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Anatomical variations in the human paranasal sinus region studied by CT

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ABSTRACT

A precise knowledge of the anatomy of the paranasal sinuses is essential for the clinician. Conventional radiology does not permit a detailed study of the nasal cavity and paranasal sinuses, and has now largely been replaced by computerised tomographic (CT) imaging. This gives an applied anatomical view of the region and the anatomical variants that are very often found. The detection of these variants to prevent potential hazards is essential for the use of current of endoscopic surgery on the sinuses. In the present work, we have studied the anatomical variants observed in the nasal fossae and paranasal sinuses in 110 Spanish subjects, using CT in the coronal plane, complemented by horizontal views. We have concentrated on the variants of the nasal septum, middle nasal concha, ethmoid unciform process and ethmoid bulla, together with others of lesser frequency. The population studied showed great anatomical variability, and a high percentage (67%) presented one or more anatomical variants. Discounting agger nasi air cells and asymmetry of both cavities of the sphenoidal sinus, which were present in all our cases, the variations most often observed were, in order, deviation of the nasal septum, the presence of a concha bullosa, bony spurs of the nasal septum and Onodi air cells.

Key words: CT imaging; nasal cavity; paranasal sinuses.

INTRODUCTION

The nasal fossae and paranasal sinuses constitute an anatomical and functional unit. Covered by the same mucosa, the paranasal sinuses communicate with the nasal cavities via small openings and narrow ducts that allow both aeration and sinus drainage.

Because of structural superimposition, conventional radiology does not allow precise exploration of the region, especially of the anterior ethmoidal air cells, the frontal recess, and the upper two thirds of the nasal cavities (Meschan, 1951), zones closely related to sinus physiopathology, and therefore interesting from the point of view of applied anatomy. The revolutionary changes in the surgical treatment of sinusitis in recent years, particularly in endonasal endoscopic surgery, require the clinician to have a precise knowledge of nasal sinus anatomy and of the large number of anatomical variants in the region, many of which are detectable only by the use of CT (Bolger et al. 1991).

MATERIALS AND METHODS

The study comprised 110 CTs of the nasal sinus region, in patients suspected of inflammatory sinus pathology. They were explored in the Radiodiagnostic Service of the National Health Hospital, Jerez de la Frontera, Spain. Of the patients, 57 were males and 53 females, age range 20–70 y. For the tomographic study, a Sytec 3000 (General Electric Medical Systems) CT scanner was used, yielding extremely precise high-resolution reconstructions of the anatomical structures studied. In all cases, systematic studies of the nasal sinus region were performed in frontal or coronal and in horizontal scans. Taking the hard palate as reference axis, in the coronal study the plane of section was perpendicular to this structure.

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Direct scans 3 mm in thickness were made, from the anterior walls of the frontal sinuses to the posterior wall of the sphenoid sinus.

For the axial scans, which were 5 mm thick, the orbitomeatal line was taken as reference. Parallel scans were made upwards from the upper dental arch to the roof of the frontal sinuses. Radiological investigation of anatomical variants was performed both using a soft parts window and a bone density window. Selected scans were chosen for photography. In all cases, the existence of the following variants was investigated: (1) nasal septum: septal deviation, septal bony spur, deformity of the chondrovomerine articulation; (2) middle nasal concha: concha bullosa, paradoxical (false) middle concha, hypoplasia, and secondary middle concha; (3) ethmoid uncinate process: deviation of the upper edge, pneumatisation; (4) ethmoid air cells: agger nasi cells, Haller cells, great ethmoid bulla, Onodi cells (extramural sphenoid cells); (5) other variants: hypoplasia of the maxillary sinus and asymmmetry of both cavities of the sphenoid sinus.

The scans were assessed by 2 independent observers. In cases of marked discrepancy between them a third observer participated in the discussion to obtain an agreed decision.

RESULTS

There was high concordance between anatomical variants detected by each of the 2 observers. Less than 10 % of the cases required the participation of the third observer to discuss and adopt a final resolution which in all cases was reached unanimously.

In all cases studied, we observed the existence of agger nasi cells (Fig. 1*a*) and asymmetry of the sphenoid cavities corresponding to the sphenoid sinus, so that we have not considered them as anatomical variants. Of the 110 cases studied, 74 (67 %) presented some anatomical variant and, in many, more than one variant was present in the same subject.

In absolute percentage terms, the highest degree of variability was for the nasal septum (55 %), followed by the middle nasal concha (25 %), the ethmoidal air cells (10 %), the ethmoidal uncinate process (4 %), and other sites (6 %).

Nasal septum

We detected 80 variants at this site. Most were nontraumatic deviations of the septum (64 cases, 80 %); the numbers of left and rightward (Fig. 1*b*) deviations were similar, with a slight predominance of the former. We included in this group any visually detectable nasal deviation from the midline. The rest of the variants found were septal bony spurs (15 cases, 18 %; Fig. 1*c*) and deformity in the chondrovomerine articulation (5 cases, 2 %).

Middle nasal concha

The middle nasal concha is normally a flat bone. When it becomes pneumatised by extension of anterior ethmoid cells or, less frequently, posterior ones, it is referred to as concha bullosa (Bolger et al. 1991). The true concha bullosa is produced following pneumatisation of both portions (vertical lamina and inferior bulb) of the middle nasal concha. With this criterion, a concha bullosa (Fig. 1*d*) was detected in 27 of 37 cases (73 %) showing any anatomical variant of the middle nasal concha. Of these, in 11 cases it appeared only on the left side (Figs 1*d*, 2*c*), in 10 only on the right and in 6 was bilateral.The other variant found was the presence of a paradoxical or false middle concha (11 cases, 27 %). On 9 occasions, this appeared on the right side (Fig. 2*a*), against 1 on the left; 1 case was bilateral. In our series, there were no instances of a hypoplasic middle concha or of a secondary middle concha.

Uncinate process of the ethmoid bone

All 5 variants at this site were a deviation of its upper edge. In 3 cases, the deviation was bilateral, while it appeared only on the right or the left sides in 1 case each. No example of pneumatisation was observed.

Ethmoid sinuses

Of the 15 variants observed, 12 (80 %) were the so-called Onodi air cells (Fig. 2*b*), while the 3 remaining cases (20 %) showed the presence of Haller air cells (Fig. 2*c*). No cases with a great ethmoidal bulla were encountered. The criterion for the existence of this variant was the presence of a detectable obstruction of the middle nasal meatus and especially of the ethmoidal infundibulum provoked by a strong development of the ethmoidal bulla (Zinreich, 1993).

Other sites

In 7 cases hypoplasia of the maxillary sinus were detected. A hypoplasic sinus shows a much thicker anterior wall than normal and the pterygoid plates

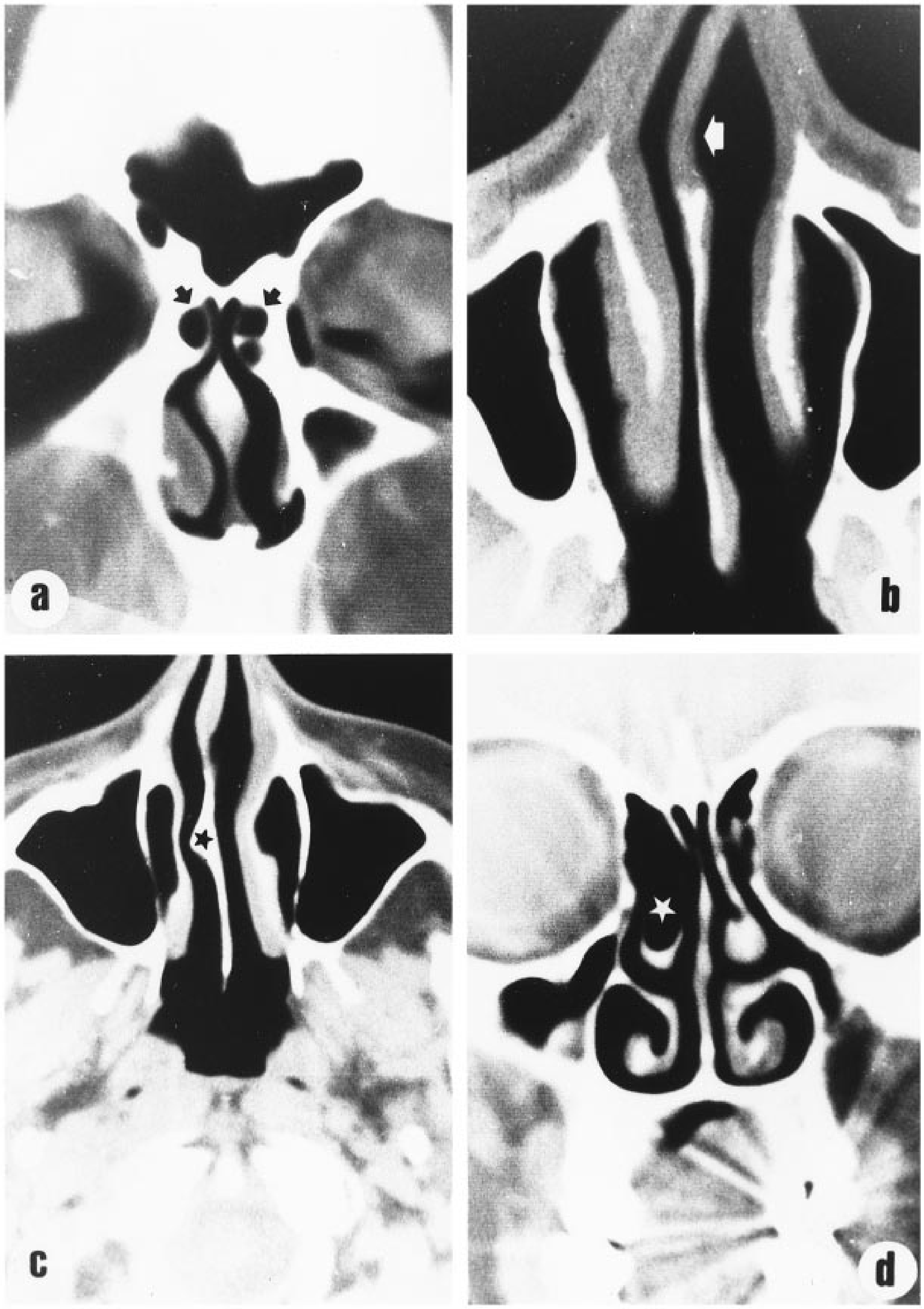

Fig. 1. CT images of some of the nasal sinus anatomical variants observed. (*a*) Coronal scan; agger nasi air cells (arrows); (*b*) horizontal scan; deviation of the nasal septum (arrow); (*c*) horizontal can; bony spur of the nasal septum (black star); (*d*) coronal scan; concha bullosa (white star).

posteriorly have an abnormal lateral angulation. Additionally, the medial wall of the sinus is characteristically laterally placed and there is an inferior displacement of the orbital floor (Mancuso & Hanafee, 1982). The hypoplasia was bilateral in 1 case, and in the remainder it was found equally on the right (3 cases; Fig. 2*d*) and the left (3 cases). The uncinate process was absent in 2 cases (Fig. 2*d*).

DISCUSSION

We agree with Chow & Mafee (1989) that, when performed with the appropriate technique, an anatomical study of the paranasal sinuses by CT in a frontal plane is more informative than in the transverse plane. Moreover, frontal CT shows the anatomical structures progressively, much as a surgeon

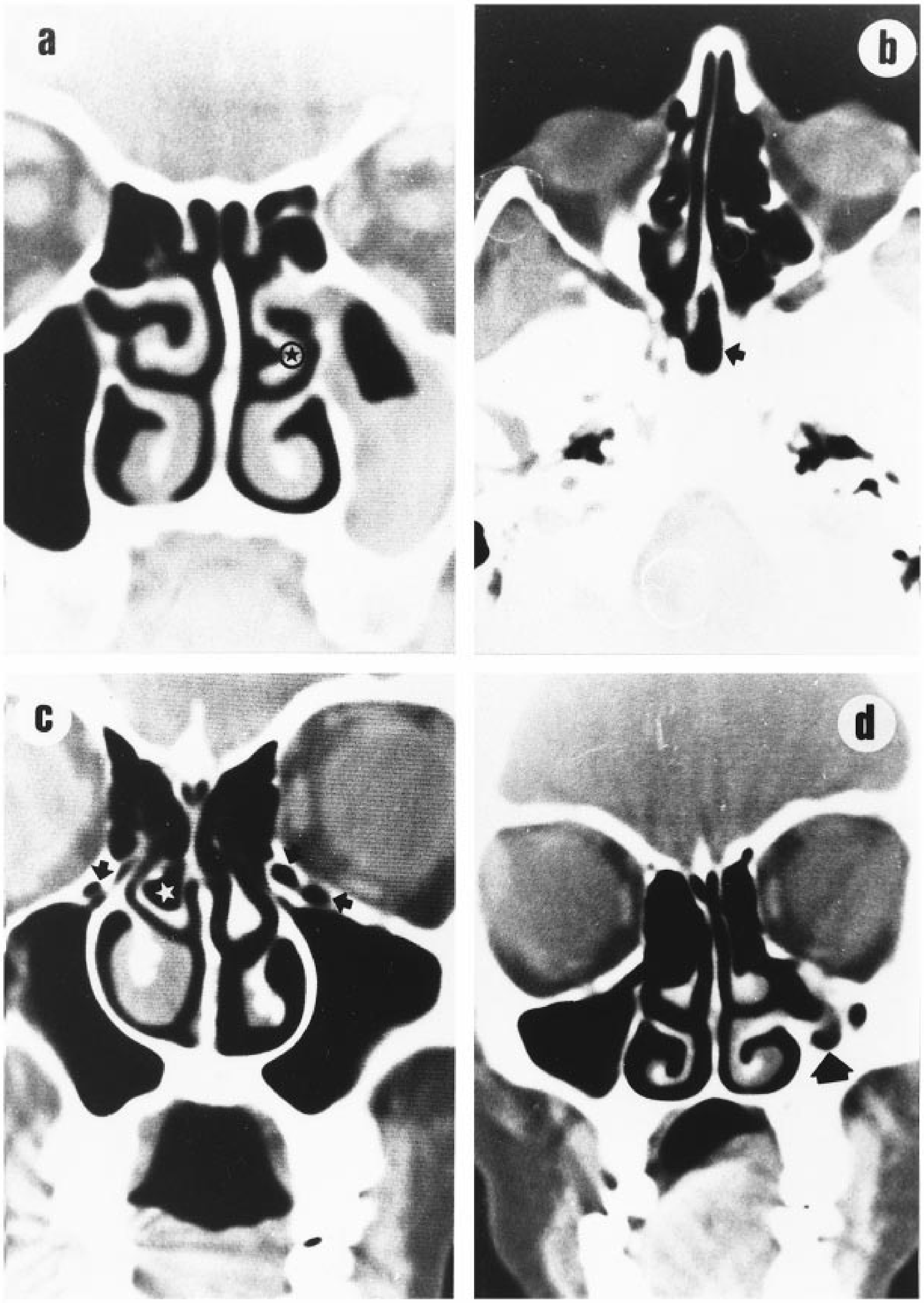

Fig. 2. CT images of some of the nasal sinus anatomical variants found. (*a*) Coronal scan: paradoxical middle nasal concha (black star); (*b*) horizontal scan: Onodi air cells (arrow); (*c*) coronal scan: bilateral Haller air cells (arrows); a concha bullosa is also seen on the left, marked by a white star; (*d*) coronal scan; hypoplasia of the right maxillary sinus (arrow) accompanied by absence of the uncinate process.

would see them, and affords optimal visualisation of the relationships between the different sinus cavities and adjacent structures. However, the coronal study should be accompanied by an axial study, which provides a better view of the anterior and posterior walls of the frontal sinuses and of the anatomical relations between the posterior ethmoid cells and the sphenoid sinus.

In our series, the presence of the agger nasi cells, which are anterior ethmoid cells, and the asymmetry between both loculi of the sphenoid sinus, were constant findings. The deviation of the nasal septum and the presence of a bony spur, the variants of the middle nasal concha, especially its great pneumatisation (concha bullosa), and the existence of a paradoxical middle concha, were, after the firstmentioned, the most frequently observed variants. These data are in accord with those of the series studied by Scribano et al. (1993). However, Zinreich (1993) reported the concha bullosa (36%) as the most common, followed in descending order by deviation of the nasal septum (21%), a paradoxical middle concha (15%), Haller cells (10%), a prominent ethmoid bulla (9%) and, finally, deviation (3%) and pneumatisation (0.4%) of the ethmoid uncinate process.

Nasal septum

The nasal septum is fundamental in the development of the nose and paranasal sinuses. It is the 'epiphyseal platform' for the development of the facial skeleton (Takanishi, 1987). The nonalignment of the 3 components of the adult nasal septum (septal cartilage, perpendicular ethmoidal lamina, and vomer) gives rise to a deviation of the septum, deformity of the chondrovomerine articulation, or the presence of a septal spur (Takanishi, 1987). According to Blaugrund (1989), nontraumatic septal deviation is observed in some 20% of the population, especially at the level of the chondrovomerine articulation. The proportion increased to 44% in the series studied by Earwaker (1993). That author also observed dislocation of the chondrovomerine junction in 5.5% of the cases, and the presence of a bony spur on the septum in 7.2%. In our series, we observed an even higher frequency of septal deviation (58%) and the presence of septal spurs (13.6%), while chondrovomerine deformation (4.5%) was close to the findings of those authors.

Middle nasal concha

The presence of a concha bullosa has ranged between 4% and 80% in different studies; our data gave 24.5%. Such a wide range of incidence is due to the criteria of pneumatisation adopted. With the criterion also used by us, Bolger et al. (1991) observed the variant in 15.7% of the population. However, if any degree of pneumatisation is considered, the incidence increases to 34% (Zinreich et al. 1988). Goldman (1987) observed an incidence of 80% in patients with chronic sinusitis, and considered that the existence of a concha bullosa is a predisposing factor of inflammatory sinusal disease, although such opinion is not shared by others (Bolger et al. 1991).

We found the presence of a paradoxical or false middle nasal concha in 10% of our cases. Earwaker (1993), in a CT study of 800 patients, detected a large concha of this type in 135 cases, and a small paradoxical middle concha, which was often bilateral, in 134 cases. In addition, in 94% of cases with a large concha, this was associated with septal deviation, and 56% of cases also showed pneumatisation.

Unilateral hypoplasia of the middle nasal concha was often observed in cases of septal deviation (Earwaker, 1993). A secondary middle nasal concha, not observed in our series, is an infrequent variant. It was identified in 6 of 400 individuals studied with CT, always without concomitant obstruction of the ostiomeatal complex (Khanobthamchai et al. 1991).

Uncinate process of the ethmoidal bone

The uncinate process is a key bony structure of the lateral wall of the nasal cavity. Together with the ethmoid bulla, it limits the semilunar hiatus and the ethmoid infundibulum, where the frontal and maxillary sinuses drain. The upper edge of the uncinate process may present lateral, medial, or anterior deviation with respect to the middle nasal meatus, appearing as a second middle concha (Stammberger & Wolf, 1988). When the deviation is lateral, it can result in narrowing of the semilunar hiatus and infundibulum, jeopardising their patency. When the deviation is medial, the uncinate process makes contact with the middle nasal meatus, threatening its permeability. The exact incidence of these variants is not known. Earwaker (1993) observed a horizontal orientation of the uncinate process, unilaterally or bilaterally, in 19% of cases (ours were 4.5%). In 95% of these, the variant was associated with a great ethmoidal bulla and, in some cases, with contralateral septal deviation. In 32% of cases, that author observed a vertical orientation of the process which appeared enlarged or deformed in 2.6%. Earwaker (1993) also reported a hypoplasic uncinate process in 0.2% of cases.

Pneumatisation of the uncinate process, which we did not observe, is believed to be due to extension of the agger nasi cells within the anterosuperior portion of the process (Som & Curtin, 1993). Bolger et al. (1991) reported an incidence of between 0.4% and 2.5% of the population.

Ethmoid sinuses

The ethmoid air cells comprise 3 groups: anterior, middle and posterior. Those extending within the ethmoid complex to the frontal recess are intramural. However, the anterior ones, which extend to the supraorbital edge, agger nasi, and maxillary orbital process, and the posterior ones, which reach the sphenoid bone, are extramural (Stammberger & Wolf, 1988). The prevalence of the extramural cells, known as Onodi cells (Onodi, 1910), varies: 10% (Schaefer, 1989), 96% (Earwaker, 1993), and 98% in the series of Van Alyea (1939); our data are closer to the low end (10.9%). The posterior ethmoid cells may extend into the anterior portion of the sphenoid body. In the opinion of Lang (1989), these cells may surround the optic nerve and even reach the anterior wall of the sella turcica. In the series of Earwaker (1993), this type of posterior ethmoidal cells is present in 24% of cases.

The definition of ethmoid cells given by Haller in the eighteenth century (Bolger et al. 1991) is now controversial. Some authors (Kennedy & Zinreich, 1988) considered as ethmoid cells the air cavities projecting below the ethmoid bulla within the orbital floor in the region of the opening of the maxillary sinus, observing them in 10% of the population. With this criterion, we have found them in 2.7% of our cases. However, Bolger et al. (1991) considered the term to include any cell located between the ethmoidal bulla, the orbital lamina of the ethmoid bone, and the orbital floor. Using this criterion, we found them in 45% of our cases. Stammberger & Wolf (1988) considered the existence of this variant a predisposing factor for the recurrence of maxillary sinusitis. Kainz et al. (1993) defined the Haller cells as ethmoid cells developing within the orbital floor or maxillary sinus, and found them in 43 of 528 cases (8.1%). They were more frequent in women than in men (2:1).

The ethmoid bulla is the largest air cell of the ethmoid complex. When this air cell reaches sufficient size it can tighten or even obstruct the middle nasal meatus and the infundibulum. In this case it is considered as a great ethmoid bulla. According to Zinreich (1992), the prevalence of this anatomical variant is 8%. However, from Laine & Smoker (1992), the exact incidence of a great ethmoid bulla is unknown. We did not observe this variant in any case.

Other variants

Although we have found a constant asymmetry between both cavities of the sphenoid sinus, the identification of an asymmetric intersphenoid septum is very important especially when it shows a considerable deviation, as its advance marks the line of the internal carotid artery, which may protrude into the posterior ethmoid cells (Kennedy et al. 1990).

Hypoplasia of the maxillary sinus, which in our series was present in 6.3% of cases, was reported in 10.4% of cases by Bolger et al. (1990). In such cases, it is important to detect variants of the ethmoidal uncinate process, as this is a significant anatomical signpost in sinus surgery to prevent inadvertent penetration of the medial wall of the orbit (Bolger et al. 1990).

The clinical significance of anatomical variants of the nasal sinus region is controversial. Most CT anatomical studies of the sinus region have been made in patients suspected of a clinical syndrome suggesting inflammatory sinus pathology. Zinreich (1993) found that 62% of his patients presented at least one anatomic variant, against 11% in the normal control group. These findings seem to suggest a possible correlation or clinical significance of anatomical variants regarding the appearance of inflammatory sinus pathology. However, Bolger et al. (1991), in a series of 202 patients studied by CT, observed 131 anatomical variants, but found the incidence in patients with sinus pathology was similar to that in persons studied for other reasons. Calhoun et al. (1991) compared 100 CTs carried out to evaluate sinus disease with 82 CTs from a study of orbital pathology. The existence of a concha bullosa was more frequent in the first group, as was septal deviation. However, the existence of a paradoxical middle nasal concha was observed equally in the 2 studies, without association in any case with a sinus anomaly. In a population of patients with chronic sinusitis, 62% presented at least 1 anatomical variant, while in the normal control group, this appeared only in 13% (Zinreich, 1993). Of all the anatomical variants of Lloyd's series (Lloyd, 1990), only the concha bullosa was associated with a high incidence of sinusitis (85%). Bolger et al. (1990) and Stammberger & Wolf (1988) detected the presence of anatomical variants both in patients studied for sinus problems and in those studied for other reasons. They concluded that the simple presence of variants does not mean a predisposition to sinus pathology, except when other associated factors are present. This opinion is not shared by Yousem (1993), who claimed that they may be predisposing factors, depending on their size.

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