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Main Article

Effect of nasal septal deviation on total ethmoid cell volume

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Abstract

Background: The aim of this study was to evaluate the effect of nasal septal deviation (NSD) on ethmoid cell volume and to determine whether there was any correlation between NSD grade and ethmoid cell volume.

Methods: Forty computerized tomography (CT) scans from patients with rhinosinusitis symptoms with NSD were evaluated. Septal deviations were classified into three groups according to the degree of deviation on CT. Ethmoid cell volumes were measured and the relationship between NSD and ethmoid cell volume was investigated.

Results: There was a moderate but significant negative correlation between the septal deviation angle and the percentage of the ethmoid cell volumes ($p = 0.001$, $r = -0.5152$, $r^2 = 0.2654$). Total ethmoid cell volume on the ipsilateral side compared with the contralateral side was found to decrease as the degree of NSD increased.

Conclusions: Nasal septal deviation affects the total ethmoid cell volume of the nasal cavity. The results of our study underline the role of ethmoid cell volume in the compensation mechanism equalizing the nasal cavity airflow changes due to NSD.

Key words: Nasal Septum; Ethmoid Sinuses; Computed Tomography

Introduction

Nasal septal deviation (NSD), either congenital or acquired, is one of the most common diagnoses in daily otolaryngology practice. Prenatal, natal or post-natal traumas, external traumas, growth anomalies of the maxilla and incisors, facial anomalies, congenital deformities, breathing through the mouth, applying pressure to the palate with the tongue, and finger-sucking are among the common causes of septal deviation.[1] The incidence of NSD is lower in neonates than in adults, showing an increasing trend with age.[1–5] Embryologically, the ethmoid cells appear after nasal septal development; their development starts at 11–12 weeks with epithelial invagination, and 94 per cent of the ethmoid cells are present at birth. Active pneumatization of the ethmoid cells occurs between 0–4 and 8–12 years. Pneumatization continues until 20 years of age.

The nasal structures attempt to equalize the amount of air passing through the nasal cavities. An NSD jeopardizes nasal aerodynamics and diminishes the amount of nasal airflow at the convex side. This difference in airflow between the two nasal cavities initiates the differentiation of the paraseptal structures.[6] Nasal cavity volume decreases on the ipsilateral (convex) side of the septal deviation and increases on the contralateral (concave) side. Paraseptal structural changes occur in an attempt to compensate for such volume changes. The lateral nasal wall and the middle turbinate play major roles in this compensation mechanism. The increased incidence of Haller and agger nasi cells, pneumatization of uncinates and turbinates, and hypertrophy of turbinates have been reported previously as a consequence of NSD.[1,7,8] To the best of our knowledge, changes in ethmoid cell volume in association with NSD have not previously been investigated. Elahi *et al.*[7] reported a positive correlation between the angle of nasal deviation and ethmoid bulla prominence but did not undertake volumetric measurement. In this study, we aimed to evaluate the effect of NSD on ethmoid cell volume and to determine if there was any correlation between the grade of the NSD and the ethmoid cell volume.

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Materials and methods

In this prospective study, we evaluated a total of 40 patients with NSD and sinusitis symptoms, who underwent paranasal computerized tomography (CT) scans (24 women, 16 men; mean age of 35 $\mp$ 13.62, ranging between 20 and 70 years old).

The following exclusion criteria were chosen: prior paranasal surgery, history of sinonasal trauma, maxillofacial anomalies, nasal polyposis disease, mass lesions of the sinonasal region and acute rhinosinusitis attacks.

Computed tomography examinations (Philips Medical Systems, Secura, Netherlands) were performed in the prone position with the head hyperextended. Coronal CT images with contiguous, 2 mm-thick slices angled perpendicular to the hard palate were obtained. The bone algorithm with wide window (300/2350 HU) was used to obtain appropriate images. The image files were transferred to an Easy Vision computerized workstation (Philips Medical Systems) for evaluation of NSD and ethmoid cell volumes.

The direction of the septal deviation was noted and the angle of deviation calculated utilizing a protractor by measuring the angle between the apex of the septal deviation and the plate crossing the anterior nasal spine and the crista Galli.[7,8] Patients were grouped by their NSD angles according to the Elahi *et al.* grading system: Group I, NSD $\leqslant 9°$; group II, $9 < \text{NSD} \leqslant 15°$, and group III, NSD $> 15°$.

The ethmoid cell volumes of the 80 nasal cavities belonging to the 40 patients were evaluated using the volume measurement system of the Easy Vision computer workstation. Anterior and posterior ethmoid cells, including infraorbital and supraorbital cells, agger nasi and Onodi cells, were taken into account in calculating total ethmoid cell volumes. Ethmoid cell variations, such as supraorbital and infraorbital cells, were included in the assessment of the effects of septal deviation on total ethmoid cell volume. Including these volumetric variations in the calculation of total ethmoid cell volume is logical as an NSD could cause these cells to appear. Volume was calculated by defining the borders of the ethmoid cell boundaries in each slice, and margins were determined by a semi-automated system. Border points were set and these points connected with parabolic lines generated by the software programme. After determining the area of the ethmoid cells in each slice, the total volume was calculated according to the trapezoid rule of Ikeda *et al.*:[9]

$$\text{Volume} = (A1 + A2)h/2 + (A2 + A3)h/2 + \cdots$$

where A1, A2 ... = cross-sectional area of ethmoid cell in cm^2 and h = slice thickness.

Normal distribution of the groups and homogeneity of variances were analysed by the Kolmogorof–Simirnov test and the Levene test, respectively. The unpaired *t*-test was used in the analysis of difference between the right and left nasal cavity volumes. One-way analysis of variance (ANOVA) and the further Scheffe test were used to compare the percentage of ipsilateral and contralateral nasal volumes (Vipsilateral, Vcontralateral) and the differences between the ipsilateral and contralateral volumes (Vcontralateral − Vipsilateral) between the groups. The Pearson correlation coefficient test was preferred for evaluating the correlation between the angles of septal deviation and the percentage of bilateral volumes (Vipsilateral/Vcontralateral). The level of statistical significance was determined as $p < 0.05$.

Results

Nasal septal deviations were towards the right in 25 patients and towards the left in the remaining 15 patients. Nasal septal deviation angles were found to range between 4.1 and 20.2° (mean 10.46 ± 4.21°). Patients were grouped according to the severity of their NSD, as previously described, to give the following: group I, 20 patients; group II, 11 patients; group III, nine patients. The NSD angle characteristics of the groups are described in Table I.

The total ethmoid cell volumes, independent of group and side of NSD, were 5.83 ± 1.57 cm^3 and 5.69 ± 1.82 cm^3, on the right and left side, respectively. There was no statistically significant difference between the ethmoid cell volumes of each side ($p > 0.05$). On the convex (ipsilateral) side the total ethmoid cell volume was 5.42 ± 1.64 cm^3 and on the concave (contralateral) side it was 6.10 ± 1.69 cm^3. No statistically significant difference was noted between the total ethmoid volumes on the ipsilateral and contralateral sides of the NSD ($p = 0.075$). The ethmoid volume characteristics on the ipsilateral and contralateral sides of the NSD for each group are given in Table II. Within each group, there was no significant difference between the total ethmoid cell volumes on the ipsilateral and contralateral sides of the NSD ($p > 0.05$).

TABLE I

NASAL SEPTAL DEVIATION: GROUP CHARACTERISTICS

	Group I	Group II	Group III	Total
n	20	11	9	40
%	50	27	23	100
NSD angle mean ± SD (°)	7.00 ± 1.32	11.53 ± 1.50	16.83 ± 1.57	10.46 ± 4.21
NSD angle range (°)	4.1–8.8	9.1–14.1	15.7–20.2	4.1–20.2

Group I, NSD $\leqslant 9°$; group II, $9 < \text{NSD} \leqslant 15°$, and group III, NSD $> 15°$.

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TABLE II

TOTAL ETHMOID CELL VOLUME: GROUP CHARACTERISTICS

	Group I	Group II	Group III
TECV ipsilateral (cm^3)*	5.40 ± 1.88	5.36 ± 1.18	5.55 ± 1.74
TECV contralateral (cm^3)*	5.80 ± 1.88	6.05 ± 1.28	6.82 ± 1.66
Vipsilateral/Vcontralateral†	0.93 ± 0.12	0.89 ± 0.07	0.80 ± 0.09
Vcontralateral − Vipsilateral‡ (cm^3)	0.40 ± 0.70	0.69 ± 0.48	1.26 ± 0.33

*$p > 0.05$ for differences between ipsilateral and contralateral total ethmoid cell volume (TECV) within all groups. †$p = 0.013$ for difference between group I and other groups. ‡$p = 0.028$ for difference between group III and other groups.

These data could be explained by the extreme variation in patients' total ethmoid cell volumes, which ranged between 1.58 and 9.40 cm^3. In order to eliminate the influence of this variation, the differences between the sides (Vcontralateral − Vipsilateral) and the ratio of ethmoid volumes between the sides (Vipsilateral/Vcontralateral) were calculated (Table II). As a percentage of the total ethmoid cell volume, ipsilateral volumes were 93 per cent of contralateral volumes in group I, 89 per cent of contralateral volumes in group II and 80 per cent of contralateral volumes in group III (Table II). When comparing the groups according to the percentage of the volumes, a statistically significant difference ($p = 0.013$) was found, with the volume ratio of group I being higher than that of the other groups. When the differences between the total ethmoid cell volumes were compared (Vcontralateral − Vipsilateral), statistically significant differences were also found between the groups ($p = 0.028$), with higher values in group III.

The correlation between the septal deviation angle and the ratio of the ethmoid volumes (Vipsilateral/Vcontralateral) is shown on Figure 1; there was moderate but significant negative correlation between these variables ($p = 0.001$, $r = -0.5152$, $r^2 = 0.2654$). The total ethmoid cell volume on the ipsilateral side compared with the contralateral side was found to decrease in correlation with the increase in degree of NSD.

Coronal CT images from patient group III, revealing the NSD angle and the difference in total ethmoid cell volumes between the sides of the NSD, are shown in Figure 2.

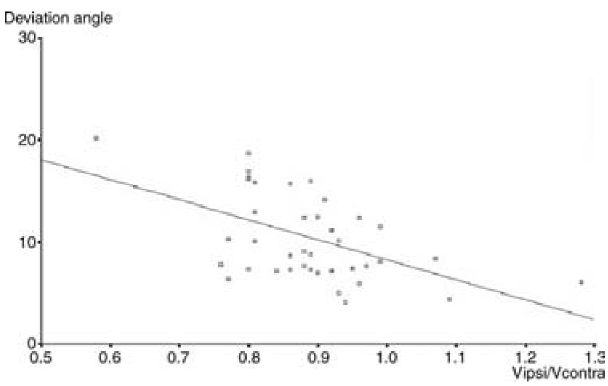

FIG. 1

The correlation between nasal septal deviation angle and the Vipsilateral/Vcontralateral (Vipsi/Vcontra) ratio of the total ethmoid cell volumes ($p = 0.001$, $r = -0.5152$, $r^2 = 0.2654$).

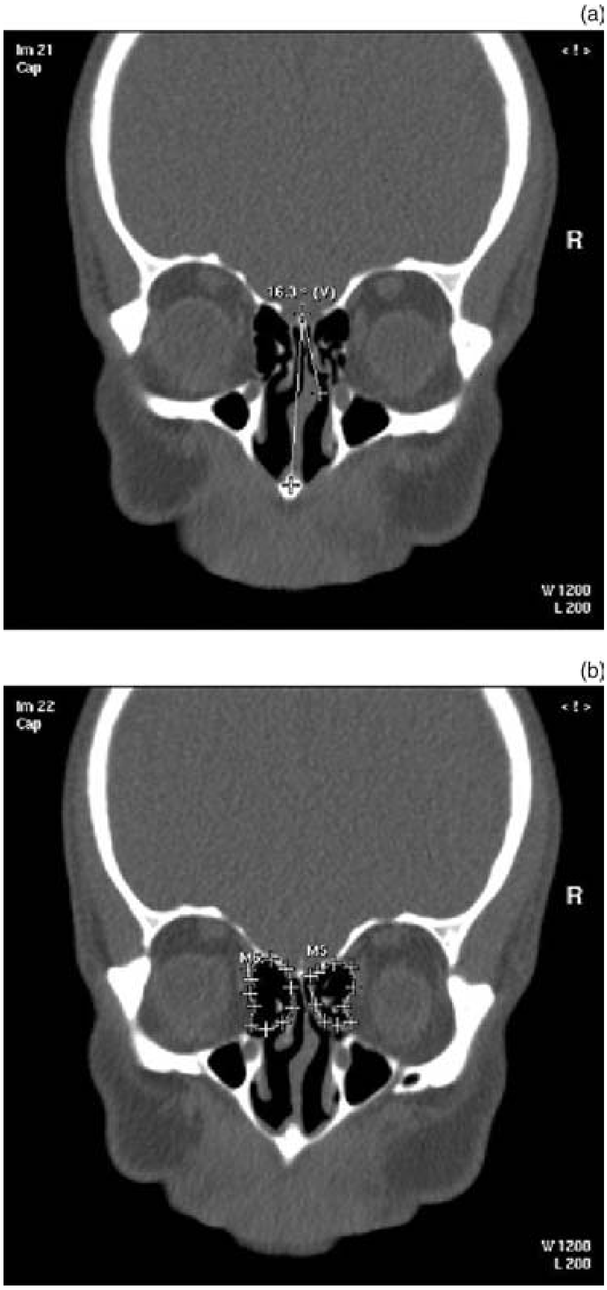

FIG. 2

Coronal paranasal computed tomography images of a patient from group III. (a) nasal septal deviation angle measurement method; (b) evaluation of ethmoidal cell volumes. The ethmoidal cell area difference between the nasal cavities was noted.

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Discussion

The incidence and type of anatomic variations of paraseptal structures related to NSD have been comprehensively described in the literature.[1,7,8] The prominence of the ethmoid bulla on the contralateral side of the NSD was found to be the most frequent ethmoid cell variation associated with NSD.[7] We reviewed the literature and found no study analysing the ethmoid cell volumes in patients with NSD; such evaluation can be valuable in pre-operative assessment and in determining an appropriate surgical approach.

The relationship between the structural variations associated with septal deviation, and chronic sinusitis had been already investigated with qualitative and quantitative evaluations. Stammberger *et al.*[10] proposed agger nasi cells, middle concha and uncinate process variations and Haller cell and septal deviations as a etiologic factors in the development of sinus disease. However, these authors reached no consensus about the role of septal deviation in the pathogenesis of chronic sinusitis. Collet *et al.*[11] reviewed literature of the past 20 years investigating the relationship between NSD and chronic sinusitis and found few studies revealing a statistically significant association (they also stated that the results and methodologies of those studies were contradictory). This conclusion is supported by recent studies showing no evidence for a contribution from NSD to rhinosinusitis disease (incidences of NSD were the same in rhinosinusitis patients and the control group).[11,12] However, anatomic variations and NSD located near the osteomeatal area may lead to obstruction and play a role in the pathogenesis of chronic sinusitis.[12]

It can be speculated that the location of anatomic variations is more important than their presence. The volumetric increase on the concave side of an NSD could result in osteomeatal complex (OMC) obstruction. In our study, ethmoid cell variations were not studied separately but were included in the calculation of the total ethmoid cell volume. The volumes of ethmoid cell variations obstructing the OMC could be separately evaluated; however, this was outside the scope of our current research.

The total ethmoid cell volume differences on either side of an NSD are a routinely observed clinical issue in daily rhinology practice. However, we could find in the literature no volumetric investigation clarifying the role of NSD-related ethmoid cell volume differences in the pathogenesis and treatment of rhinosinusitis. There were few studies investigating the relationship between chronic sinusitis and variations and mucosal thickening of ethmoid cells. Bolger *et al.*[13] studied paranasal CT scans of patients with chronic sinusitis, investigating mucosal thickening of the ethmoid infundibulum and the anterior ethmoidal cells. Aktas *et al.*[1] reported a greater incidence of ethmoidal sinusitis on the same side of the septal deviation. However, ethmoid cell volume was not evaluated by these studies. Our study is unique in presenting primary data on changes in total ethmoid cell volume in patients with NSD and sinusitis. We hope that this will stimulate new research on this topic. Further studies investigating the incidence of complications of endoscopic sinus surgery and of infection in the nasal cavities with the smaller ethmoid cell volume and the importance of ethmoid volume in the education by virtual endoscopic sinus surgery. Preoperatively evaluated, exact anatomic data including volumetric measurements could be expected to improve the success rates of functional endoscopic sinus surgery by giving the surgeon better knowledge of the patient's individual anatomy. As a result, this will decrease the incidence of complications.

In this study, ethmoid cell volume was estimated by a semi-automatic, computerized measurement system, which could also measure the volume of paranasal sinuses, nasal cavity and paraseptal structures. This method allows no gap between slices, so volumetric estimation is closer to the real volume. It is, however, time-consuming and has some restrictions. For example, there were problems in delineation of the borders of ethmoid cells, especially at the boundaries adjacent to the superior meatus, fronto-ethmoidal recess and sinus lateralis. In order to overcome these problems, a radiologist and an otolaryngologist worked together to establish consensus on the delineated ethmoid cell borders. In cases of disagreement, the previous coronal slices and saggital reconstructions were examined. Despite these disadvantages, this system is more accurate for paranasal sinus measurements than applying an elipsoid volume calculation formula, which requires only the three dimensions of the ellipsoid:

$$\text{Sinus volume index} = \tfrac{1}{2}\text{A} \times \text{B} \times \text{C}$$

where A = height, B = length and C = width.[14]

The similarity of the total ethmoid cell volume calculations reported in our study and those reported in previous studies supports the accuracy and reliability of our measurement method.

Conclusion

Nasal septal deviation affects the total ethmoid cell volumes of the nasal cavity. In this study, ethmoid cell volume was estimated by a semi-automatic, computerized measurement system. The angle of septal deviation was calculated utilizing a protractor by measuring the angle between the apex of the septal deviation and the plate crossing the anterior nasal spine and crista Galli. The results of our study elucidate the role of ethmoid cell volume in the compensation mechanism equalizing the nasal cavity airflow changes due to NSD, especially when severe (this effect has been previously reported for other paraseptal structural changes).

Studies with larger patient and control groups are needed to eliminate the effect of variations of the total ethmoid cell volumes. Further studies could investigate the consequences of such ethmoid cell volume variation for endoscopic sinus surgery.

- **This study correlates ethmoid cell volume with degree of nasal septal deviation. The authors assessed 40 sinus CT scans from patients with rhinosinusitis**
- **Septal deviation was found to be significantly related to ethmoid volume, with the side of the septal deviation being associated with a smaller ethmoid volume**
- **These findings are relevant in the pre-operative planning of surgery in patients with rhinosinusitis and nasal septal deviation**

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