Eur Arch Otorhinolaryngol (2013) 270:3069–3073
DOI 10.1007/s00405-013-2435-y

RHINOLOGY

The effect of nasal septal deviation on maxillary sinus volumes and development of maxillary sinusitis

Zeliha Kapusuz Gencer · Mahmut Özkırış · Aylin Okur · Seyhan Karaçavuş · Levent Saydam

Received: 7 January 2013 / Accepted: 5 March 2013 / Published online: 20 March 2013

Abstract

Objectives The purpose of this study was to determine the possible role of nasal septal deviation on volume of maxillary sinuses and its relationship with development of maxillary sinusitis.

Materials and methods Between May 2010 and September 2012, paranasal sinus computed tomography (CT) findings of 825 patients (470 males, 355 females), who admitted to Ear Nose and Throat Department of Bozok University Medical Faculty were retrospectively analyzed. By excluding the other co-existent sino nasal pathologies, 109 consecutive patients (47 males, 62 females mean age 36 ± 13.4 years; range 18–71 years) with isolated nasal septal deviations were recruited for the study. The convex side of the septal curvature was accepted as the direction of deviation. The findings were grouped according to the radiologically measured angle of nasal septal deviations. The deviation angle of the nasal septum was described as; mild (<9°), moderate (the angle between 9° and 15°), or severe (15° and up). The volume of each maxillary sinus (ipsi- and contralateral to the deviation side) was also calculated using the computer program. Sinusitis was defined as any evident thickening of the maxillary sinus mucosa.

Results There were 62 females and 47 males with a mean age of 36 ± 13.4. Nasal septal deviation angles were found to range between 5° and 27.2° (mean 13° ± 3.4°). The right sided deviations included 19 mild (<9°, Group I), 16 moderate (9°–15°, Group II), and 16 severe (15° and up, Group III) cases. The left sided deviations included 19 mild (<9°, Group I), 19 moderate (9°–15°, Group II), and 20 severe (15° and up, Group III) subjects. Maxillary sinus volumes were compared between right and left sided deviation groups. We could not demonstrate a statistically significant difference between the right maxillary sinus volumes of Groups I and II in left sided deviation cases ($p = 0.77$). In the same side, comparison of Groups I–III and Groups II–III, the maxillary sinus volume differences were found to be significantly meaningful ($p = 0.001$ and $p = 0.013$, respectively). Identical results were yielded in the right sided septal deviation group related to the maxillary sinus volumes of Groups I and II and Groups I–III and Groups II–III compartments ($p = 0.99$, $p = 0.004$ and $p = 0.003$, respectively). In both right and left deviation groups, ipsi and contralateral maxillary sinus volume comparements produced statistically significant results ($p = 0.002$ and $p = 0.04$, respectively). The presence of maxillary sinusitis findings were significantly increased in both group ($p = 0.00$). Statistical significance was set at $p < 0.05$.

Conclusion Our findings suggest that maxillary sinus volumes tend to be higher at the contralateral side of the severe septum deviations. In addition, the chance of finding maxillary sinusitis findings on ipsilateral to the severe septum deviation was significantly increased.

Keyword Maxillary volume · Maxillary sinusitis · Septum deviation

Z. Kapusuz Gencer (✉) · M. Özkırış · L. Saydam
Department of Otolaryngology, Head and Neck Surgery, Bozok University Medical Faculty, Adnan Menderes Bulvarı No. 42, Yozgat, Turkey
e-mail: mzeliha19@hotmail.com

A. Okur
Department of Radiology, Bozok University Medical Faculty, Yozgat, Turkey

S. Karaçavuş
Department of Nuclear Medicine, Bozok University Medical Faculty, Yozgat, Turkey

Introduction

The maxillary sinuses are contained within the maxillary bone and are situated behind the orbita. The development of the maxillary sinuses begin in the third week of gestation, and continue through early adulthood. The maxillary sinuses develop from the mesodermal structures arising from the first branchial arch [1]. The growth between the ages of three and seven and after 12 years of age, occurs at a slower pace, and lasts until early adulthood. The average volume of maxillary sinus is 15 ml, with the dimensions of 33 mm in height, 23–25 mm in width, and 34 mm in the anteroposterior axis [2].

Textbook descriptions of the morphology of the adult maxillary sinuses address the volume and the degree of pneumatization lateral to the zygoma and inferiorly relative to the nasal floor and maxillary dentition [2].

The most frequently encountered variations in maxillary sinus volume and configuration involve posterior extension toward the zygoma (zygomatic recess), and inferior pneumatization into the dental alveolus about the roots of the posterior teeth, or between them in edentulous areas. Anteriorly, the maxillary sinus does not extend beyond the first premolar tooth, with the canine and incisor teeth positioned below the nasal cavity [3].

The mechanisms for paranasal sinus growth are still poorly understood [4–7]. Some mechanisms are proposed to explain the phenomenon of paranasal cavity development: nasal airflow, brain growth, muscle mass traction and facial structures and, more recently, cell mechanisms (adherence and migration) [4]. The size of the sinus and its anatomic relationships also depend upon the extent of pneumatization [8].

The lack of air flow resulting in low oxygen pressure, interrupts paranasal sinus growth, decreases cilia motility, and consequently favors bacterial growth [9]. Despite the common belief that the difference of volume is related to sinusitis there are only a few studies suggesting the role of nasal septal deviation and maxillary sinus volume in the etiology of sinusitis [8]. The purpose of this study was to determine the role of nasal septal deviation on the volume of maxillary sinuses and possible relationship to maxillary sinus disease.

Materials and methods

Between May 2010 and September 2012, paranasal sinus computed tomography (CT) findings of 825 patients (470 males, 355 females) who admitted to Ear Nose and Throat Department of Bozok University Medical Faculty were retrospectively analyzed. One hundred and nine consecutive patients (47 males, 62 females) mean age 36.7 ± 13.4 years; range 18–71 years) with nasal septal deviations were included to the study. Seven hundred and sixteen subjects with additional co-existent pathologies, such as concha bullosa, sinonasal polyps, tumors or prior sino-nasal surgery which had destroyed the anatomic structures were excluded.

The images were acquired with a 64 slice CT (Philips Medical System, Brillance 64, Best, Netherlands) in the supine position. After scanograms, examinations consisted of 120 kV, 110 mA and images with bone algorithms were performed. Slice thickness was 1 mm with 1 mm increments. The images were evaluated for volumetric analysis at the workstation (Extended Brilliance, Version; 3.5.0.2254, Philips Medical System; Best, The Netherlands) using a multiplanar reformat and volume rendering techniques (VRT). Aeration was calculated in volume–tissue–air mode. CT scans of each patient were evaluated for degree angle of nasal septum deviation, the presence of various bony changes consistent with sinusitis and maxillary volume.

The CT examinations were simultaneously reviewed by a radiologist and an otolaryngologist.

The evidence of mucosal disease on the left and right maxillary sinuses and the direction of septal deviations were assessed separately. Sinusitis was defined as 3 mm or more mucous thickening of the mucosa in the maxillary sinus which was denoted as present or absent. Rak et al. [10] reported abnormal sinusitis were occurred only if 3 mm or more of mucous thickening was present. The direction of deviation was described by the convexity of the septal curvature. The patients were divided into three groups according to the measured angle of nasal septal deviation as: mild (<9°), moderate (9°–15°), or severe (15° and up) (Fig. 1) according to the grading system described by Elahi et al. [11]. The coronal CT image that best correlates with the ostiomeatal complex was utilized fort the calculation of the degree of septal deviation [11]. The volume of each maxillary sinus was also calculated using the computer program described by Apuhan et al. [12] (Fig. 2).

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) 15.0 software package (Version 15, SPSS Inc., Chicago, IL, USA). Parameters were expressed as mean ± SD. Differences between angle degree groups were assessed by ANOVA and Tukey's post hoc test. Left and right maxillary sinus volume parameters were evaluated using paired t test. Pearson's correlation coefficients were used to evaluate the strength of association between deviation and sinusitis parameters and expressed as r^2. Statistical significance was set at $p < 0.05$.

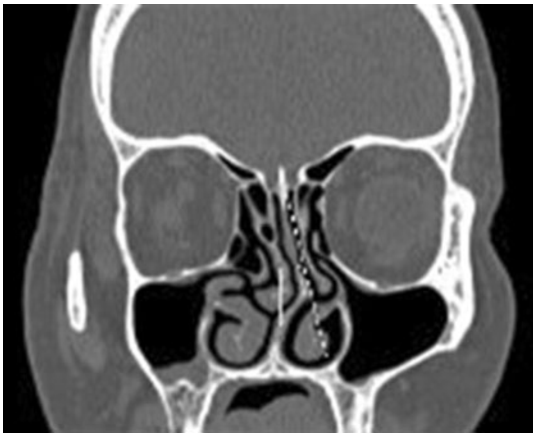

Fig. 1 Coronal paranasal sinus CT image demonstrating technique for measurement of the nasal septal angle

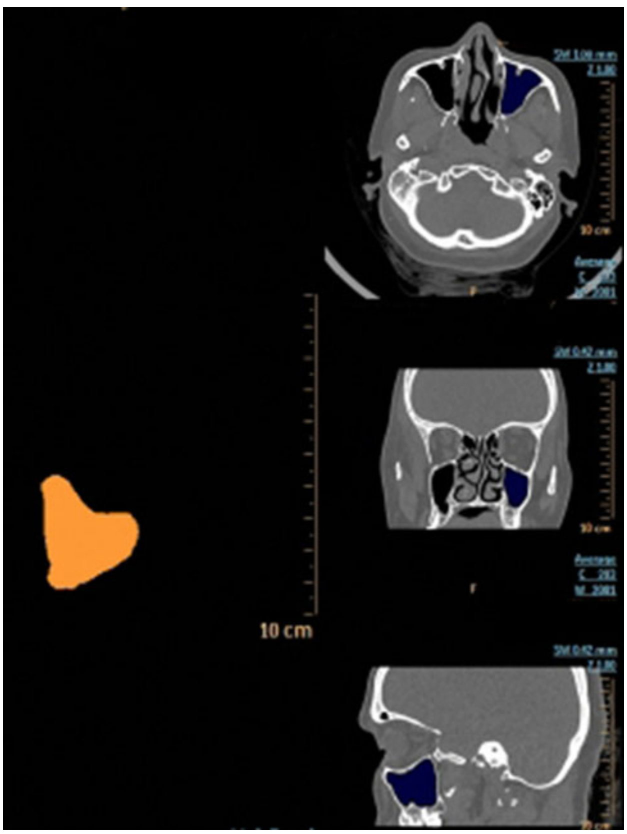

Fig. 2 Three-dimensional (3D; axial–coronal–sagittal planes) reconstruction image of left mastoid air cell. Maksillary sinus aeration volume was calculated automatically at the workstation after volumetric marking using a VRT and tissue characterization program

Results

Nasal septal deviations were towards the right in 51 patients and towards the left in the remaining 58 patients. There were 62 females and 47 males with a mean age of 36 ± 13.4 years. Nasal septal deviation angles were found to range between 5° and 27.2° (mean 13° ± 3.4°). The right sided deviations included 19 mild (<9°, Group I), 16 moderate (9°–15°, Group II), and 16 severe (15° and up, Group III) cases. The left sided deviations included 19 mild (<9°, Group I), 19 moderate (9°–15°, Group II), and 20 severe (15° and up, Group III) subjects.

Maxillary sinus volumes were calculated in both right and left sided deviation groups. In the patients with left sided septal deviations the right maxillary sinus volumes of Groups I, II and III were 13.37 ± 4.18, 13.24 ± 4.49 and 19.23 ± 6.93 cm^3, respectively (Table 1). The statistical evaluation of the right maxillary sinus volumes did not produce significant difference between Groups I and II ($p = 0.77$). We demonstrated statistically significant differences in comparison of Groups I to III and Groups II to III ($p = 0.001$ and $p = 0.013$, respectively) (Table 1).

In the right septal deviation group, mean volumes of left maxillary sinus volumes for Groups I, II and III were 11.49 ± 2.84, 12.46 ± 3.26, 16.78 ± 4.67 cm^3, respectively (Table 3).

There was no statistically significant difference between Groups I and II ($p = 0.99$) left maxillary sinus volumes in the right sided deviation group, but statistically significant difference was demonstrated in Groups I to III and Groups II to III compartments ($p = 0.004$ and $p = 0.003$) (Table 3).

For both right and left sided deviation groups, the comparison of ipsilateral and contralateral maxillary sinus volumes produced statistically significant differences ($p = 0.04$ and $p = 0.002$) (Tables 2, 3, and 4).

The probability to encounter maxillary sinusitis ipsilateral to the all septum deviation groups was significantly increased in both right and left sided subjects ($p = 0.00$) (Table 5). Statistical significance was set at $p < 0.05$.

Discussion

The role of nasal septal deviation in the etiology of sinusitis remains unclear. We have found not much evidence evaluating the relation between the lack of nasal airflow and inflammatory sinus disease. In Proetz's pioneer studies [13] about nasal airflow, he observed that inspiratory air flow does not reach the sinuses ostia, at least not directly, but rather the expiratory flow, already warm, moist and rich in CO_2. Consistent histologic alterations may be found in the paranasal sinuses exposed to nasal airflow, contrary to what happens to those in whom nasal flow was interrupted, in the former they have seen metaplasia of the columnar cuboid epithelium [14].

Nasal septal deviation is reported in 20–31 % of the population and severe deviation has been noted as a contributing factor for sinusitis [15–17]. Hatipoglu et al. [18]

Table 1 Right maxillary volumes in left sided septal deviation cases

	Group I (0°–9°)	Group II (9°–15°)	Group III (15 + °)	Total	*p* I–II	I–III	II–III
N	19	19	20	58			
Mean volume	13.37 +/4.18	13.24 ± 4.49	19.23 ± 6.93	15.35 ± 6.00	0.77	0.001*	0.013*

* $p < 0.05$, *n* number of patient, mean volume = cm^3

Table 2 Right and left maxillary volumes in left sided septal deviation cases

Left septal deviation	Left	Right	*p*
Mean volume	15.35 ± 6.00	12.91 ± 3.87	0.002*

* $p < 0.05$ mean volume = cm^3

found that there was an association between the degree of deviation and the presence of sinusitis. Contrarily in another study reported by Stallman et al. [19], they found that nasal septal deviation of some degree was present in 65 % of the cases and no relationship was present between nasal septal deviation and sinus disease. An experimental study performed by Mogensen and Tos [20], surgically closed side of the nasal cavities did not produce any anatomical change and/or histologic alterations in the maxillary sinus mucosa. By using a similar technique Shin et al [21], reported that anatomical and histologic alterations were demonstrated on obstructed side. In an interesting study performed by Diner et al. [22], the authors used congenital choanal atresia (uni- or bilaterally) as a model of absence of airflow in the nasal passages, they showed in two series (6 and 11 patients) asymmetrical development of the paranasal sinuses in patients with choanal atresia. In our study, while mild and moderate septal deviations lacked any significant affect on maxillary sinus volumes and sinusitis findings, severe deviations were found to have significant impact on these parameters. The contralateral maxillary sinus volumes of the severe septum deviation group were significantly bigger when compared to the ipsilateral maxillary sinus volumes.

Coronal CT scans have dramatically improved the imaging of the nasal cavity and paranasal sinuses. Subtle variations or anomalies of paranasal bony anatomic

Table 4 Right and left maxillary volumes in right sided septal deviation cases

Right septal deviation	Left	Right	*p*
Mean volume	12.49 ± 3.23	14.20 ± 5.13	0.04*

* $p < 0.05$, mean volume = cm^3

Table 5 Right and left maxillary sinusitis

	Left deviation (%)	Right deviation (%)
No sinusitis	9 (15.5)	11 (21.6)
Left maxillary sinusitis	43 (74.1)	0 (0)
Right maxillary sinusitis	0 (0)	28 (54.9)
Bilateral maxillary sinusitis	6 (10.3)	12 (23.5)
Total	58 (100)	51 (100)

structures and mucosal abnormalities can easily be detected with coronal plane CT imaging [23, 24]. Some authors have measured the volume by directly injecting different materials into the paranasal sinuses [25, 26]. However, this procedure cannot be used in living subjects. Furthermore, using such methods usually result in underestimation of the volume in the presence of mucosal thickening and other sinus pathologies [25–27].

The different anatomical dimensions of the paranasal sinuses can be obtained from CT images. Kawarai's [28] report on volume quantification of the paranasal sinuses on three-dimensional CT scans was followed by different studies as this technique has been continuously developed and improved [29, 30]. The mean values of the maxillary sinus volume have been reported to range from 11.1 ± 4.5 to 23.0 ± 6.7 cm^3 in the previous studies [27]. We found the maxillary sinus volumes in our series ranging from 5.1

Table 3 Left maxillary volumes in right septal deviation cases

Deviation angle	Group I (0°–9°)	Group II (9°–15°)	Group III (15+°)	Total	*p* I–II	I–III	II–III
N	19	16	16	51			
Mean volume	11.49 ± 2.8	12.46 ± 3.3	16.78 ± 4.7	13.45 ± 4.7	0.99	0.004*	0.003*

* $p < 0.05$, *n* number of patient, mean volume = cm^3

to 28.2 which were fairly consistent with the literature findings (mean 14.1 $\pm$ 2.5).

The relationship of septal deviation to paranasal sinus disease continues to be debated among otolaryngologist [15–19]. To the best of our knowledge, the relationships between septal deviation and maxillary sinusitis or maxillary sinus volumes have not been previously reported.

Conflict of interest None.

References

1. Wang RG, Jiang SC, Gu R (1994) The cartilaginous nasal capsule and embryonic development of human paranasal sinuses. J Otolaryngol 23:239–243
2. Lawson W, Patel ZM, Lin FY (2008) The Development and pathologic processes that influence maxillary sinus pneumatization. Anat Rec 291:1554–1563
3. Marquez S, Lawson W, Schaefer S, Laitman J (2002) Anatomy of the nasal accessory sinuses. In: Wackym PA, Rice D, Schaefer SD (eds) Minimally invasive surgery of the head, neck, and cranial base. Lippincott, Philadelphia, pp 153–193
4. Kossowska EC, Gasik C (1976) Results of surgical treatment of choanal atresia. Rhinology 17:155–160
5. Legent F, Bordure P, Korb G, Calais C, Beauvillain C (1991) Pneumosinus dilatans: longterm result of modelling osteoplasties. Ann Otolaryngol Chir Cervicofac 108:30–33
6. Libersa C, Laude M, Libersa JC (1980) La pneumatisation de cavités annexes des fosses nasales au cours de la croissance. Anatomica Clinica 2:265–273
7. Shapiro R, Schorr S (1980) A consideration of the systemic factors that influence frontal sinus pneumatization. Invest Radiol 15:191–202
8. Fatua C, Puisorub M, Rotaruc M, Truta AM (2006) Morphometric evaluation of the frontal sinus in relation to age. Trutad Ann Anat 188:275–280
9. Parsons DS, Wald ER (1996) Otitis media and sinusitis: similar diseases. Otolaryngol Clin North Am 29:11–25
10. Rak KM, Newell JD 2nd, Yakes WF, Damiano MA, Luethke JM (1991) Paranasal sinuses on MR images of the brain: significance of mucosal thickening. AJR Am J Roentgenol 156:381–384
11. Elahi MM, Frenkiel S, Fageeh N (1997) Paraseptal structural changes and chronic sinus disease in relation to the deviated septum. J Otolaryngol 26:236–240
12. Apuhan T, Yıldırım YS, Özaslan H (2011) The developmental relation between adenoid tissue and paranasal sinus volumes in 3-dimensional computed tomography assessment. Otolaryngol Head Neck Surg 144:964–971
13. Proetz AW (1951) Air currents in the upper respiratory tract and their clinical importance. Ann Otol Rhinol Laryngol 60:439–467
14. Hilding A (1932) Experimental surgery of the nose and sinuses. 1. Changes in the morphology of the epithelium following variations in ventilation. Arch Otolaryngol 16:9–18
15. Lam WW, Liang EY, Woo JK et al (1996) The etiological role of concha bullosa in chronic sinusitis. Eur Radiol 6:550–552
16. Lebowitz RA, Brunner E, Jacobs JB (1995) The agger nasi cell: radiolog-ical evaluation and endoscopic management in chronic frontal sinusitis operative techniques. Otolaryngol Head Neck Surg 6:171–175
17. Wanamaker H (1996) Role of Haller's cell in headache and sinus disease: a case report. Otolaryngol Head Neck Surg 114:324–327
18. Hatipoglu HG, Cetin MA, Yuksel E (2008) Nasal septal deviation and concha bullosa coexistence: CT evaluation. B-ENT 4:227–232
19. Stallman JS, Lobo JN, Som PM (2004) The incidence of concha bullosa and Its relationship to nasal septal deviation and paranasal sinus disease. AJNR Am J Neuroradiol 25:1613–1618
20. Mogensen C, Tos M (1978) Experimental surgery on the nose airflow and goblet-cell density. Acta Otolaryngol 86:289–297
21. Shin SH, Heo WW (2005) Effects of unilateral naris closure on the nasal and maxillary sinus mucosa in rabbit. Auris Nasus Larynx 32:139–143
22. Diner PA, Andrieu-Guitrancourt J, Dehesdin D (1986) Unilateral congenital choanal atresia and maxillary sinus development. J Maxillofac Surg 14:285–288
23. Bolger WE, Butzin CA, Parsons DS (1991) Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope 101:56–64
24. Zinreich SJ, Kennedy DW, Rosenbaum AE, Gayler BW, Kumar AJ, Stammberger H (1987) Paranasal sinuses: CT imaging requirements for endoscopic surgery. Radiology 163:769–775
25. Schumacher GH, Heyne HJ, Fanghanel R (1972) Anatomy of the human paranasal sinuses. 2. Volumetric measurement. Anat Anz 130:143–157
26. Uchida Y, Goto M, Katsuki T, Akiyoshi T (1998) A cadaveric study of maxillary sinus size as an aid in bone grafting of the maxillary sinus floor. J Oral Maxillofac Surg 56:1158–1163
27. Pirner S, Tingelhoff K, Wagner I, Westphal R, Rilk M, Wahl FM, Bootz F, Eichhorn KW (2009) CT-based manual segmentation and evaluation of paranasal sinuses. Eur Arch Otorhinolaryngol 266:507–518
28. Kawarai Y, Fukushima K, Ogawa T, Nishizaki K, Gunduz M, Fujimoto M, Masuda Y (1999) Volume quantification of healthy paranasal cavity by threedimensional CT imaging. Acta Otolaryngol Suppl 540:45–49
29. Sanchez Fernandez JM, Anta Escuredo JA, Sanchez Del Rey A, Santaolalla Montoya F (2000) Morphometric study of the paranasal sinuses in normal and pathological conditions. Acta Otolaryngol 120:273–278
30. Emirzeoglu M, Sahin B, Bilgic S, Celebi M, Uzun A (2007) Volumetric evaluation of the paranasal sinuses in normal subjects using computer tomography images: a stereological study. Auris Nasus Larynx 34:191–195