundamental structure of the objects displayed in the image. Texture analysis identifies structures that cannot be visually evaluated and provides more valuable data on the models compared to volume-based measurements [32]. Often, texture analysis allows the classification of a tissue as pathological or healthy by distinguishing various anatomical structures. Evaluation of MRI images using tissue analysis or histogram analysis methods has become the focus of interest in investigating the etiology of psychiatric disorders [33, 34].

Texture analysis of the dorsal striatum in patients with OCD has not been reported previously. A statistical approach was adopted in the current study to determine the texture information of the images based on the gray level distribution of the pixels. This method provides better results with medical imaging when compared to structural approaches [35]. It identifies the structures that are not visible to the human eye and is based on microstructural data that provides more valuable information compared to shape-based measurements [36].

The current study has some limitations. First of all, the retrospective and long-term design made it necessary to utilize data from past cases. Another limitation is that since there were no previous studies that analyzed the OCD using texture analyses, we could not directly compare the study findings.

CONCLUSION

Tissue parameters in the dorsal striatum in OCD cases were found to be significantly different from healthy controls. The study findings demonstrated that tissue analysis can be a useful technique for demonstrating tissue changes in the dorsal striatum using MRI images of patients with OCD. Future prospective and comparative studies with multi-participants are needed to relate the differences observed in MRI images to possible structural changes in the examined brain areas. The current study can be considered as a pioneering study and a reference point for better elucidating the etiology of OCD.

DECLARATIONS

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Ethical Approval

All procedures in the study involving human participants conformed to the 1964 Declaration of Helsinki or ethical standards. A local Ethics Committee approval was obtained (date: 12/16/2021, session: 01, decision: 13-15).

Competing interests

The authors of this study declare that they have no conflict of interest among themselves or with others.

Authors' contributions

S.B and M.B designed the study and reviewed the data. H.N.B and H.O.K collected data, and designed the study. S.B and M.B. wrote the manuscript. All authors have read and approved the submitted manuscript.

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