The radiological evaluation of the nasal cavity, conchae and nasal septum volumes by stereological method: A retrospective cone-beam computed tomography study

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

Abstract

Background. The nasal cavity (NC) is the entrance to the respiratory system. Many studies have been conducted on the structure, function and volume of the NC. Only a few studies were performed assessing the volumetric values of NC and conchae.

Objectives. The aim of this study was to evaluate the volumetric measurements of the NC, conchae and nasal septum using the stereological method.

Material and methods. Cone-beam computed tomography (CBCT) images of 200 individuals (100 females and 100 males) aged 8–59 years were retrospectively evaluated. Inferior nasal concha and middle nasal concha, NC and nasal septum volumes were measured on these images. Measurements were made using point counting method, which is based on the Cavalieri principle. The mean values of the measured structures for 2 age groups and for each gender were obtained. Differences between the groups and genders of all parameters were examined. The volume fractions of measured volumes were calculated.

Results. The mean volumes of the nasal septum, left and right NC, left and right inferior nasal concha, and left and right middle nasal concha were 4.99 ±1.51 cm³, 7.44 ±2.93 cm³, 7.68 ±2.99 cm³, 3.10 ± 1.11 cm³, 3.04 ± 1.02 cm³, 1.32 ±0.56 cm³, and 1.28 ±0.49 cm³, respectively. Gender and age differences were statistically significant in all volumes (p < 0.05).

Conclusions. The data obtained in this study may assist clinicians in planning treatment, assessing the treatment results of pathological conditions within the NC, and help surgeons in preoperative and postoperative evaluations, especially in dentistry, otorhinolaryngology and plastic surgery.

Key words: Cavalieri principle, stereology, nasal cavity volume, cone-beam computed tomography
Introduction

The nasal cavity (NC) is the first part of the respiratory system. It opens posteriorly into the nasopharynx through the choanae and the anterior openings are nares. The NC is divided into 2 parts with a compartment which is called the nasal septum. Conchae are prominent bony structures on both lateral walls of the NC, which are covered with mucosa. Also, the conchae are dynamic structures because the area where they are located has the thickest mucous membrane of the NC and intense vascularization. The dynamic nature of the conchae allows the air flow rate and the amount of air to be adjusted.\textsuperscript{6,26,27} The volumes of the mentioned structures can be calculated with cross-sectional tomography images using the stereological methods.

Stereological methods provide numerical data, such as volumes, surface areas, as well as densities and lengths of structures objectively and efficiently.\textsuperscript{10,16} The Cavalieri principle, a stereological method, is effective in volumetric measurements of anatomical structures. In this principle, parallel and equally thick sections of a structure are taken, the total of section areas multiply by the thickness of section and the volume of the structure is calculated. It is accepted that the Cavalieri principle is the gold standard and provides realistic measurements.\textsuperscript{1,2}

The sectional images obtained with conventional computed tomography (CT) and magnetic resonance imaging (MRI) can be used in the calculation of the volume of a structure using the Cavalieri principle.\textsuperscript{13} There are only few quantitative studies of NC volumetric analysis performed with cone-beam computed tomography (CBCT).

The most important advantage of CBCT is that the practitioner can obtain 3-dimensional images in sagittal, axial and coronal planes. Three-dimensional reconstruction of CBCT images is also possible. This imaging technique provides valuable information to clinicians and researchers.\textsuperscript{23,31}

There is no published study about analyzing the volumes of the NC, conchae and nasal septum using CBCT images with stereological method. In this study, we aimed to calculate the volumes of all these structures on CBCT images with the stereological method.

Material and methods

Samples

Patients, admitted to Gaziantep University Faculty of Dentistry in Department of Dentomaxillofacial Radiology for computed tomography examination between January 2015 and February 2017, were retrospectively evaluated. All of the patients had been referred for the diagnosis and treatment planning because of different problems involving the dentomaxillofacial region. All CBCT images were obtained in the sitting position (scanning time: 14–18 s, collimation height: 13 cm and voxel size: 0.4 mm) using the same device (Planmeca ProMax 3D Mid; Planmeca, Helsinki, Finland). Age groups were established in order to show the differences between the measurements of adults and children. The age limit of 18 years was taken into account which is important for the development and the rapid growth. Images on axial, coronal and sagittal planes of 100 female (50 adults, 50 under 18 years of age) and 100 male (50 adults, 50 under 18 years of age) individuals without craniofacial anomalies and artifacts were evaluated (Fig. 1).

Procedures

A computer-assisted stereological analysis system (StereoInvestigator v. 8.0, MicroBrightField Bioscience, Williston, USA) was used for the measurements. Ethical approval was obtained from the ethical committee of Gaziantep University (ethics committee decision No: 111/6, date of approval: 12.02.2016).

Volumetric estimations were determined on the coronal images using point-counting (Cavalieri method) approach within stereological methods. All measurements were performed by the same researcher. The volumes of the right and left nasal cavities (RNCV and LNCV) were calculated from the air-filled areas, except for the soft tissue and bony structures. The right and left inferior nasal conchae volumes (RINCV and LINCV), right and left middle nasal conchae volumes (RMNCV and LMNCV) and nasal septum volume (NSV) were calculated from the bony structures and the soft tissue lying over them (Fig. 2).

The volume fraction (Vv) representing the proportion of a component in the whole structure was calculated. The volume ratio of each component to the total volume (TV) was determined as a percentage (%).

The volume fraction formula can be written as follows:

\[ Vv\ (a, b) = \frac{\Sigma a}{\Sigma b} \times 100 \]

(a: each of the components, b: total volume)\textsuperscript{27}
We estimated the volume fraction of the middle nasal conchae, inferior nasal conchae and nasal septum within the TV (RINCV + LINCV + RMNCV + LMNCV+ NSV + RNCV + LNCV) with the volume fraction approach, i.e., the MNC volume within the TV volume using the following formula:

\[
V_v (\text{middle nasal conchae, total volume}) = \frac{\sum \text{middlenasalconchae \times 100}}{\sum \text{total volume}}
\]

### Statistical analysis

The data was evaluated using SPSS v. 22.0 for Windows (IBM Corp., Armonk, USA) and by analyzing descriptive statistics (frequency, mean and standard deviation (SD)). Before the statistical analysis, Shapiro-Wilk test was used to test for normal distribution of data. All continuous variables were normally distributed. Independent sample t-tests were used to compare the groups. A p < 0.05 was considered statistically significant.

### Results

The mean age of all individuals, females and males was 26.00 ±15.34, 24.80 ±14.69 and 27.21 ±15.95, respectively (Table 1).

Mean RNCV, LNCV, RINCV, LINCV, RMNCV, LMNCV, and NS values of all subjects were 7.68 ±2.99 cm³, 7.44 ±2.93 cm³, 3.04 ±1.02 cm³, 3.10 ±1.11 cm³, 1.28 ±0.49 cm³, 1.32 ±0.56 cm³, and 4.99 ±1.51 cm³, respectively.

The mean volumes of measured structures of female and male subjects are represented in Table 2. The NC and nasal septum volumes of males were larger than those of females (p < 0.05). On the other hand, there was a significant difference between the inferior nasal concha volumes of male and female subjects (p < 0.05). Also, there was a significant difference between the 2 genders regarding middle nasal concha volumes (p < 0.05) (Table 2).

The mean volumes of measured structures in adults and children are shown in Table 3. The nasal cavities of adults were larger than those of children (p < 0.05). Also, the volumes of all structures were larger in adults (p < 0.05).

There was no statistically significant difference between the right and the left NC volumes of all individuals (p = 0.07). Also, there was no statistically significant difference between the right and the left middle and inferior nasal concha volumes (p = 0.247 and p = 0.449, respectively).

The volume fractions (%) of structures in total NC volume are shown in Table 4.

### Discussion

Many studies have been conducted on the structure, function and volume of the NC. In these studies, the structures of the NC, conchae and meatuses, anatomical variations, and air flow in the NC were examined. Radiological imaging,
dissection, measurements on dry bone, acoustic rhinometry, and rhinomanometry methods were used.\textsuperscript{5,8,14,20,22,28} Terheyden et al.\textsuperscript{29} accepted that the CT is the gold standard for measuring the NC and its components. Low radiation exposure, multiple display modes in combination with high accurate images, thin thickness of slices, real size analysis, and minimal superimposition make the CBCT ideal for the evaluation of the NC.\textsuperscript{9,12,30}

The CBCT allows not only the “real-time” images in the axial plane but also 2-dimensional images in the sagittal, coronal and even oblique or curved image planes.\textsuperscript{23} Despite the lower cost and less radiation dose compared to conventional CT, studies on CBCT images about calculating the volume of NC and its structures are limited in number.

There are studies that examined some changes before and after rapid maxillary expansion treatment using the CBCT images.\textsuperscript{3,4,25,32} In these studies, skeletal changes, changes in the all upper airway volumes, oropharyngeal volume, mandibular position, respiratory performance, and airway resistance were discussed and data obtained from CBCT images was evaluated with 3D software.

In literature, only 2 studies evaluated the volumetric changes of the NC using the stereological method on CT images.\textsuperscript{6,7} Also, these studies researched the changes in structures visible on CT images. In this study, we used CBCT images, where the resolution is better than the resolution of CT images. Emirzeoğlu et al.\textsuperscript{6} worked on individuals who were 18–40 years old. Ertekin et al.\textsuperscript{7} studied children 8–11 years of age. We conducted this study on a wide range of age groups (8–59 years of age), including the age range of both mentioned studies. This study is a reference study in Turkish population, where wide-scale volumetric calculations are made using stereological method. Also, the volume of the nasal septum was evaluated in this study, unlike in the study conducted by Emirzeoğlu et al.\textsuperscript{6} Ertekin et al.\textsuperscript{7} and Emirzeoğlu et al.\textsuperscript{6} used CT images with a cross-sectional thickness of 0.6 mm and 3 mm, respectively. Unlike these 2 studies, we examined a 0.4 mm slice of thickness on CBCT images. The mean volumes of structures measured in mentioned studies are given in Table 5 as a comparison of literature.

Table 4. Volume fractions of structures in total volume according to age and gender. Values are given as mean ± standard deviation (SD).

<table>
<thead>
<tr>
<th>Volume fraction</th>
<th>Female adults [%]</th>
<th>Female children [%]</th>
<th>Male adults [%]</th>
<th>Male children [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>RINCV/TV [cm³]</td>
<td>10.59 ±2.65</td>
<td>11.01 ±2.77</td>
<td>9.59 ±1.82</td>
<td>11.11 ±2.82</td>
</tr>
<tr>
<td>LINCV/TV [cm³]</td>
<td>11.38 ±2.50</td>
<td>11.38 ±3.35</td>
<td>10.10 ±1.89</td>
<td>10.56 ±3.38</td>
</tr>
<tr>
<td>RMNC/TV [cm³]</td>
<td>4.76 ±1.75</td>
<td>4.94 ±1.74</td>
<td>4.10 ±0.86</td>
<td>4.46 ±1.41</td>
</tr>
<tr>
<td>LMNC/TV [cm³]</td>
<td>5.01 ±1.53</td>
<td>4.97 ±2.05</td>
<td>4.17 ±1.01</td>
<td>4.50 ±1.68</td>
</tr>
<tr>
<td>NSV/TV [cm³]</td>
<td>16.81 ±3.14</td>
<td>19.56 ±3.43</td>
<td>17.68 ±4.72</td>
<td>16.91 ±2.07</td>
</tr>
<tr>
<td>RNCV/TV [cm³]</td>
<td>25.48 ±3.81</td>
<td>24.13 ±4.27</td>
<td>28.02 ±3.09</td>
<td>26.91 ±3.45</td>
</tr>
<tr>
<td>LNCV/TV [cm³]</td>
<td>25.58 ±4.10</td>
<td>23.97 ±3.91</td>
<td>26.31 ±3.77</td>
<td>25.52 ±3.98</td>
</tr>
</tbody>
</table>

TV – total volume; RINCV – right inferior nasal concha volume; LINCV – left inferior nasal concha volume; RMNC – right middle nasal concha volume; LMNC – left middle nasal concha volume; NSV – nasal septum volume; RNCV – right nasal cavity volume; LNCV – left nasal cavity volume.

Table 5. Comparison of literature.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ertekin et al.\textsuperscript{1}</th>
<th>Emirzeoğlu et al.\textsuperscript{35}</th>
<th>This study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age interval [years]</td>
<td>8–11</td>
<td>18–40</td>
<td>B–59</td>
</tr>
<tr>
<td>Number of cases</td>
<td>342</td>
<td>60</td>
<td>200</td>
</tr>
<tr>
<td>NCV [cm³]</td>
<td>R  F: 0.32–1.79 M: 0.45–2.19 (min–max)</td>
<td>L  F: 0.31–1.85 M: 0.45–2.20 (min–max)</td>
<td>R  F: 5.95 ±0.10 M: 7.01 ±0.18 (4.10–12.71 cm³) (min–max)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L  F: 6.13 ±2.22 M: 9.24 ±2.86</td>
</tr>
<tr>
<td>INCV [cm³]</td>
<td>R  F: 0.07–0.68 M: 0.09–0.71 (min–max)</td>
<td>L  F: 0.08–0.54 M: 0.08–0.70 (min–max)</td>
<td>R  F: 1.45 ±0.68 M: 1.59 ±0.98 (0.41–3.94) (min–max)</td>
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<td></td>
<td></td>
<td></td>
<td>L  F: 2.67 ±0.95 M: 3.42 ±0.95</td>
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<tr>
<td>MNCV [cm³]</td>
<td>R  F: 0.03–0.25 M: 0.04–0.30 (min–max)</td>
<td>L  F: 0.03–0.25 M: 0.04–0.30 (min–max)</td>
<td>R  F: 0.66 ±0.22 M: 0.67 ±0.31 (0.25–1.29) (min–max)</td>
</tr>
<tr>
<td>NSV [cm³]</td>
<td>F: 0.24–1.00 M: 0.23–1.24 (min–max)</td>
<td>–</td>
<td>L  F: 1.14 ±0.46 M: 1.41 ±0.47</td>
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<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>L  F: 1.21 ±0.55 M: 1.43 ±0.54</td>
</tr>
</tbody>
</table>

R – right; L – left; F – female; M – male; NSV – nasal septum volume; NCV – right nasal cavity volume; INCV – inferior nasal concha volume; MNC – right middle nasal concha volume.
Similarly as Emirzeoglu et al.\(^6\) and Ertekin et al.,\(^7\) we reported that a significant difference between male and female subjects in the NC measurements. We detected, as in these 2 studies, that the males' NC volumes and other structures' volumes in NC were greater than those in females. According to the obtained data, no significant difference was found in size between the right and left parts of the NC and the conchae.

It is known that nasal conchae are dynamic structures on the lateral wall of the NC. The changes in their sizes and variations of these structures give rise to various clinical consequences. For example, inferior nasal conchae hypertrophy is a kind of variation seen in conchae, resulting in nasal obstruction.\(^{24}\) Patients with nasal obstruction have difficulties in breathing in general or mouth breathing and suffer from drying in the throat and mouth, sleeping disorders with snoring, and sometimes apnea.\(^{18}\) Another variation that causes nasal obstruction is the paradoxical development of the middle nasal conchae. The paradoxical middle nasal conchae is defined as the lateral inclination of middle nasal conchae. This condition may cause recurrent infundibular disease when it occurs with ethmoid bulla and uncinate process variations.\(^{19}\) Also, it is stated that the middle nasal concha and the inferior nasal concha region have a critical prescription in terms of sinus surgery.\(^{21}\) Evaluation of conchae is important in the treatment of such clinical conditions and also after treatment. Although there are many studies investigating the anatomical variations of nasal conchae, the studies which assess conchae dimensions are rare.

It is clinically important to know the proportions of the structures in the whole volume of the NC. There is only 1 study that shows the proportion of concha volumes in the whole NC volume. According to the study by Ertekin et al.,\(^7\) the volume proportion of inferior nasal concha is in the range of 9–15% of the total volume of the NC. In the same study, the middle nasal concha volume proportion was reported in a range between 19–31% of the total volume of the NC. Despite the fact that the study by Ertekin et al.\(^7\) was conducted on children, the volume ratios of our study are similar.

This study revealed that the volume of the NC, nasal septum and conchae can be accurately calculated with the stereological method on the CBCT images. We believe that the data obtained in this study may assist clinicians in evaluating the treatment of pathological conditions related to the NC and in the planning of treatment as well preoperational and postoperative evaluations, especially in dentistry, otorhinolaryngology and plastic surgery.

**Limitations of the study**

In stereological studies, the statistical coefficient error is accepted as 0.05 or less.\(^{15}\) Similarly, the value of the coefficient error in the volumetric calculations is accepted as 0.05 or below in the present study. However, since the superior nasal concha can be detected in a few sections, the coefficient error of the volume of this structure is over than 0.05, so superior nasal concha volume cannot be calculated.

**References**

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