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THE ROLE OF MAXILLARY SINUS VOLUMETRY IN CHILDREN WITH OBSTRUCTIVE SLEEP APNEA

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THE ROLE OF MAXILLARY SINUS VOLUMETRY IN CHILDREN WITH OBSTRUCTIVE SLEEP APNEA (Abstract): **Aim**: Obstructive sleep apnea (OSA) is a common sleep disorder that can also affect children and represents a risk factor for childhood developmental problems. The aim of this study was to demonstrate if there is a correlation between the maxillary sinuses and nasal airway volumes and the presence of OSA in children. **Material and methods**: We retrospectively analyzed 59 patients from which 28 were diagnosed with OSA and 31 were healthy patients. We calculated the total nasal airway volume and maxillary sinuses volume using a open-source software for segmentation from CBCT (cone-beam computed tomography) data. **Results**: There was a significant difference regarding the BMI and the maxillary sinuses volume between the OSA patients and the control group. **Conclusions**: The maxillary sinuses reduced volume can be used as a predictor for OSA in pediatric patients with ages between 12-18 years old. **Keywords**: OBSTRUCTIVE SLEEP APNEA, CHILDREN, MAXILLARY SINUS, AIRWAY VOLUME.

Obstructive sleep apnea (OSA) is a common sleep disorder characterized by repetitive episodes of partial or complete upper airway obstruction during sleep. These episodes lead to disrupted breathing patterns, recurrent awakenings, and diminished oxygen levels in the body. OSA affects a significant portion of the population, with estimates ranging from 9% to 38% in middle-aged adults (1).

Obstructive sleep apnea is not limited to adults; it can also affect children. OSA prevalence in children varies, but estimates suggest it affects around 1-5% of children (2).

OSA in childhood is a strong risk factor for childhood developmental problems. It is closely related to neurobehavioral problems such as attention deficits, hyperactivity, learning disabilities, memory impairment, poor academic performance, and depression (3, 4) and is a risk factor for physical problems such as developmental delays (5), cardiovascular comorbidities (6), metabolic

disorders, and inflammation (7, 8).

The paranasal sinuses, including the maxillary, ethmoid, sphenoid, and frontal sinuses, are air-filled cavities within the skull bones surrounding the nasal passages. These sinuses play a role in reducing skull weight, providing structural support, and regulating air humidity and temperature (9).

Limited research has explored the correlation between pediatric OSA and paranasal sinus volume and understanding the relationship between them has clinical implications. Reduced sinus volume may impact nasal airflow and ventilation, potentially exacerbating OSA

symptoms (10). Additionally, sinus inflammation and infections may further contribute to airway obstruction in individuals with OSA (11).

The aim of this study was to reveal the associations between paranasal sinuses and nasal cavity volume and the presence of OSA in teenagers.

MATERIAL AND METHODS

Study population

This is a retrospective study of 28 patients (13 females and 15 males) aged 12-18 years old, already diagnosed with OSA based on clinical and physical examinations and polysomnography with AHI (apnea-hypopnea index ≥5), sent by the referring physician for a CBCT (cone beam computed tomography) examination at the "Medimagis Imaging Clinic" between March 2020 and December 2022.

The control group consisted of 31 subjects (13 females and 18 males) with ages between 12-18 years old and without any respiratory complaints, with a CBCT examination in the same clinic, in the same period of time.

We excluded patients with chronic or acute rhinosinusitis and allergic rhinitis, cranio-facial abnormalities or history of cranio-facial surgery.

Acquisition and Postprocessing of CBCT (cone-beam computed tomography) Data

The patients were placed in a sitting position with the Frankfurt plane parallel to the floor and the mid-sagittal plane perpendicular to the floor. The patients were told not to move, to avoid swallowing and to keep a regulated breathing interval during acquisition of images.

All included patients had CBCT examination in an interval of 1-3 months after the diagnosis and it was performed by CBCT ProMax 3D Max (Planmeca, Helsinki, Finland) with the largest field of view (FOV) available (502x502x437) with a voxel size of 0.4 mm, tube potential 90 kV, and tube current 10 mA.

Images were then exported in picture archiving and communication system (PACS) in standard DICOM format (digital imaging and communication in medicine). The data was loaded to the segmentation software, 3D Slicer, a free and open-source application for medical image manipulation (12).

The delimitations of the nasal cavity and paranasal sinuses were the following:

-a midsagittal reference plane (MSRP) was defined as a plane passing through nasion (N), anterior nasal spine (ANS), and the posterior nasal spine (PNS);

-the anterior plane was a line passing through external narines;

-the superior border was a plane passing through N, parallel to the palatal plane (that passes through ANS and PNS and is perpendicular to MSRP).

The nasal cavity and paranasal sinuses

were segmented using a threshold method that selected a range of pixels between a predefined interval related to the density of air (-1000 and -400) and the segmented volume was calculated automatically with the software's feature (fig. 1). The right and left maxillary sinuses were separated from the whole nasal airway for volume measurements (fig. 2). The process was done by radiologists.

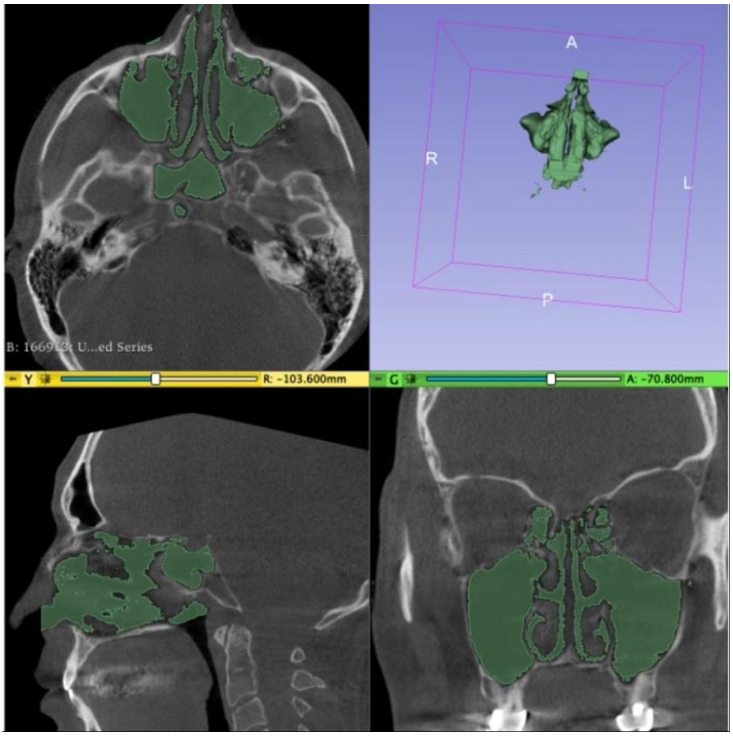

Fig. 1. Nasal airway segmentation using 3D Slicer.

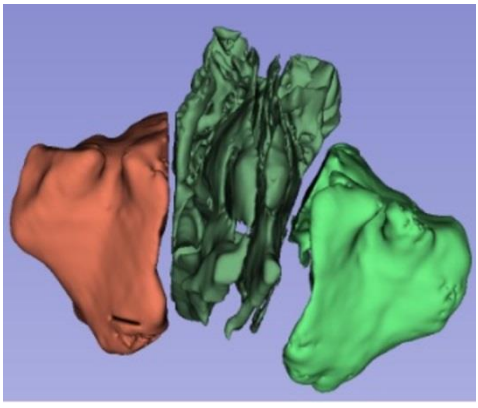

Fig. 2. Right and left maxillary sinuses separated from the rest of the nasal airway using 3D Slicer software

Statistical analysis

Statistical significance was established at a *p*-value below 0.05. Statistical analysis was performed using *SPSS* (IBM SPSS Statistics, release 24.0, Armonk, New York, NY, USA).

RESULTS

The descriptive statistics of control and OSA patients groups are displayed in Table I.

TABLE I.

Descriptive statistics of group 0 (control group) and group 1 (OSA patients).

	Age	BMI (body mass index)	Total nasal airway volume (cm3)	Maxillary sinuses volume (cm3)	Sinus/nasal airway ratio (%)
Group 0 (control)	15.06 ± 1.98	24.09 ± 3.99	84.58 ± 10.69	49.48 ± 3.54	59.57 ± 9.85
Group 1 (OSA patients)	15.39 ± 1.85	27.18 ± 1.77	82.05 ± 6.95	42.38 ± 3.29	51.83 ± 3.9
p-value	0.529	<0.001	0.268	<0.001	0.002

There was no significant differences between age or sex but there was significant differences in BMI index between the groups.

No significant difference between the volumes of total nasal airway in the two groups was found. The maxillary sinuses volume and the ratio to the total nasal airway was significantly reduced in patients with OSA compared to control group.

DISCUSSION

In this study we analyzed the correlation between the nasal airway volume, maxillary sinuses and the presence of OSA in pediatric patients above 12 years old. We found that that children with OSA had significantly smaller maxillary sinus volumes compared to the control group. Therefore, it may be said that decreased maxillary sinus volume can be a predictor of OSA development but not necessarily an exacerbating factor. Kim YJ *et al.* (13) conducted a study on 109 adult patients with OSA that underwent overnight polysomnography and CT (computed tomography) of ostiomeatal unit and found that patients with OSA had decreased ratios of maxillary sinus volume to whole nasal airway volume compared with normal subjects. Also, he didn't find any correlation between the volumes of total nasal airway or maxillary sinuses with the severity of OSA. In another study, Rodriguez *et al.* used CT and nasal fiber-optic endoscopy to assess the nasal airway volume and the anatomical changes of nasal cavity in patients with OSA and also found no association between nasal cavity volume and the severity of OSA (14).

Our study focused on pediatric patients between 12 and 18 years old because maxillary sinuses volume increase from postnatal period to adult stage but studies have shown that there isn't a significant size change after the age of 12 years. A study performed by Weiglein *et al.* on Australian cadavers' dried skulls reported that the final size of maxillary sinus is reached at 12 years of age (15). Bhushan B *et al* studied the changes of maxillary sinuses volume with age in children under 18 years old by measuring the height, weight and depth in groups 0-6 years, 6-12 years and

12-18 years using CT. The result showed that there was not a significant increase in maxillary sinus volume in patients older than 12 years old (16).

The majority of studies in the literature that measured the nasal airway volume used medical CT (13), (14), but considering we included in our study children, CBCT used as an imaging method for the nasal airway volume assessment has the advantage of a lower radiation dose and thinner slices that provide a better accuracy. CBCT is a widely used three-dimensional imaging technique and when utilizing a large field of view (FOV) protocol, it becomes a useful diagnostic tool for the upper airway assessment because it is visible in the whole CBCT volume. However, CBCT acquire images with patients in upright position unlike CT machines that require patients to be in supine position. This can be also a limitation of the study as the upright position does not simulate conditions during sleep but also an advantage considering the base of the tongue can protrude in the oropharynx airway and therefor, underestimate the volume of the airway. However, in our study we included only the nasal airway that is not influenced by the supine or upright position.

The ideal method for measuring nasal airflow remains controversial. Because the nasal airway contains not only bony structures but also dynamic ones, such as alar cartilages, turbinate, CT/CBCT images may have some limitations for airway function assessment. These aspect be considered, functional tests like nasal resistance could provide more information about nasal function.

Another aspect that must be discussed is the software used for the segmentation and volume calculation. In this study we used 3D Slicer, an open-source software (12) that has been found to be suitable for segmentation as well as in other studies (17), (18), because it is free and certified for medical use.

The effects of obesity on the development and severity of OSA are well known (19), (20). Our results supported the idea that a high BMI is correlated with the presence of OSA in children.

Nasal inflammatory conditions can also play an important role in the development of OSA (21). In our study we excluded patients with chronic or acute rhinosinusitis and allergic rhinitis in order to have a higher accuracy airway volume but there are studies that report a correlation between nasal obstruction and OSA (11), (22), (23). A survey study in Sweden has shown that respiratory conditions like rhinitis, chronic bronchitis, asthma, were significantly associated with OSA related symptoms (24). A study in Switzerland reported that perennial allergic rhinitis was found in 11% of patients with OSA and in only 2.3% of patients with chronic obstructive pulmonary disease (25). Although the potential mechanisms of the association between OSA and chronic rhinosinusitis are not completely elucidated, a study reported that some nasal inflammatory indicators (number of polymorphonuclear leukocytes, concentrations of bradykinin and the vasoactive intestinal peptide) were significantly higher in patients with OSA than in those without OSA (26). Another study found that chronic intermittent hypoxia due to OSA can determine a release of inflammatory cytokine that may contribute to mucosal and muscular inflammation of the upper airway (27).

Therefore, knowledge of other associated conditions with OSA such as nasal inflammatory diseases is important because it

can either contribute to the pathogenesis of OSA, either decrease the quality of life and the efficiency of CPAP treatment.

CONCLUSIONS

Reduced maxillary sinus volume can be a predictor for obstructive sleep apnea in pediatric patients and understanding the relationship between OSA and paranasal sinus volume has clinical implications. Further research is necessary to explore the underlying mechanisms linking OSA and paranasal sinus volume changes and to investigate potential therapeutic approaches targeting both conditions.

CONFLICT OF INTEREST AND FUNDING

The authors declare that there is no conflict of interest, and they received no specific funding regarding this scientific research.

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