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The usefulness of MRI in olfactory bulb volumetric studies in chronic nasal obstruction

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Abstract---Background: A lack of smell (anosmia) is one of the most prevalent symptoms of persistent nasal obstruction. The olfactory bulb (OB) is a pliable structure with many active afferent neurons, and its size is regulated by the stimulus. Patients with persistent nasal blockage for more than 6 months without prior intervention were included in this research. Volumetric analysis of their olfactory bulb was done using magnetic resonance imaging (MRI), and three-dimensional imaging. The volume was calculated for them and compared with the control group that had no nasal problems. The study group's age ranged from 18 to 66 years, with a mean of 38.6 and an SD of 13.3. It was discovered that the mean olfactory bulb volume was significantly lower in patients than controls (23.48 vs 44.48 mm3, P=0.001), and that the mean olfactory bulb volume was significantly lower in patients aged 40 years or older than those without polyposis (P=0.019).There is a slight negative connection between symptom duration and olfactory bulb volume (r= - 0.28, P= 0.03). Also, there is a modest negative connection between symptom severity score and olfactory bulb volume (r=-0.328, P=0.01). According to the results of this research, MRI plus volumetric analysis is an effective approach for measuring OB volume in individuals with persistent nasal blockage. For these individuals, early intervention means higher preservation of smell function and return of OB volume to normal range.

***Keywords*---**Olfactory bulb, MRI, chronic nasal obstruction.

Introduction

Olfaction is the process of producing scent perception. When an odour connects to a receptor in the nose, it sends a signal to the brain. Olfaction is used to

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identify threats and pheromones and is involved in taste. Obtained by binding particular locations on olfactory receptors found in the nasal cavity. The olfactory bulb is where the sensory input interacts with areas of the brain responsible for scent recognition, memory, and emotion [1].The olfactory system detects smells (olfaction). Olfaction is a particular sensation that is linked to various organs. Most animals and reptiles have two olfactory systems. The auxiliary olfactory system detects fluid-phase stimuli, whereas the main olfactory system detects air [1].

Anatomy and function:

1-The human nose

The most pronounced facial feature. It is the initial respiratory organ and carries the nostrils. It is also the main olfactory organ. The nasal bones and cartilages, particularly the nasal septum, which separates the nostrils and splits the nasal cavity into two, form the nose. Sagittal nasal septum extends from the skull base superiorly to hard palate inferiorly, nasal tip anteriorly to sphenoid sinus, nasopharynx posteriorly.The septum's bony components include the ethmoid perpendicular plate, vomer, and maxillary crest, which comprise maxillary and palatine contributions. The septum's caudal quadrangular cartilage.The septum's osseous and cartilaginous sections are not continuous. Dense decussating fibers span the two levels. The nasal septum contributes to the internal and exterior nasal valves [2].The nasal mucosa lining the nasal cavity and paranasal sinuses performs the essential conditioning of breathed air by warming and moistening it. Nasal conchae, shell-like bones in the cavities, aid in this process. Olfaction, or scent, is another important nose function. The upper nasal cavity has specialized olfactory cells that perform this job [3].

2-The nasal cavity and paranasal sinuses:

The nasal cavity connects the external nose to the nasopharynx. The frontal, ethmoid, sphenoid, and maxillary sinuses are paired and surround the nasal cavity. The mucus secreting epithelium lines the complex. , In the sagittal plane, the nasal septum divides the nasal cavity. It is both bony and cartilaginous. The palatine process of the maxilla forms the floor of the nasal cavity, with the palatine bone forming the roof. The maxillary, palatine, lacrimal, and ethmoid bones contribute to the cavity's lateral walls. These walls have three curving extensions called turbinates or conchae that divide the cavity into inferior, middle, and superior meati[4].

The sphenoethmoidal recess is above the superior turbinate.

- The sphenoid air cells drain into the sphenoethmoidal recess.
- The posterior group of ethmoidal air cells drain into the superior meatus.
- The frontal sinus opens in the most anterior opening of the middle meatus. The anterior ethmoidal air cells and maxillary sinus drain into the middle meatus at the hiatus semilunaris, below the ethmoid bulla.
- The nasolacrimal duct opens into the inferior meatus, draining the lacrimal secretions[4].

Olfactory tract:

Formed of mitral cell axons (the majority of the tract, although unknown centrifugal fibers also flow to the olfactory bulb, perhaps inhibiting and faciliting).

The olfactory tract crosses the anterior Cranial fossa and optic nerves immediately in front of the front Medial, intermediate, and lateral olfactory stria olfactory network [5].

Mitral cell axons extend to:

- anterior olfactory nucleus which modulates information processing in the olfactory bulb
- anterior cortical nucleus of the amygdala and the olfactory tubercle, which together are thought to be important in the emotional, endocrine, and visceral consequences of odors,
- piriform cortex which may be important for olfactory perception
- The rostral entorhinal cortex which is thought to be important in olfactory memories.
- And axons of tufted cells extend to the anterior olfactory nucleus and anterior perforated substance.

Methods

A cross sectional analytic study was performed in the radiology department at AL-Yarmouk teaching hospital, Baghdad, Iraq. the study was conducted from December 2019 to December 2020. 45 adult participants their ages between (18-66 years) was included in the study, (divided to control group and patient group).

<u>Control group</u> subjects were selected from radiology department that had MRI for other health problem, after taking their permission and exclude any nasal problem by ENT assessment.

<u>Patient group</u> are those with chronic nasal obstruction for more than 6 months (15 of them have chronic sinusitis with polyposis , and 15 with nasal septal deviation)some had subjective smell function loss and some had not this complaint, all referred from otorhinolaryngology department after have routine ENT assessment by history, examination (including nasal endoscopy) and filling questionnaire formula(NOSE scale) to assess symptoms severity , then come to the MRI unit in our hospital to assess olfactory bulb volume for them after explaining the exam procedure and consent is taken.

<u>Inclusion criteria</u>: Age range between 18-66 years old
-The patient suffered from chronic nasal obstruction for more than 6 months
-The absence of Sino nasal complaint for control group, with no obvious septal deviation

Statistical analysis:

The data analyzed using Statistical Package for Social Sciences (SPSS) version 25. The data presented as mean, standard deviation and ranges. Categorical data presented by frequencies and percentages. Independent t-test (two tailed) was used to compare the olfactory bulb volume accordingly. Pearson's correlation test (r) was used to assess correlations between olfactory bulb volume and other continuous variables accordingly. A level of P – value less than 0.05 was considered significant.

Results

The distribution of study groups by age and gender is shown in figures (1 and 2) and tables (1 and 2). Study groups age was ranging from 18 – 66 years with a mean of 38.6 years and a standard deviation (SD) of ± 13.3 years. Half of patients in case group and 60% of controls were aged < 40 years.Regarding gender, proportion of males was higher in case and control groups than females (60% versus 40% and 53.3% versus 46.7% respectively).

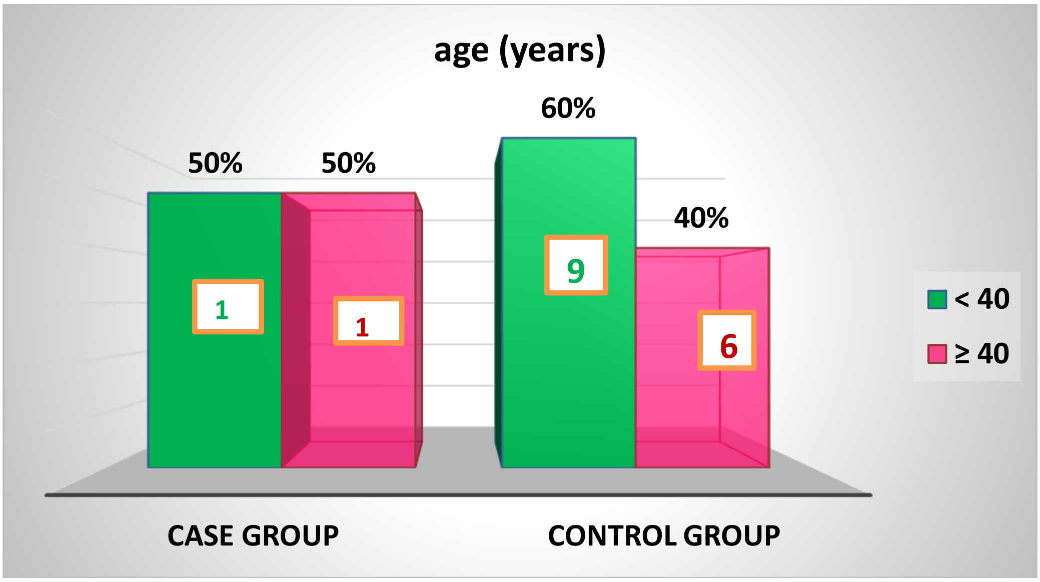

Figure (1): Distribution of study groups by age

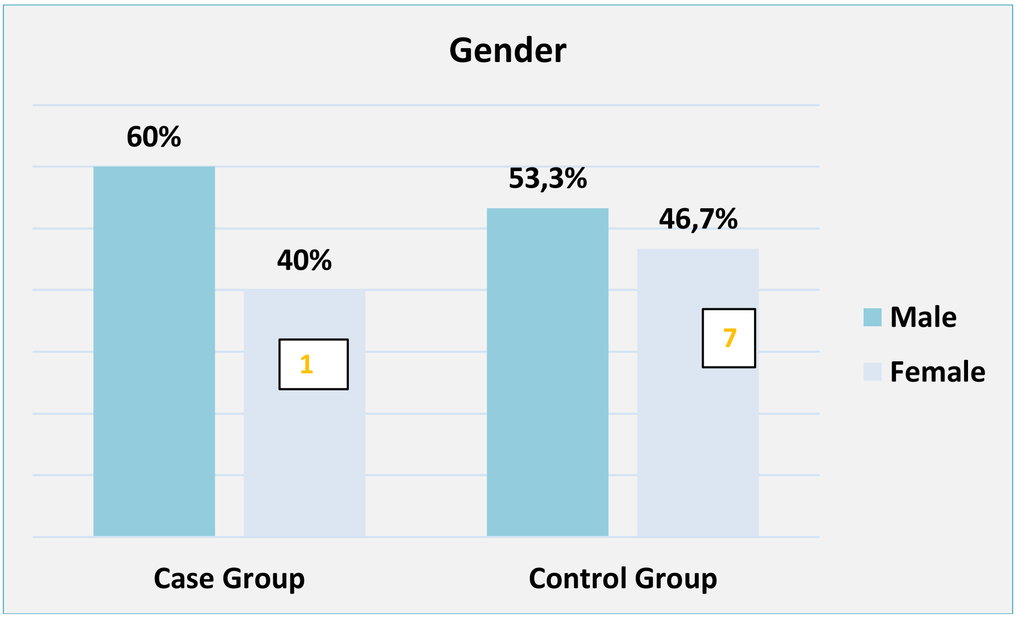

Figure (2): Distribution of study groups by gender

The comparison in age and gender between study groups is shown in tables (1 and 2). In this study, no statistical significant differences (P ≥ 0.05) in age and gender between study groups.

Table 1: Comparison between study groups by age

Age (Years)	Study group		P - Value
	Case Mean ± SD	Control Mean ± SD	
	40.56 ± 14.2	34.66 ± 10.4	0.123

Table 2: Comparison between study groups by gender

Gender	Study group		Total (%) n= 45	P - Value
	Case (%) n= 30	Control (%) n= 15		
Male	18 (60.0)	8 (53.3)	26 (57.8)	0.67
Female	12 (40.0)	7 (46.7)	19 (42.2)	

1. Clinical information of case group

Table 3 shows the distribution of case group by clinical information. We noticed that 50% of patients were diagnosed with polyposis and two thirds of them (66.7%) were complaining for more than two years' duration.More than half of patients (53.3%) were complaining from anosmia and two thirds of those with septal deviation (66.7%) had severity of more than 50%.Some of the cases that were worked on in our study. As shown in figure (3,4).

Table 3: Distribution of case group by clinical information

Variable	No. (n= 30)	Percentage (%)
Finding		
Polyposis	15	50.0
Right Septal Deviation	10	33.3
Left Septal Deviation	5	16.7
Anosmia		
Yes	16	53.3
No	14	46.7
Duration of symptoms (Year)		
< 2	10	33.3
≥ 2	20	66.7
Severity of septal deviation (%)	n= 15	
< 50	5	33.3
> 50	10	66.7

2. Olfactory bulb volume
A. Between study groups

The comparison between study groups by olfactory bulb volume is shown in table (4). Mean of olfactory bulb volume was significantly lower in case group than that in controls (23.48 versus 44.48 mm3, P= 0.001).

Table 4: Comparison between study groups by olfactory bulb volume

Study group	Olfactory bulb volume (mm^3)		P - Value
	Mean ± SD	Range	
Case	23.48 ± 7.2	10.4 – 38.4	0.001
Control	44.48 ± 10.7	29.4 – 60.6	

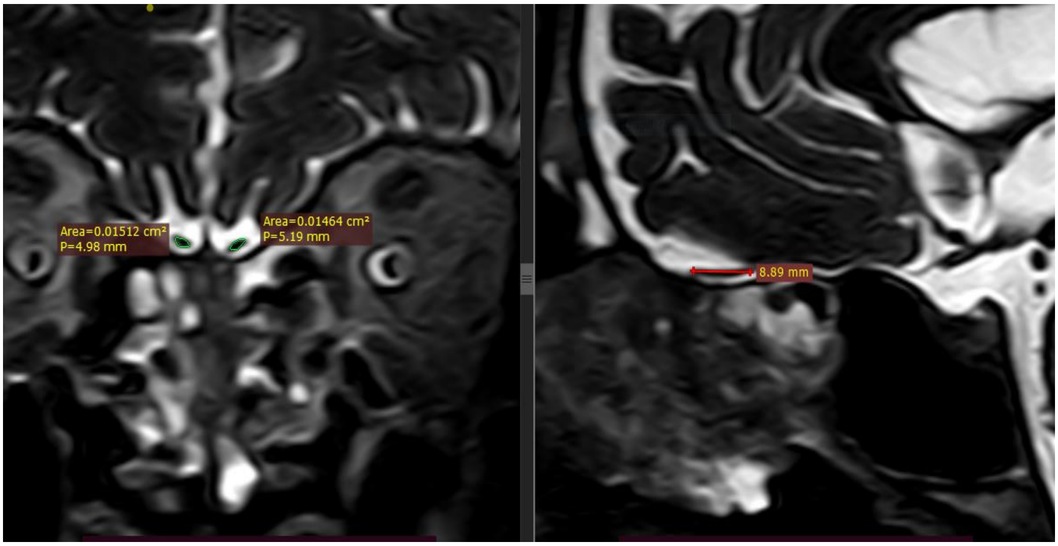

Figure (3): 45 years old male presented with chronic nasal obstruction for 3 years with anosmia , MRI and endoscopy of patient show severe nasal polyposis. In the Nasal endoscopy of right nasal cavity shows the septum (white arrow), the inferior turbinate (blue arrow) and the polyp extending beyond inferior turbinate(asterisk), The 3D T2 MRI sequence with volumetric study of OB shows small volume (left side 12.3 mm3) (right side=13.5mm3).

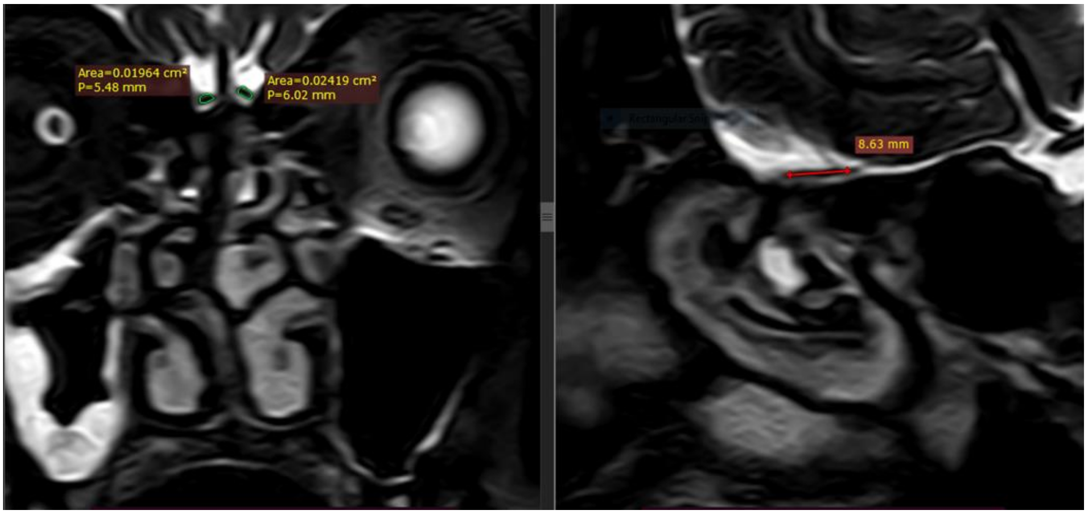

Figure (4): 35 years old female presented with chronic nasal obstruction for 2 years. MRI and nasal endoscope for patient show right sided septal deviation, the white arrow refers to deviated septum.Volume measurement of OB volume shows that the bulb in the deviated side (right) measure (16.3mm3) which is smaller than the left one (21.6 mm3)

B. In case group

Table 5 shows the comparison in olfactory bulb volume according certain characteristics of case group. We noticed that mean olfactory bulb volume was significantly lower in patients aged ≥ 40 years than that in those who aged < 40 years (P= 0.019),also in those with polyposis lower than that in septal deviation (0.001), in the affected side than that in the other sides(0.024), in those complaining from anosmia than that in those not complaining (0.003), in those who complained from symptoms for two years and more than that in those complaining for less than two years (0.005), and in those with septal deviation > 50% than those with septal deviation < 50% (P= 0.004).

Table 5: Comparison in olfactory bulb volume according certain characteristics of case group

Variable	Olfactory bulb volume (mm^3) in case group Mean ± SD	P - Value
Age (Year)		
< 40	25.66 ± 7.9	0.019
≥ 40	21.31 ± 5.8	
Finding		
Polyposis	20.53 ± 5.4	0.001
Deviation	26.43 ± 7.7	
Side		
Deviation side	23.28 ± 6.2	0.024
Other side	29.58 ± 8.0	

Anosmia		
Yes	20.84 ± 5.5	0.003
No	26.5 ± 7.8	
Duration of symptoms (Year)		
< 2	26.64 ± 4.6	0.005
≥ 2	21.9 ± 7.8	
Severity of septal deviation (%)		
< 50	30.58 ± 3.5	0.004
> 50	21.88 ± 6.2	

C. In healthy control group

Table 7 shows the comparison in olfactory bulb volume according certain characteristics of control group. Mean of olfactory bulb volume was significantly lower in females than that in males (P= 0.006). No significant difference in olfactory bulb volume (P= 0.833) between both sides

Table 3.7: Comparison in olfactory bulb volume according certain characteristics of control group

Variable	Olfactory bulb volume (mm^3) in control group Mean ± SD	P - Value
Gender		
Male	49.25 ± 10.9	0.006
Female	39.04 ± 7.6	
Side		
Right	44.06 ± 10.5	0.833
Left	44.9 ± 11.1	

Discussion

MRI-based volumetric investigations are a useful tool for evaluating the OB volume, which seems to be linked to the olfactory system's functioning condition.The present research has two groups: control and patients. 30 patients have chronic sinusitis with polyposis, 15 have nasal septal deviation, 16 have loss of smell, and 20 have nasal obstruction for over 2 years without surgical intervention.The control group (15 people) had no complaints, no abnormalities in imaging or exam.

Age and sex match both research groups.

1. In control group

In this study the volume of olfactory bulb in both sides of normal control group ranged between **(29.4 and 60.6 mm^3)** (mean 44.4 ± 10.7). The olfactory bulb volumes for normal subjects in the current study are comparable to those reported by ALarabawy et al[6]. who reported measurements between **25 and 63.3 mm^3** (mean 39.6 ± 13.8) ,and Herzalla et al..[7]who said that the volume was (35-75.8mm3). The average OB volume (44.4 mm3) in our study group is relatively comparable with Altundag et al. [8] study that found the average volume equal to **(40.2 mm^3).**However they are lower than those reported by Buschhuter et al.[9]

who reported an olfactory bulb volume in normal individuals to be between **37 and 98 mm^3** .This difference may be attributed to difference in the sample size(their sample was 125), environmental conditions, genetic factors or the method of examination and volume assessment , or the machine used (as they used 1.5 TESLA MRI system).
In this study there was no statistically significant difference in OB volume between the left and right side in the control group (left mean =44.9±11.1mm^3) (right mean=44.06±10.5mm^3)(p-value=0.833) as compared to other study that show that Herzalla et al..[7] and Askar et al [10].
There is significant difference in olfactory bulb volume between males and females in control group, the mean volume for **men =49.25±10.9mm^3**, while it measures **39.04±7.6mm^3 for women**. The overall difference in entire brain volume between men and women may explain this difference and this comparable with Buschhuteret el.[9] and Rombaux et al.[11] studies (men =70mm3)(women=65mm3)for both, and Herzalla et al..[7]who reported the volume for men =50.4mm^3,for women =42.7mm^3

2. between study groups

*The OB volume in patient group ranged between (10.4 _ 38.4mm3) and there is statistically significant difference between this and control group (p-value 0.001), ALarabawy et al[6] reported the OB volume in patient group who had chronic nasal sinusitis =(10_34 mm^3) and this comparable with our study, while Herzalla etal..[7]reported lower than this (5.2-19.5mm^3)(although the difference between control and patient as significant as our study p-value<0.001)this may due to their patients all had polyposis which cause more obstruction than septal deviation and more effect on OB volume)

3. In the case group

I. Age and volume

In our study we found that there is significant effect of age on the olfactory bulb volume as the OB volume was significantly smaller in patient above 40 years (21.3±5.8mm^3) than those lower than 40 years (25.6±7.9mm^3) (p-value=0.019) is comparable to Buschhuter et el.[9]study who found that OB volume decreased significantly with advancing age(although their normal range was higher than ours).

II. Polyposis vs septal deviation

In this study we found that the effect of nasal polyposis is more than that of septal deviation on the OB volume (for polyposis the volume was 20±5.4mm^3) (for septal deviation =26.4±7.7mm^3) with p-value 0.001
To the best of my knowledge there is no study before have this result to approve that the polyposis has more effect on OB volume than septal deviation, this can be due to more severe or complete obstruction to air flow and odorant inside the nose to reach olfactory epithelium in the superior aspect of nasal cavity.

III. In patients with nasal septal deviation

We found that there is significant difference in OB volume between side of deviation and contralateral side, (ipsilateral side measure 23.2±6.2mm3) (contralateral side =29.5±8mm3) with p-value=0.024

And this was concordant with Askar et al[10] who reported the deviation side (14.3±3.7mm^3) while other side measure (43.49±10.7mm^3)(with p-value=0.03) which is significant, and also with Altundag et al.[8]who found significant difference in OB volume between wide and narrow side in patient with septal deviation.

Also, we found that the more severe the deviation the more decrease in OB volume by comparing the volume in patient with more and less than 50% deviation of the septum from mid line and the result was that (more than 50%=21.88±6.2mm^3)(less than 50%=30.58±3.5mm^3)with significant difference p-value=0.004

IV. Duration of symptom

In this study there is significant negative correlation between the duration of symptoms and the OB volume as show in (figure 3.4) (R= -0.28)

For patients who complaint for more than 2 years duration, the mean bulb volume =21.9±7.8mm^3, while those with less than 2 years measure 26.64±4.6mm^3 with (p-value=0.005)

This finding is concordant with the result of Askar et al[10]who said that there is strong negative correlation between the duration of symptoms and the OB volume(R = -0.9761). while Herzalla et al[7] found that no correlation between duration and OB changes. This can be attributed to their smaller sample size or to inability of most patients to accurately describe their disease or symptom duration.

V. In correlation with smell function

In previous studies they used olfactory function tests to assess olfaction and correlate it with OB volume, because we don't have these tests here, we depend on subjective complain of anosmia

We found in this study that the patients presented with nasal obstruction and anosmia had significantly smaller OB volume than those presented with nasal obstruction not associated with anosmia (with anosmia the mean =20.84±5.5mm^3) (without anosmia= 26.5±7.8mm^3) (p-value =0.003). Altundag et al.[8]agree with our study , they found that there is significant positive correlation between OB volume and odor discrimination ,identification and odor threshold, also in Askar et al.[10]study found that OB volume change in parallel to smell function.

VI. In correlation with symptom severity (nose score)

In our study each patient had a severity symptom (nose score) according to a questionnaire paper he filled before have MRI, this range from 0 to 100, we found that there is significant negative correlation between OB volume and this score (r= -0. 328)

A previous study conducted by Rombaux et al.[12]and his colleagues on patients with chronic rhinosinusitis without polyps showed no significant difference between patients and controls with regard to OB volume. However, patients with a higher degree of Sino nasal inflammation were found to have significantly smaller OB volume when compared with patients with lower inflammation scores. This seems to correlate with our findings in which patients with more severe symptoms had significantly lower OB volume.

Conclusion

This study highlights that the MRI with volumetric analysis is a useful tool in assessing the OB volume in patients with chronic nasal obstruction as compared with a normal control group and shows a significant reduction in OB volume. We conclude that the longer period of nasal obstruction results in more reduction in OB volume, which affects the surgical outcome mean the earlier intervention for these patients the more preservation of their smell function and restoring the OB volume to normal range.

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