Nasal cavity and paranasal sinus bony variations: a computed tomographic study*

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SUMMARY *Variations of the nasal cavity are very important for the otolaryngologist in functional endoscopic sinus surgery. To provide data on bony variations of this region, we performed high resolution computed tomography images of paranasal sinuses on 82 adult patients without sinus pathology and on 90 adult patients with sinus disease. We observed paradoxical curvature of the middle concha in 11 (12.22%) sinus patients and 6 (7.31%) in non-sinus patients. Concha bullosa was observed in 26 sinus patients (28.88%) and 22 (26.83%) in non-sinus patients, deviated nasal septum in 20 (22.22%) sinus and 10 (12%) non-sinus, Haller's cell in 5 (5.55%) sinus and in 3 (3.65%) non-sinus, agger nasi cell in 7 (7.77%) sinus and 4 (4.88%) non-sinus patients. Pneumatisation of cristae galli was observed in 8 (8.88%) sinus and 2 (2.44%) non-sinus, of the anterior clinoid process in 5 (5.55%) sinus and 1 (1.22%) non-sinus patients, pneumatisation of the nasal septum in 7 (7.77%) and of the pterygoid recess in 12 (13.33%) sinus patients. We did not find any correlation between age intervals and paranasal sinus variations, and also no statistically significant difference was observed between males and females. These data provide very important information to guide the otolaryngologist and/or radiologist in the evaluation of patients with coronal CT which guides functional endoscopic sinus surgery.*

Key words: bony, CT, nasal cavity, paranasal sinus, variation

INTRODUCTION

Functional endoscopic sinus surgery has become of particular importance for the otolaryngologist and is preferred for the treatment of nonneoplastic pathologies of paranasal sinuses, especially for chronic infective and polypoid sinusitis (Meloni et al., 1995). With this technique, it is possible to open the obstructed ostia of paranasal sinuses to provide normal ventilation without damaging the adjacent structures (Kennedy et al., 1988). Clear understanding of sinonasal anatomy and anatomic variants provides a better surgical approach in this constricted and vital area. This makes computed tomography (CT) an important preoperative test and also complementary in the diagnosis and treatment of nasal cavity and paranasal sinus diseases. Plain radiographics are of little value for functional endoscopic sinus surgery because sinus walls are obscured by overlying structures. It is possible to detect bony variations and mucosal abnormalities of paranasal sinuses with CT, clearly visualizing anatomic variations of the bone which have been reported as factors contributing to recurrent and chronic sinusitis. Especially, the convoluted anatomy of the ethmoid cells does not provide endoscopic evaluation of deeper ostiomeatal, posterior ethmoid, and sphenoid sinus diseases, where coronal and axial CT provide detailed information (Zinreich et al., 1987). Osborn et al. utilized direct sagittal scanning in examination of face and paranasal sinuses, but they did not find it as valuable as coronal and axial CT scans (Osborn et al., 1978). For sinonasal tumors, CT and magnetic resonance imaging are complementary. CT provides bony detail and anatomic landmarks at the skull base, whereas magnetic resonance imaging is superior in mapping the extent of the tumor and differentiating it from adjacent inflammation (Rao and El-Noueam, 1988). Intraoperative three-dimensional computed tomography is also very useful in functional endoscopic sinus surgery especially when the anatomy is distorted or obscured (Roth et al., 1995). This study presents normal anatomy and variational radiographic anatomy of the adult nasal cavity, concentrating on variations significant for functional endoscopic sinus surgery, to provide a better surgical approach, and avoid operative complications due to the anatomic variations.

Anatomic variants

1. Frontal sinus variants

The frontal sinus divided into a number of communicating recesses by incomplete septa, agenesis of the frontal sinus, one sinus overlapping in front of the other, or extending posteriorly

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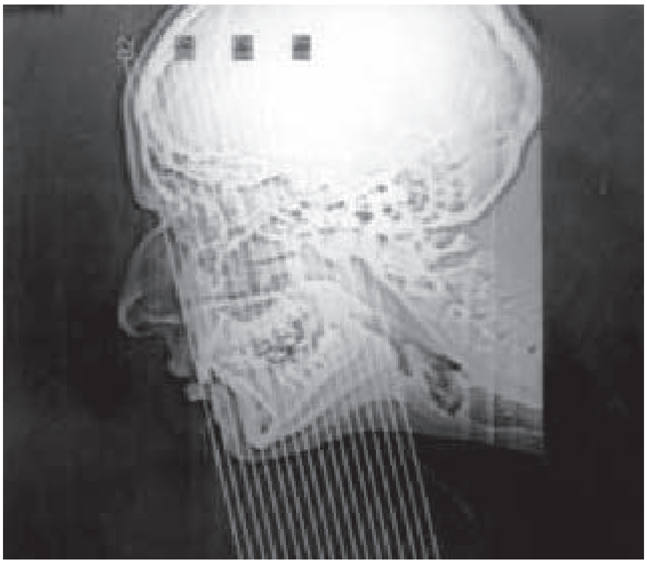

Figure 1. Coronal CT scanning of the nasal cavity.

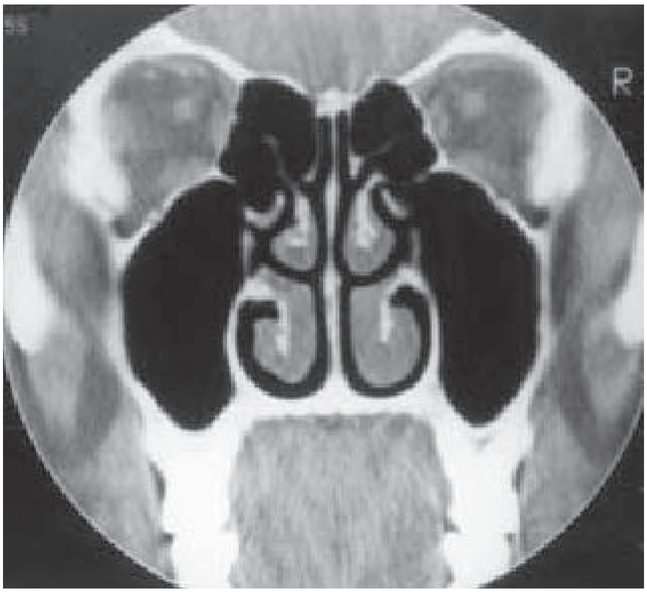

Figure 2. Normal anatomy of the nasal cavity as seen on CT.

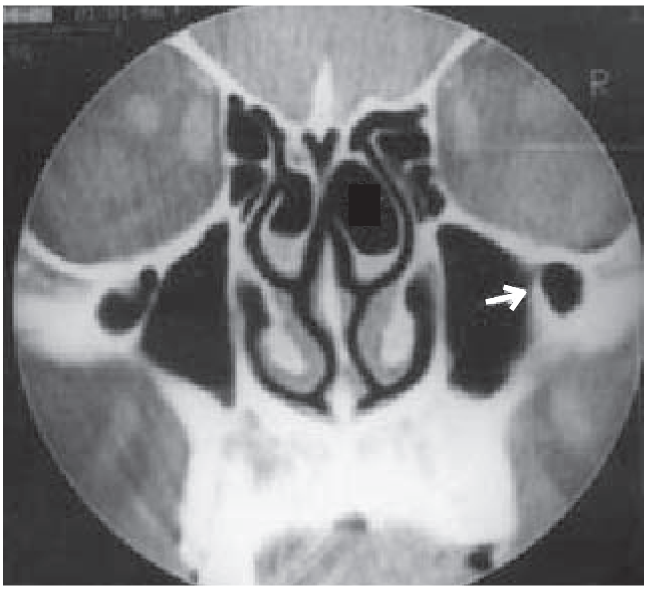

Figure 3. Bilateral septation in the maxillary sinus.

as far as the lesser wing of the sphenoid bone are variants of the frontal sinus (Williams et al., 1995).

2. Ethmoid sinus variants

Variations of the ethmoid sinus are cells arising from the superior nasal meatus and from the supreme nasal meatus, postremal ethmoidal cells, agenesis of the posterior ethmoidal cells, dehiscence due to extensive pneumatisation, rarefaction and prominent ethmoid bulla (Lang, 1989). The ethmoid bulla may be fused with the uncinate process, then the duct of the frontal sinus opens into the middle meatus medial to the blind end of the infundibulum (Williams et al., 1995). Haller's cell is the pneumatisation of the anterior ethmoid cells into the roof of the maxillary sinus and extending into the floor of the orbit. *Agger nasi cells* are the most constant ethmoidal air cells located in the anterior floor of the frontal sinus. *Pneumatisation of the uncinate process* is supposed to be related to ostiomeatal obstruction, narrowing of the infundibulum and producing impaired sinus ventilation (Zinreich et al., 1987). Deviation of the uncinate process and atelectatic uncinate process adherent to the inferomedial orbit are also variants of the uncinate process (Laine and Smoker, 1992; Rao and El-Noueam, 1998).

3. Maxillary sinus variants

Maxillary sinus septation, duplication, rudimentation and complete agenesis are anatomic variants of the maxillary sinus (Lang, 1989).

4. Sphenoid sinus variants

Dehiscence in the bony wall between the carotid arteries and sphenoid sinus, deviated septum or accessory septa, posterosuperior ethmoidal cells lying within the sphenoid bone, intercommunication of right-left sinuses or one side of a sinus overlapping the other, complete agenesis or rudimentation are variants of the sphenoid sinus (Lang, 1989; Rao and El-Noueam, 1998).

5. Variations of the conchae

Conchae normally bend medially toward the nasal septum. If they bend in the reverse from the usual direction, this is called 'paradoxical curvature'. This can be observed for the superior, middle and inferior conchae (Lang, 1989). *Paradoxical curvature of the middle concha (turbinate)* may lead to impingement of the middle meatus and thus to sinusitis. Other variations of the middle nasal concha are extreme furrow formation observed as grooves and lobules on the middle concha, absence of the concha or bony bridges between the posterior ends of the middle and inferior conchae. Extensive pneumatisation of the middle concha is termed 'concha bullosa'. This is a common variant of intranasal anatomy and with the development of coronal CT, it is possible to note even a very small pneumatisation.

6. Nasal septal variants

Septal deviations may be cartilaginous, cartilaginous-bony type, or a combination of both. Severe deviated nasal septum results in compression of the middle turbinate and causing an obstruc-

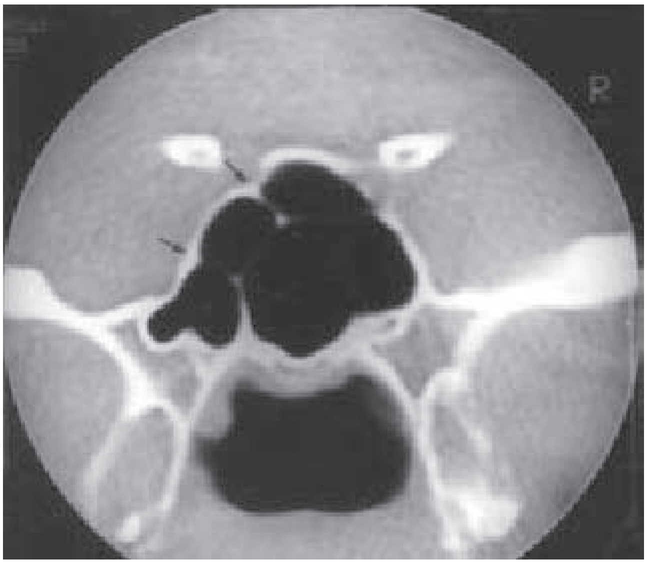

Figure 4. Multiseptation of the sphenoid sinus.

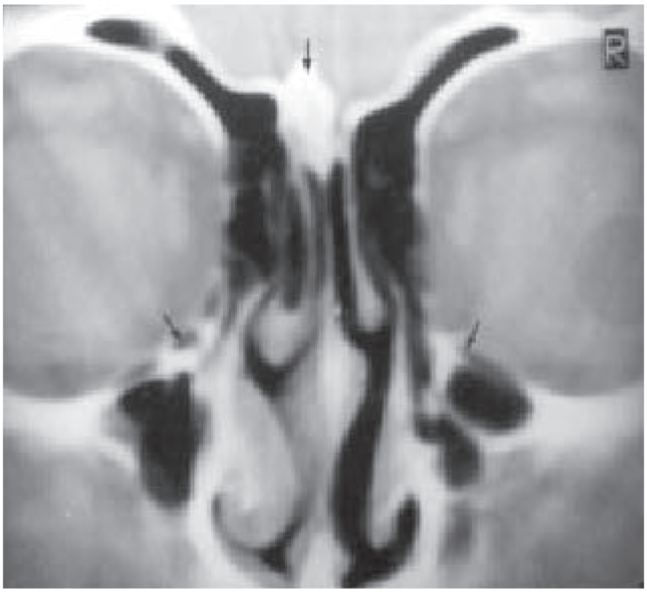

Figure 5. Pneumatisation of crista galli and septum deviation.

Figure 6. Bilateral Haller's cell.

tion in the normal mucus flow, thus resulting in a secondary inflammation and infection. Absence of the posterior part of the nasal septum, pneumatisation or aplasia of the nasal septum are also other variants of the nasal septum (Lang, 1989).

MATERIAL AND METHODS

High resolution CT images of paranasal sinuses were obtained through a period of six months and analyzed retrospectively from 82 patients undergoing CT for non-sinus reasons (e.g. ophthalmologic diseases) (mean age 36.45; range 19-65; 42 males, 40 females) and 90 patients for the evaluation of symptomatic sinus disease (mean age 34.7 years; range 18-69 years; 43 males, 47 females). The sinus patients were suffering from fever, chills, headache, and rhinorrhea. We performed coronal CT scanning in 160 and axial scanning in 12 patients with cervical arthrosis to provide better sinus visualization. Six patients received topical anticongestant drug therapy before CT examination to provide better sinus aeration. Sinus patients were scanned when they were clinically well, between bouts of sinusitis. The patients were not subjected to any trauma, carcinoma, papilloma or surgery that might result in alteration of paranasal sinus anatomy.

CT examinations were performed with a Philips Tomoscan CX unit (Shelton, Conn.; 20 KV, 150 mA, 2.8 sec) set for 3 mm contiguous slices. We scanned the area starting from glabella to dorsum sellae. Coronal images were done with the patient in prone (neck extended) position (Figure 1). A normal coronal CT scan of the nasal cavity and paranasal sinuses is shown in Figure 2. Axial images were taken perpendicular to the infraorbitomeatal line. All images were evaluated by the same radiologist who was informed about the clinical pre-diagnosis.

Males and females were divided separately into 5 sub-groups according to their age (age subgroups: 18-20, 30-40, 40-50, 50-60 and 60-70). Variance analysis was made for comparison of incidences of variations for sinus and non-sinus patients for age and sex sub-groups.

RESULTS

From the 90 patients evaluated for sinus reasons, radiological features of sinusitis were observed in 79 (87.77%) patients, such as air-fluid levels in a sinus, which usually correlates with acute sinusitis, mucosal thickening which is notoriously interpreted as chronic sinusitis, polypoid thickening, and areas of atrophy and fibrosis. Nasal polip of the maxillary sinus was observed in 4 (4.44%), antro-choanal polip in 2 (2.22 %), osteom of the frontal sinus in 3 (3.33%) and of the ethmoid sinus in 2 patients (2.22%). Concha hypertrophy was observed in 56 (62.22%) patients. Mucosal thickening up to 2-3 mm in the nasal cavity is accepted as normal as a part of the nasal cavity. Thickness over 5 mm was accepted as mucosal thickening and was observed in 34 patients (37.78%). We noted retention in the maxillary sinus of 13 patients (14.44%), and in the frontal sinus of 2 patient (2.22%). Obliteration of the osteomeatal complex was also observed in 5 patients (5.55%). Hypoplasy in the maxillary sinus was observed in 2 (2.22%), unilateral rudimentation of the frontal sinus in 1 (1.11%), multiseptated sphenoid sinus in 1 (1.11%) and bilateral

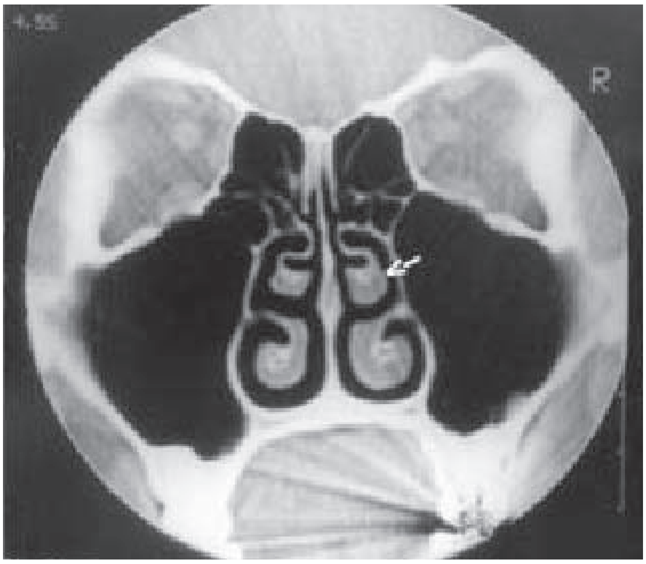

Figure 7. Bilateral paradoxical curvature of the middle turbinate.

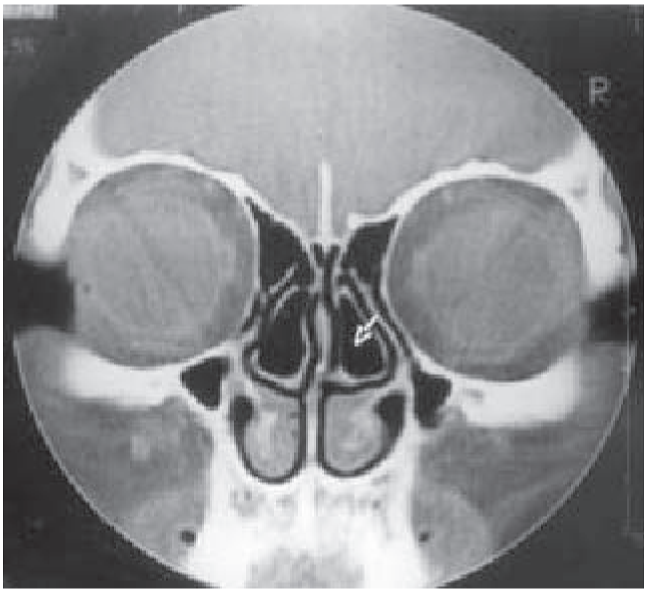

Figure 8. Bilateral concha bullosa.

septation of the maxillary sinus were observed in 2 (2.22%) patients (Figures 3-4). We did not observe any of these features in our non-sinus patients

Pneumatisation of cristae galli was observed in 8 (8.88%; 5 males and 3 females), of the pterygoid recess in 12 (13.33%; 6 males and 6 females) and of the anterior clinoid process in 5 (5.55%; 3 males, 2 females) sinus patients (Figure 5). All sinus patients with pneumatisation in the anterior clinoid process had also pneumatisation in the pterygoid recess. We observed pneumatisation of the nasal septum in 7 sinus patients (7.77%; 2 males, 5 females), 4 of them in the posterior segment (4.44%). Hyperpneumatisation was present in the ethmoid sinus of 2 (2.22%; 1 male, 1 female), and in the frontal sinus of 8 sinus patients (8.88%; 5 males, 3 females). We observed pneumatisation of the anterior clinoid process in 1 (1.22%; 1 female) and of crista galli in 2 (2.44%; 2 males), non-sinus patients.

Deviated nasal septum was observed in 20 (22.22%; 11 males, 9 females), deviated uncinate process in 2 (2.22%; 1 male, 1 female), Haller's cell in 5 (5.55%; 3 males, 2 females) and agger nasi cell in 7 (7.77%; 3 males, 4 females) sinus patients (Figures 5-6). In non-sinus patients, deviated nasal septum was observed in 10 (12%; 5 males, 5 females), Haller's cell in 3 (3.65%; 2 males, 3 females), agger nasi cell in 4 (4.88%; 2 males, 2 females) patients.

We observed paradoxical curvature of the middle concha in 11 (12.22%; 6 males, 5 females) sinus patients and 6 (7.31%; 3 males, 3 females) non-sinus patients (Figure 7).

Concha bullosa was observed in 26 sinus patients (28.88%; 12 females, 14 males), 11 of the conchae bullosae (42.3%; 6 males, 5 females) were bilateral and 15 (57.7%; 8 males and 7 females) unilateral (Figure 8). Many anatomic variations were observed in our patients with conchae bullosae. In sinus patients, we observed paradoxical curvature of the middle concha in 6 (23.07%; 3 males, 3 females), septum deviation in 7 (26.92%; 3 males, 4 females), Haller's cell in 1 (3.84%; 1 female), agger nasi cell in 2 (7.69%; 2 females), septum pneumatisation in 2 (7.69%; 1 male, 1 female), bilateral pneumatisation of the anterior clinoid process in 3 (11.53%; 1 male, 2 females), pneumatisation of crista galli in 1 (3.84%; 1 female) and pneumatisation of the pterygoid recess in 2 (7.69%; 1 male, 1 female) patients. Retention cyst in the maxillary sinus was also observed in 7 (26.92%; 4 males, 3 females) of our patients with concha bullosa. In non-sinus patients, concha bullosa was observed in 22 patients (26.8%; 13 males, 9 females), 4 (18%) of these were bilateral and 18 (82%) unilateral. In this group, we observed paradoxical curvature of the middle concha in 5 (23%; 3 males and 2 females), septum deviation in 3 (14%; 2 males and 1 female), Hallers cell in 1 (4.5%; 1 male) and septum pneumatisation in 1 (4.5%; 1 female) patients.

We did not find any correlation between age intervals and paranasal sinus variations, and also no statistically significant difference was observed between males and females.

DISCUSSION

Agger nasi cells are located in the anterior floor of the frontal sinus, on the drainage pathway of the frontal sinus, and therefore are possibly involved in recurrent or chronic frontal sinusitis. The prevalence of agger nasi cell varies widely among investigators due to its anatomic definition. We accepted the cells on the lateral wall of the nasal cavity at the level of hiatus semilunaris as agger nasi cells, whereas Zinreich et al. describe agger nasi cell as an air chamber below the frontal sinus which extends to the frontal recess superiorly and reaches the lacrimal fossa inferiolaterally and is arched anteriorly by the nasal bones (Zinreich et al., 1988). We observed agger nasi cell in 7 (7.77%) sinus patients and in 4 (4.88%) non-sinus patients. The comparison of our results with the literature is presented in Table 1. Schaefer et al., reported an incidence of 10% while van Alyea had observed an incidence of 89% in their series of anatomic dissections (Van Alyea, 1939; Schaefer et al., 1989). During endoscopy these cells provide access to the frontal sinus and recess. Due to the close relationship of agger nasi cells with the lacrimal sac and orbit, sinus disease in these cells may lead to ocular symptoms.

Table 1. Incidence of Agger nasi cell, Haller's cell, concha bullosa and paradoxical curvature of the middle concha in sinus and non-sinus patients.

	Agger nasi cell		Haller's cell		Concha bullosa		Paradoxical curvature of the middle concha	
	sinus	non-sinus	sinus	non-sinus	sinus	non-sinus	sinus	non-sinus
Messerklinger, 1967	10-15%	-	-	-	34%	-	-	-
Goldman, 1987	-	-	-	-	-	80%	-	-
Kennedy and Zinreich, 1998	100%	-	10%	-	-	-	-	-
Bolger, 1991	98.5%	-	45.9%	-	53%	-	26.1%	-
Calhoun, 1991	-	-	-	-	29%	-	12%	-
Lloyd et al., 1991	3%	-	15%	-	24%	-	15%	-
Meloni, 1992	-	-	10%	-	21%	-	-	-
Earwaker, 1993	-	-	20%	-	-	-	25%	-
Kösling, 1993	23.6%	-	23.6%	-	23.6%	-	13.3%	-
Tonai and Baba, 1996	86%	88.9%	33.3%	38.9%	28.1%	27.8%	29.8%	11.1%
Kayalioglu et al., 1999	7.77%	4.88%	5.5%	3.65%	28.88%	26.83%	12.22%	7.31%

Haller's cell is the pneumatisation of the anterior ethmoid cells into the roof of the maxillary sinus extending into the floor of the orbit. We accepted the ethmoid cells adjacent to the roof of the maxillary sinus roof as Haller's cells, and found an incidence of 5.55% in sinus patients and 3 (3.65%) in non-sinus patients (Figure 6). Bolger et al. defined Haller's cell as any cell located beneath the ethmoid bulla, lamina papyracea or orbital floor and observed Haller's cells in 45.9% of sinus patients (Bolger et al., 1991). Kennedy and Zinreich defined Haller's cell as ethmoid cells that project inferiorly to the ethmoidal bulla into the floor of the orbit, they observed Haller's cells in 10% of their patients with chronic sinus complaints (Kennedy and Zinreich, 1988). The incidence of Haller's cell in studies of Bolger, Kennedy and Zinreich, Tonai and Baba, Kösling et al., Earwaker, Lloyd, Meloni et al., are presented in Table 1. It is important to recognize Haller's cells because they may narrow the ostium of the maxillary sinus or the ethmoid infundibulum. Stammberger and Wolf consider the presence of these cells a predisposing factor for recurrent maxillary sinusitis (Stammberger and Wolf, 1988).

Concha bullosa: Extensive pneumatisation of the middle concha is termed 'concha bullosa'. This is a common variant of intranasal anatomy and with the development of coronal CT it is possible to note even a very small pneumatisation. Zinreich et al. report that conchae bullosae are best diagnosed radiographically and easily identified with CT. The appearance is that of an air space of the middle concha surrounded by an oval bony rim (Zinreich et al., 1988). Bolger et al., reported this pneumatisation in 53% of the sinus patients, as an extension of the anterior air cells (55%) or posterior (45%) ethmoidal air cells. The highest incidence of 80% was found in the study of Goldman in patients with chronic sinusitis on resected middle concha materials (Goldman, 1987). Zinreich et al., observed concha bullosa in 34% of their patients having CT for evaluation of symptomatic sinus disease, 34 of these (45%) were bilateral and 44 (55%) were unilateral (Zinreich et al., 1988). The results of studies of Calhoun et al., Lloyd et al., Kösling et al., Meloni et al., are presented in Table 1. We observed concha bullosa in 26 (28.88%) of our sinus patients and 22 (26.83%) of our non-sinus patients. Eleven of these (42.3%) were bilateral and 15 (57.7%) were unilateral (Figure 8). These discrepancies in the incidence may depend on the criteria of pneumatisation of different researchers and on the method of analysis. Some researchers accept very small and physiologically insignificant conchae as conchae bullosae. Also, the incidence depends on the patients group, as some studies including ours are performed on patients with sinusitis. Tonai and Baba reported a higher of 28.1% in chronic sinus patients, when compared to an incidence of 27.8% in non-sinus patients (Tonai and Baba, 1996). Zinreich et al., and Stammberger et al., report concha bullosa as a possible etiologic factor in recurrent sinusitis due to its negative influence on paranasal sinus ventilation and mucociliary clearance (Stammberger et al., 1988; Zinreich et al., 1988). Zinreich et al., reported many patients with concha bullosa had additional anatomic variations: nasal septal deviation in 28%, Haller's cell in 7%, prominent ethmoid bulla in 6% and paradoxical curvature of the middle concha in 6% (Zinreich et al., 1988). Similarly, in our patients with conchae bullosae, we observed paradoxical curvature of the middle conchae in 6 (23.07%), septum deviation in 7 (26.92%), Haller's cell in 1 (3.84%), agger nasi cell in 2 (7.69%), septum pneumatisation in 2 (7.69%), of crista galli in 1 (7.69%), bilateral pneumatisation of the anterior clinoid process in 3 (11.53%), and pneumatisation of the pterygoid recess in 2 (7.69%) patients. Retention cyst in the maxillary sinus was also observed in 7 (26.92%) of our patients with concha bullosa.

Pneumatisation of the uncinate process is supposed to be related to ostiomeatal obstruction, narrowing of the infundibulum and producing impaired sinus ventilation (Zinreich et al., 1987). Bolger et al., proposed that this pneumatisation is due to the growth of agger nasi cells into the uncinate process (Bolger et al., 1991). We did not observe any pneumatized uncinate process in our series consistent with the findings of Tonai and Baba (Tonai and Baba, 1996). Bolger et al. report its prevalence as 2.5% in sinus patients and Kennedy and Zinreich as 0.4% in patients with chronic sinus complaints (Kennedy et al., 1988; Bolger et al., 1991).

Paradoxical curvature of the middle concha: Stammberger and Wolf accept paradoxical curvature of the middle concha as an etiologic factor because it may cause obliteration or alteration in nasal air flow dynamics (Stammberger and Wolf, 1988). We observed it in 12.22% of our sinus and 6 (7.31%) of our non-sinus patients (Figure 7). Comparison of the literature is presented in Table 1.

Deviated nasal septum: Severe deviated nasal septum results in compression of the middle turbinate and narrowing of the middle meatus. This results in obstruction of the normal mucus flow from the sinuses and secondary inflammation and infection. We observed septum deviation in 20 patients (22.22%) in sinus and 10 (12%) non-sinus patients (Figure 5). Blaugrund reports the incidence of nasal septum deviation as 20% (Blaugrund, 1989).

In this study, we observed paradoxical curvature of the middle concha, concha bullosa, deviated nasal septum, Haller's cell, agger nasi cell, pneumatisation of cristae galli, of the pterygoid recess, of the anterior clinoid process and of the nasal septum as common variants of nasal anatomy. We observed a wide range in the literature for the incidence of variations. This depended sometimes on the description of the variation as in Haller's cell and agger nasi cell and concha bullosa, or on the group of patients studied. The incidence of variations in the literature was higher in sinus patients when compared to that in non-sinus patients, because these variations usually predispose sinus diseases. It is also possible that the incidences may vary due to the ethnic differences of the populations studied. There was no correlation between age intervals and paranasal sinus variations, and also no statistically significant difference between sexes. It was not possible for us to compare these results with former studies, because they do not include this information.

This study provides numerous variations of the nasal cavity for the otolaryngologist to be a guide for the most accurate information in therapeutic decisions and also to be a guide for the otolaryngologist and/or radiologist in the evaluation with coronal CT which provides easy identification of the intricate anatomy, complements endoscopic examination and guides functional endoscopic sinus surgery.

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