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ORIGINAL ARTICLE

Evaluation of olfactory bulbus volume and olfactory sulcus depth by 3 T MR

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Abstract

Objective The aim of this study was to evaluate olfactory bulbus volume (OBV) and olfactory sulcus depth (OSD) according to age and sex with 3 T MRI in a healthy Turkish population.

Materials and methods In the current study, 200 patients who had cranial MRI were retrospectively evaluated. They were divided into the following groups to examine the effects of age: group 1: 18–30 years old; group 2: 31–40 years old; group 3: 41–50 years old; group 4: 51–60 years old; and group 5: >60 years old. OBV and OSD measurements were performed on coronal T2-weighted brain MR images. The mean right and left olfactory bulb volume and sulcus depths were used for evaluation.

Results The mean age was 46.5 ± 18.1 (range 18-86) years. The mean OBV value of both sides was 91.17 ± 7.8 mm 3 in all patients. The mean OSD value of both sides was 8.62 ± 0.84 mm in all patients. There was no statistically significant difference in OBV and OSD between sexes ($P < 0.236$; $P < 0.482$). Group 5 (>60 years old) was found to have significantly lower OBV and OSD values than the other groups (all $P < 0.001$).

Conclusion The normal values of OBV and OSD should be established according to age to determine decreased OBV and OSD values.

Keywords Bulbus olfactorius · Olfactory sulci · MRI scans

Introduction

Olfactory bulbus (OB) is an ovoid-shaped anatomic structure located in the cribriform plate [11]. OB has an important role in processing and evaluating the sense of smell [16]. Previous studies have demonstrated a close relationship between OB volume and olfactory functions [3]. In other words, there is a definite relationship between olfactory bulb volume and odor dysfunction in humans [12]. OBV measurements by MRI (magnetic resonance imaging) may provide clinical benefits in patients with olfactory function loss and help clinicians to follow the improvement of olfactory function [14]. On MRI, the detection rate of OB atrophy has a high rate of differentiating normal patients from dysfunctional patients [4]. In many studies, there is evidence that OBV and OSD measurements obtained on MRI images are reliable [7, 17].

Many diseases are associated with a decrease in OBV such as postinfectious, posttraumatic, Parkinson's disease, Alzheimer's disease, idiopathic, and congenital diseases [14]. Olfactory sulcus depth (OSD) is another parameter in the assessment of olfactory dysfunction. Many diseases including Behcet's, Alzheimer's, Parkinson's, major depression/anxiety are associated with decreased olfactory sulcus depth and reduction of the sense of smell [1, 5, 8]. In the Paschen et al. study, there was no significant relationship between Parkinson's disease (PD) and OBV values in the healthy control group. OBV was 42.1 ± 11.6 mm^3 in the patient group and 46.6 ± 12.3 mm^3 in the healthy control group. Another important result of this study is that high-resolution 3 T MRI examination is not sufficient to identify OBV reduction in PD [13]. In the study of Wang et al., olfactory bulb volume and olfactory sulcus depth were significantly lower in patients with PD. OBV was 37.30 ± 10.23 mm^3 in PD and 44.87 ± 11.84 mm^3 in the

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control group ($P < 0.05$) and OSD was 8.90 ± 1.42 mm vs. 9.67 ± 1.24 mm ($P < 0.05$) [17]. In the study of Doğan et al., Behçet's disease was associated with decreased odor function. OBV and OSD were decreased in Behçet's disease [5]. In the study by Zhang et al., decreased olfactory function and OBV were observed in patients with allergic rhinitis. However, there was no correlation between OSD and olfactory function [20]. In the study of Rottstaedt et al., the OBV was lower in people over 50. However, in patients with impaired mental status such as major depression, it was emphasized that the decrease in OBV accelerated in relation to the duration of the onset of the first mental state change [15]. In the study of Yu et al., it was found that OBV decreased in Alzheimer's disease compared to the healthy control group. There was no significant difference in OSD between the two groups. OBV values were measured as 30.05 ± 5.08 mm^3 in AD and 36.46 ± 4.11 mm^3 in control group ($P < 0.01$) [19].

In the normal population, olfactory bulbus volume and olfactory sulcus depth may vary according to age and gender. There is still no clear idea about normal values. The goal of this study is to evaluate olfactory bulbus volume and olfactory sulcus depth by 3 T MRI according to age and gender in healthy Turkish population.

Materials and methods

This retrospective study was performed in muğla sitki koçman university radiology department. This study was approved by the ethics committee of muğla sitki koçman university. Individuals with any disease (trauma, infection, tumor, congenital, psychiatric, endocrinological diseases, etc.) were excluded from the study. Patient files were taken as the basis for evaluation. Patients with diabetes mellitus, COPD, chronic drug use, smoking and alcohol use were excluded from the study. Patients with nonspecific symptoms and without pathology who underwent MRI were included in the study. In general, patients had headache and vertigo. These patients were not diagnosed with any disease during file scans. In the current study, 200 patients who had cranial MRIs were retrospectively evaluated. Patients who had cranial MRIs in the first 6 months of 2019 were included in the study. Those with poor image quality were excluded from the study. The patients were 100 men and 100 women. They were divided into groups according to their age and gender: group 1: 18–30 years old; group 2: 31–40 years old; group 3: 41–50 years old; group 4: 51–60 years old; group 5: > 60 years old; group A consisting of 100 men; group B consisting of 100 women. This study was carried out according to the bases of the Declaration of Helsinki. OBV and OSD measurements were performed on coronal T2-weighted brain MR images. MR images were obtained with a 3 T scanner (Siemens Skyra, Berlin, Germany). Images were obtained with a protocol of 256×256 matrix and a 22-cm field of view, repetition time = 3500 ms (TR 3500 ms), echo time = 75 ms (TE 75 ms), number of excitations = 2 (NEX 2) and a 4-mm slice thickness. The volume and depth measurements were calculated by a radiologist who had 10-year experience and was blinded to the subjects. Images were transferred to the workstation singo.via (Siemens, Berlin, Germany). Measurements were made on this workstation. The mean right and left olfactory bulb volume and sulcus depths were used for evaluation (Figs. 1, 2). An electronic cursor was used for delineating the contours of OB manually. The surface of each slice area was calculated in mm^2 and all surfaces were added and multiplied by front–back length to obtain a volume in mm^3. The mean of the three consecutive measurements was taken into account. The observer established the minimum of the three consecutive measurements for measuring the MRI images. The intraobserver variability was determined as less than 5%.

Statistical analysis

Statistical evaluation was done using the IBM SPSS version 20.0 software (IBM Corp, Armonk, NY, USA). Normal distribution was checked with the Kolmogorov–Smirnov test. Descriptive data were shown as mean ± standard deviation. We did statistical comparison of right and left OBV values with paired *t* test. Independent-sample *t* test was used for evaluating the statistical differences between gender groups. One-way ANOVA test was used for evaluating the statistical

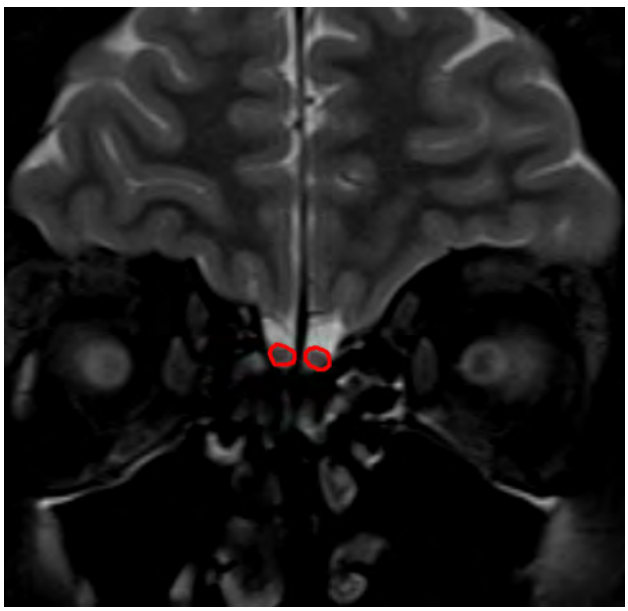

Fig. 1 Olfactory bulb volume measurement with magnetic resonance imaging. Coronal T2-weighted image shows an example measuring of olfactory bulb surface area

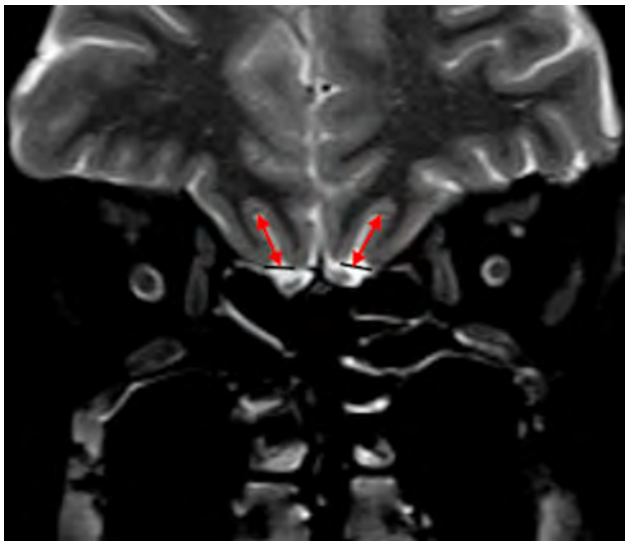

Fig. 2 Olfactory sulcus depth measurement with magnetic resonance imaging. Coronal T2-weighted image shows an example measuring of olfactory sulcus depth

differences between age groups. Multiple comparisons were made with the Tukey test. *P* value of 0.05 was accepted as statistically significant.

Results

A total of 200 patients (100 men, 100 women) were included in the study. The intraobserver variability was determined at less than 5% for OBV and OSD. The mean age was 46.5 ± 18.1 (range 18–86) years. The OBV was 91.5 ± 8.3 (range 68–115.2) mm^3 on the right and 90.8 ± 8.4 (range 72–115.2) mm^3 on the left side. There was no statistical difference between right- and left-side OBV ($P < 0.09$). Right and left OBV for men are 91.4 ± 8.1, 90.5 ± 8.3 mm^3, respectively. Right and left OBV for the woman are 91.6 ± 8.5 and 91.1 ± 8.6 mm^3, respectively. There was no statistical difference between the genders for right and left OBV ($P = 0.415$, $P = 0.637$, respectively). The mean OBV values on both side were 91.17 ± 7.8 mm^3 in all patients. OSD values were 8.6 ± 0.86 mm on the right and 8.6 ± 0.84 mm on the left. The mean OSD on both sides varied from 6.35 to 10.6 (8.6 ± 0.8) mm in all patients. There was no statistical difference between right and left in terms of OSD. Right and left OSD for the men are 8.6 ± 0.9, 8.6 ± 0.9 mm, respectively. Right and left OBV for the women are 8.6 ± 0.8 and 8.6 ± 0.7 mm, respectively. There was no statistical difference between the genders for right and left OSD ($P = 0.974$, $P = 0.993$, respectively). The distribution of age, OBV and OSD according to gender is given in Table 1. There was not a statistically significant difference between the OBV and OSD in terms of gender ($P = 0.236$; $P = 0.482$).

Table 1 The distribution of age, mean and both sides olfactory bulb volüme (OBV) and olfactory sulcus dept in according to sexes

	Group A ($n = 100$)	Group B ($n = 100$)	*P* value
Age (years)	46.8 ± 18.3	46.2 ± 18.1	0.497
OBV (mm^3)			
Mean	90.9 ± 7.6	91.4 ± 8.0	0.236
Right	91.4 ± 8.1	91.6 ± 8.5	0.415
Left	90.5 ± 8.3	91.1 ± 8.6	0.637
OSD (mm)			
Mean	8.6 ± 0.1	8.6 ± 0.7	0.482
Right	8.6 ± 0.9	8.6 ± 0.8	0.974
Left	8.6 ± 0.9	8.6 ± 0.7	0.993

The distribution of mean OBV and OSD according to age groups is given in Table 2. There was a statistically significant difference in OSD and OBV values between the groups in the one-way ANOVA test (in both $P < 0.001$).

Discussion

There are two important results of our study. First, there was no significant difference between the OBV and OSD measurements in terms of gender in the normal population. Second, OBV and OSD values of individuals over 60 years of age were lower than other age groups. There was no difference between the other age groups. Third, a decrease in OSD appeared to occur after the age of 30.

Hummel et al., found a positive correlation between OBV and olfactory function performed in children aged 1–17 years. It was emphasized that OBV and olfactory function increased with age [9]. In the study of Wang et al., in healthy subjects of middle (50–69 years = group 1) and old (> 70 years = group 2) age, left and both sides OB volumes were found to be 39.89 ± 8.7 mm^3 and 81.70 ± 16. 8 mm^3 in group 1 and 34.45 ± 10.4 mm^3 and 72.10 ± 19.3 mm^3 in group two, respectively. There was a statistically significant difference between them ($P < 0.05$). OBV was more on the right side than on the left. The OBV was higher in women than in men [18]. In the study conducted by Hang et al., 100 healthy individuals with age range 20–70 years were evaluated for OBV and olfactory functions. Right, left and mean OBV values in males were 84.65 ± 7.11 mm^3, 87.79 ± 7.57 mm^3 and 86.14 ± 7.37 mm^3, respectively. Right, left and mean OBV values of women were 69.58 ± 4.72 mm^3, 71.43 ± 5.29 mm^3 and 70.22 ± 5.02 mm^3, respectively. There was no significant difference in right and left OBV in both men and women ($P > 0.05$). OBV was significantly lower in women compared to men ($P < 0.01$). As a result of this

Table 2 The distribution of age, mean and and both sides olfactory bulb volume (OBV) and olfactory sulcus dept in according to age groups

	18–30 ($n=40$)	31–40 ($n=40$)	41–50 ($n=40$)	51–60 ($n=40$)	>60 ($n=40$)
Age (years)	22.3 ± 3.2	34.9 ± 4.2	45.3 ± 3	59.3 ± 9	70.7.3 ± 7.3
OBV (mm^3)					
Mean	91.6 ± 7.4[a]	94.3 ± 7.1[a]	92.6 ± 8.0[a]	91.6 ± 7.4[b]	85.8 ± 6.7
Right	92.0 ± 7.8	94.7 ± 7.9	92.9 ± 7.9	92.1 ± 7.8	85.9 ± 7.7
Left	91.1 ± 8.3	93.8 ± 7.5	92.2 ± 9.2	91.2 ± 8.3	85.6 ± 6.7
OSD (mm)					
Mean	9.5 ± 0.6 [a, d, e, f]	8.9 ± 0.6 [a, c, f]	8.8 ± 0.5 [a, c, f]	8.2 ± 0.5 [a, c, d, e]	7.6 ± 0.4[c, d, e, f]
Right	9.6 ± 0.7	8.9 ± 0.6	8.8 ± 0.5	8.2 ± 0.5	7.6 ± 0.5
Left	9.4 ± 0.7	8.9 ± 0.6	8.8 ± 0.5	8.2 ± 0.5	7.6 ± 0.4

Data are *n* of participants, mean ± SD

[a] $P < .001$ compared with > 60-year group (One-way ANOVA–Tukey test)

[b] $P < .01$ compared with > 60-year group (One-way ANOVA–Tukey test)

[c] $P < .001$ compared with 18–30-year group (One-way ANOVA–Tukey test)

[d] $P < .001$ compared with 31–40-year group (One-way ANOVA–Tukey test)

[e] $P < .001$ compared with 41–50-year group (One-way ANOVA–Tukey test)

[f] $P < .001$ compared with 51–60-year group (One-way ANOVA–Tukey test)

study, OBV and olfactory function decreased with age [6]. The results of these studies show that different results are obtained in the same disease groups in different age and gender (Table 3).

In our study, no significant difference was found between the sexes in terms of OBV and OSD. There was no significant difference in OBV values between 18 and 60 years of age. OBV and OSD measurements were significantly reduced in patients over 60 years of age. For OSD, the highest values were seen in people between 18 and 30 years old, and the lowest values were observed in people over 60 years old. A decrease in OSD appeared to occur after the age of 30. This decrease may be due to the decrease in vascular feeding of olfactory bulbus, degeneration, decrease in regeneration capacity, microtrauma and many other reasons with age. This reduction may be related to the decrease in the regenerative capacity of the olfactory sensory neurons and epithelium with aging and changes due to aging in the peripheral olfactory system [10]. Other factors include accumulation damage of olfactory epithelium from environmental factors, decrease in mucosal metabolizing enzymes, a sensory decrease of receptor cells against smelling substances, changes in neurotransmitter and neuromodulator systems. Additionally, constructional and functional damage of the olfactory epithelium, olfactory bulb, central olfactory cortex and basic olfactory circuit may cause deterioration of olfactory sensation [2]. The other strength of our study is that the images were obtained with a 3 T MR scanner. Thus, we think that we can obtain more accurate results with cleaner and thin section images.

This study has some limitations. Our sample size was relatively small. Our study is retrospective. All information about a person's curriculum vitae and medical histories were obtained through the hospital registration system. Another limitation is that interobserver variability was not evaluated.

In conclusion, there is still no consensus on the normal values of OBV and OSD. These values may change depending on age. So, normal values should be determined according to the age for decreased OBV and OSD.

Table 3 Comparison of previous studies in terms of OBV and OSD

First author	Year	Country	Diagnosis	*N*	Age (years ± SD)	Olfactory test	Magnetic field (Tesla)	OBV (mm^3)	OSD (mm)	*P*
Wang J	2009	Chinese	Healthy middle and oldaged persons	95	Group 1. 50–69 years Group 2. > 70 years	No	1.5 T	Group 1. 81.7 ± 16.8 Group 2. 72. 1 ± 19.3		* < 0.05
Wang J	2011	Japanese	PD	29		T&T	3 T	PD:37.3 ± 10.2 C:44.87 ± 11.8	PD:8.9 ± 1.4 C:9.67 ± 1.2	* < 0.05
Hummel T	2011	France	Children and adolescent	87	8 ± 5.5(1–17)	Sniffin' Sticks	1.5 T	M: (21–98) R:68 L:71 F: (24–121) R:66 L:65		* < 0.05
Zhang Q	2014	Chinese	AR	100	Not mentioned	T&T	1.5 T	AR:29.6 ± 4.1 C:48.8 ± 7.1		* < 0.01
Paschen L	2015	Germany	İPD	52	64.4 ± 8.7	Sniffin' Sticks	3 T	PD:42.1 ± 11.6C:46.6 ± 12.3		> 0.10
Yu H	2015	Chinese	AD	50	Not mentioned	T&T	1.5 T	AD: 30.1 ± 5.1 C:36.4 ± 4.1		* < 0.01
Hang W	2015	Chinese	Healthy individuals	100	42.6 ± 4.8 (20–70)	T&T	1.5 T	86.1 ± 7.4		* < 0.01
Doğan A	2018	Turkey	BD	27	43.5 ± 7.9	No	1.5 T	BD:34.1 ± 11.4 C:45.3 ± 4.9	BD:6.53 ± 0.89 C:7.03 ± 0.64	* < 0.05
Rottstaedt F	2018	Germany	MD	73	40.4 ± 12.1	No	3 T	MD: 64.2 ± 18.5 C:74.2 ± 17.5		* < 0.01
Our study	2020	Turkey	Healthy individuals	200	46.5 ± 18.1 (18–86)	No	3 T	91.17 ± 7.8 (68–115.2)	8,6 ± 0,84 (6.3–10.6)	* < 0.001

İPD idiopathic Parkinson's disease, *PD* Parkinson's disease, *BD* Behçet's disease, *AD* Alzheimer's disease, *AR* allergic rhinitis, *MD* mental disorders, *C* control, *M* male, *F* Famale, *R* Right, *L* Left

*Statistical significance

Author contributions NC: Protocol/project development, manuscript writing, İÖY: Source search, BG: Data collection and processin g, MYÖ: Data collection and processing, İK: Data analysis.

Compliance with ethical standards

Conflict of interest The authors declare that they have no confict of interest.

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