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The Developmental Relation between Adenoid Tissue and Paranasal Sinus Volumes in 3-Dimensional Computed Tomography Assessment

Tayfun Apuhan, MD1,2, Yavuz Selim Yıldırım, MD3, and Hakkı Özaslan, MD4

Abstract
Objective. The aim of this study was to evaluate the developmental relationship between the volumes of paranasal sinuses and adenoid tissue by using a 3-dimensional (3D) reconstruction technique.

Study Design. Cross-sectional study.

Setting. Tertiary referral center.

Subjects and Methods. Multislice computed tomography (MSCT) images were obtained using 3D reconstructions and a volume-rendering technique (VRT) in 69 boys and 35 girls aged 3 to 16 years, and bilateral maxillary, frontal, and sphenoid sinus volumes, as well as adenoid tissue volume marked in axial-coronal-sagittal planes, were calculated. The patients were grouped in 3 categories according to adenoid tissue volumes, and comparisons were made.

Results. There was no significant difference between the right maxillary volume and left maxillary volume ($P = .93$). No significant difference was noted between the groups in terms of age and gender. There was no significant correlation between frontal, sphenoid, right and left maxillary, or total maxillary sinus volumes in all 3 groups of patients.

Conclusion. When classified according to adenoid tissue size, it was observed that increasing adenoid tissue volumes did not significantly affect the development of paranasal sinuses. Developmentally, there are no statistically significant correlations between the volumes of paranasal sinuses and adenoid tissues.

Keywords
paranasal sinuses, adenoid, adenoid hypertrophy, 3D, children, adenoid tissue volume

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facilitates the dissemination of several viral and bacterial agents into the nasal cavity and paranasal sinuses and is frequently accompanied by rhinological and otological problems.4 During the development of pneumatization, the nasopharynx is the area of connection. However, the role of nasopharyngeal structures on the aeration of paranasal sinuses is not known.

The difference between normal and pathologic paranasal sinus size in children may be difficult to measure, and a relationship between sinus size and pathology has not been demonstrated. Comprehensive knowledge of paranasal sinus development and normal pneumatization is important in elucidating sinus pathologies and in assigning the adequate treatment. After the introduction of CT, volumetric analyses of various tissues have been performed by the use of 3-dimensional (3D) reconstruction techniques. The aim of this study was to determine the developmental relationship between the volumes of adenoid tissue and paranasal sinuses by using a 3D reconstruction technique.

Materials and Methods
The study protocol was approved by the Committee on the Clinic Ethic Board of Hisar Intercontinental Hospital, Istanbul, Turkey. Medical records of patients, who were admitted to the Department of Otolaryngology and Head and Neck Surgery of Hisar Intercontinental Hospital and Haseki Research and Training Hospital, Department of Otorhinolaryngology and Head and Neck Surgery between 2005 and 2010, were retrospectively evaluated. In 2 hospitals, a total of 389 pediatric CT records were analyzed based on the images. One hundred four patients, who had been evaluated by paranasal sinus CT, were included in the study. Patients with a history of previous nasal, nasopharyngeal, paranasal sinus, or adenoidectomy surgery; maxillofacial trauma; congenital nasal and paranasal sinus abnormalities; acute or chronic nasal, nasopharyngeal, or otological infections; and acute or chronic sinusitis that may have affected paranasal sinus aeration were excluded from the study. Patients with antrochoanal polyps, cystic fibrosis, asthma, or immune deficiency were also excluded.

All patients were evaluated by multislice computed tomography (MSCT; Philips Brilliance 40; Philips Medical Systems, Best, the Netherlands) in supine position. The tube current was adjusted to an average 200 mAS with 120 kV. The scan field of view (FOV) was 250 mm. An average pixel pitch of 0.675 mm and an image matrix of 512 × 512

Figure 1. Three-dimensional (axial, coronal, and sagittal planes) reconstruction images of adenoid tissue volume.
were used. Slice thickness was 5 mm with 2.5-mm increments. After scanning, the images were reconstructed with a slice thickness of 2 mm, and the volumes of the paranasal sinuses were automatically calculated with a volume-rendering technique (VRT) in the workstation (Extended Brilliance, version 3.5.0.2254; Philips Medical Systems). In the determination of adenoid tissue margins, axial-sagittal-coronal reference planes were taken into consideration. All tissues within the contrast limits demonstrating similar standards with the adenoid tissue were included, and the mean volume of the adenoid tissue was calculated. The size of ethmoid sinus was not measured, as it has a complex structure, composed of numerous cells divided into anterior and posterior groups.

Volume calculations were performed using volume section, clip section, and injected dye 3-plane staining stages, and aeration was calculated in the volume, tissue, and air modes (Figures 1-5).

Statistical Analysis

The data were analyzed using MedCalc v11.1.1 software (MedCalc Software, Mariakerke, Belgium). An independent t test was used to compare volumes between genders and ages. The correlations between adenoid tissue and paranasal sinus volumes were determined using a Pearson correlation analysis. The Wilcoxon test was used for comparison of the dependent groups. The Mann-Whitney U test was used for comparison of the independent groups. A P value <.05 was considered statistically significant. We used sample size estimation to analyze the power of our study (type I error, α = 0.05; type II error, β [1 – β] = 0.20). By comparing 2 proportions, with a first group proportion of 44% and

Figure 2. Three-dimensional (axial, coronal, and sagittal planes) reconstruction images of frontal sinus volume.
a third group proportion of 23%, we determined that this study required a minimum sample size of 76.

**Results**

The mean age of 104 children (69 boys and 35 girls) included in the study was 10.6 years (range, 3-16 years). The descriptive statistics regarding the right and left maxillary sinus, total maxillary sinus, frontal and sphenoid sinus, and adenoid tissue volumes of the study population are presented in **Table 1**. There was no significant difference between right maxillary volume (RMV) and left maxillary volume (LMV; \( P = .93 \)) in all subjects.

Patients were grouped in 3 groups according to adenoid tissue volume as follows: group I, 125 to 1500 mm\(^3\) (n = 45); group II, 1500 to 2500 mm\(^3\) (n = 35); and group III, 2500 to 5500 mm\(^3\) (n = 24). Frontal sinus agenesis was noted in 4 patients in group I, 6 patients in group II, and 1 patient in group III, and sphenoid sinus agenesis was noted in 1 patient in group II; these patients were excluded from analysis. Age and gender were similar in all groups. There was no significant correlation between frontal, sphenoid, right and left maxillary, and total maxillary sinus volumes in all 3 groups of patients (**Table 2** and **Figure 6**).

Although there was no significant correlation between the volume of adenoid tissue and the volume of sphenoid and frontal sinuses, no significant correlation was noted between adenoid tissue volume and maxillary sinus volume in group I patients; however, both correlations were not significant (**Table 2**). No significant correlation was noted in all patients in group II between the volume of adenoid tissue and sinus volumes. No significant correlation was noted in all patients in group III between the volume of adenoid tissue and sinus volumes (**Table 2**).

**Discussion**

We found no association between adenoid volume and paranasal sinus volumes compared by 3D computed tomography.

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**Figure 3.** Three-dimensional (axial, coronal, and sagittal planes) reconstruction images of sphenoid sinus volume.
assessment in children. There was no significant correlation among sinus volumes.

Although the biological role of paranasal sinuses is not well understood, it is known that sinuses assist in respiratory physiology and biomechanical necessities of skull architecture. The impact of skull morphology on pneumatization is not as clear as inferred in common textbooks.¹ Maxillary sinus development begins at 3 months of intrauterine life and reaches a size of 6 to 8 cm³ at birth. It has been suggested that the age of development of the maxillary sinus varies between men and women. There are controversial opinions regarding the age at which it reaches the maximum size. Lee et al⁵ reported that maxillary sinuses reached the maximum size at age 14 years, whereas Jun et al⁶ reported the development of the maxillary sinus in the second decade in women and in the third decade in men. Sphenoid sinus development begins after birth and is completed until age 10 to 12 years. There are no gender- or race-related differences in its development.⁷

Chronic inflammation of the adenoids accompanies adenoid hypertrophy and can be frequently found in children aged 4 to 7 years. Hypertrophy and inflammation of the adenoids play a role in the mechanical obstruction of the nasopharyngeal airway. Many studies have emphasized how much the nasopharyngeal airway was blocked by using the complete size of the adenoid to influence the obstructive symptoms in adenoid hypertrophy.⁸,⁹

**Figure 4.** Three-dimensional (axial, coronal, and sagittal planes) reconstruction images of left maxillary sinus volume.
Adenoid tissue has a close relationship with paranasal sinuses. Although it has been suggested that adenoid tissue can lead to rhinosinusitis through mechanical obstruction and stasis of secretions, bacterial colonization may also play a role. Shin et al.\(^{11}\) have reported that pediatric sinusitis occurs due to mechanical obstruction rather than bacterial colonization of the adenoid tissue. Kim et al.\(^{12}\) reported in their long-term follow-up study that maxillary sinus volumes were reduced and bone thickness in paranasal sinuses was increased in pediatric patients with chronic rhinosinusitis. These findings suggest that adenoid tissue may contribute to pediatric chronic rhinosinusitis, which may eventually result in reduction of sinus volumes, and thus adenoid tissue may lead to a reduction in sinus volumes.

Lusk and Stankiewicz\(^{13}\) have suggested that adenoid tissue may impair the development of paranasal sinuses, by causing an ostial obstruction in the posterior paranasal sinus. They stated that the ratio between the diameters of adenoid tissue and nasopharynx tissue was more important in comparison to the diameter of the adenoid tissue alone. Takahashi et al.\(^{14}\) observed that adenoidectomy was effective in the management of sinusitis and otitis media with effusion, noting that adenoid tissue was considered a focus of contamination and inflammation rather than having a mass effect. Although there are arguments that the adenoid tissue leads to sinusitis and recurrent sinusitis leads to adenoid tissue hypertrophy, Lee and Rosenfeld\(^{15}\) have reported that bacteriological load, rather than the volumetric effect of adenoid tissue, leads to sinonasal symptoms. In another study, no significant relationship was found between the volume of the adenoid tissue and the severity of chronic sinusitis.\(^{16}\) We evaluated the
failed to find a statistically significant developmental relationship between adenoid tissue and paranasal sinus volumes.

High-resolution CT is the best method in evaluating the volume of paranasal sinuses. Three-dimensional image reconstruction and measurement by VRT must also be used for the best results. Computer-based 3D volume calculation can be performed more accurately, effectively, and easily by the advent of 3D reconstruction and analysis techniques. Three-dimensional measurements of volume, area, angle, and length in MSCT images have become possible by using advanced hardware and software computer technologies. Closest values to natural measurements can be obtained for volume calculation, internal structure, tissue density changes, and tissue volumes by volume- and surface-rendering techniques. Computed tomography costs less than magnetic resonance imaging, and 3D reconstruction by multidetector CT provides a perfect evaluation of the sinonasal cavities, even in the craniocaudal dimension.17

In a small case study comparing maxillary sinus volume in healthy individuals and adult patients with untreated cleft

Table 2. Comparison of Correlation, P Value, and n Values of Patients in 3 Different Adenoid Volume Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Frontal Sinus Volume, mm³</th>
<th>Sphenoid Sinus Volume, mm³</th>
<th>LMV, mm³</th>
<th>RMV, mm³</th>
<th>TMV, mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>r: -0.254 P: 0.109 n: 41</td>
<td>r: -0.171 P: 0.260 n: 45</td>
<td>0.099</td>
<td>0.518</td>
<td>0.037</td>
</tr>
<tr>
<td>II</td>
<td>r: 0.161 P: 0.403 n: 29</td>
<td>r: 0.189 P: 0.284 n: 34</td>
<td>0.154</td>
<td>0.376</td>
<td>0.164</td>
</tr>
<tr>
<td>III</td>
<td>r: -0.130 P: 0.555 n: 23</td>
<td>r: -0.179 P: 0.404 n: 24</td>
<td>-0.272</td>
<td>-0.199</td>
<td>-0.159</td>
</tr>
</tbody>
</table>

Abbreviations: LVM, left maxillary volume; RMV, right maxillary volume; TMV, total maxillary volume.

Figure 6. Schematic representation of adenoid tissue volume and frontal, sphenoid, left maxillary volume (LMV), right maxillary volume (RMV), and total maxillary volume (TMV).
palates, it has been reported that cleft palate was not a factor affecting maxillary sinus volume.\(^\text{18}\) In their study investigating the developmental effects of craniofacial anatomical structures on maxillary sinus volume, Cho et al\(^\text{19}\) did not find a relationship between dental problems and maxillary sinus volume but showed that chronic rhinosinusitis led to a decrease in maxillary sinus volume and alveolar bone height. Thus, we excluded subjects with paranasal sinus problems.

Although this is the first study evaluating the relationship between adenoid tissue volume and paranasal sinus volumes, it has some limitations. First, our study sample is relatively small. Second, we calculated the adenoid volume by using a new method that has not been verified previously.

**Conclusion**

When classified according to adenoid tissue size, development of paranasal sinuses was not significantly affected by increasing adenoid tissue volumes. Developmentally, there are no statistically significant correlations between paranasal sinuses and adenoid tissue.

**Author Contributions**

Tayfun Apuhan, acquisition of data, drafting the article, and revising it critically for important intellectual content; Yavuz Selim Yıldırım, substantial contributions to conception and design, analysis and interpretation of data; Hakkı Özaslan, acquisition of data.

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**References**


