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Anatomic variations of the sphenoid sinus on computed tomography*

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SUMMARY

Anatomic variations of the vital structures adjacent to the sphenoid sinus can be jeopardized during functional endoscopic sinus surgery (FESS). The knowledge of the size and extent of pneumatization of the sphenoid sinus (SS) is an important condition for adequate surgical treatment of its disease. The bony anatomic variations of SS as well as its relationship with adjacent vital structures were reviewed in this paper. The study was performed on 267 patients with a complaint of chronic or recurrent sinusitis. Computed tomographic (CT) scans were obtained upon completion of therapy. The evaluations of the sphenoid sinuses were regarded separately, so as 534 sides were examined. Especially bony anatomic variations as well as mucosal abnormalities of the sphenoid sinuses were examined. Pneumatization of the pterygoid process and anterior clinoid process were found in 39.7% and 17.2% of the patients respectively. Vidian canal protrusion was found in a total of 158 sides of which 60 were bilateral. These entities were encountered usually when pneumatization of the pterygoid process occurred. Carotid canal and optic canal protrusions were found in 5.2% and 4.1% of the patients respectively. Mucosal thickening, and polyps or cysts of sphenoid sinuses were detected in 20.6% and 4.5% of the patients respectively. There was a statistically significant correlation between pterygoid pneumatization and vidian canal protrusion ($p<0.001$), and vs. foramen rotundum protusion ($p=0.004$). While the optic canal protrusion was found significantly associated with the anterior clinoid pneumatization ($p<0.001$), there was no statistically significant correlation between a carotid canal protrusion and anterior clinoid pneumatization ($p=0.250$). Sphenoid sinus surgery is very risky, because of changing variations of the cavity. We are in the opinion that detailed data from CT scans of SS will enable the surgeon to interpret any anatomic variations and pathological conditions before initiation of the surgical therapy.

Key words: sphenoid sinus, bony anatomic variations, computed tomography, endoscopic sinus surgery

INTRODUCTION

Functional endoscopic sinus surgery (FESS) has been put into practice for almost a quarter of a century. Like traditional sinus surgery, it is associated with serious risks. In order to avoid potential complications of FESS, it is essential to know well-defined anatomy and anatomic variations. With the expanding usage of FESS, proper understanding of the sphenoid sinus (SS) anatomy has become increasingly important. Despite the importance and complexity of the anatomy of the sphenoid sinuses, relatively few reports have focused basically on it. The accessibility of the sphenoid sinus is regarded much difficult and it is known as the most variable cavity of the human body [1]. It is also bordered by many important structures, and its relationship to them is subject to several anatomic variations [2]. Some important neural and vascular structures may be directly exposed in the sphenoid sinus, or may be separated from them by only a thin wall. Considerable variations including cavernous sinus, internal carotid artery, optic and vidian canals are intimately related to sphenoid sinuses [3]. On the other hand, anatomic variations may predispose the sphenoid sinus to recurrent or chronic sinusitis [4].

Computed tomography (CT) has been routinely used as a part of the initial workup for patients with chronic or recurrent sinusitis, and a considerable attention has been directed toward detailed analysis of paranasal sinus anatomy through CT imaging since increasing usage of FESS among surgeons. In order to minimize risks during FESS, a cautious dissection should be coupled with a careful inspection of anatomic varia-

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tions on CT scans before surgical intervention. A CT scan can help the surgeon to enhance identification of the limits of dissection during surgery. Besides, being aware of the exact knowledge of anatomic morphology and probable anomalies are of particular importance to the surgeon. Nowadays anatomic structures, even subtle bony anatomic variations and mucosal abnormalities of this region can be delineated at CT by utmost accuracy [4]. The knowledge of the extent of pneumatization and the different type of anatomic variations of the sphenoid sinus is an important condition for adequate treatment of its disease. By this aim we focused to assess the prevalence of bony anatomic variations as well as mucosal abnormalities of the sphenoid sinus in patients with chronic or recurrent sinusitis.

MATERIALS AND METHODS

Patients with sinus complaints undergoing evaluation at the Department of Otorhinolaryngology Head and Neck Surgery at Kirikkale University Hospital between August 1999 and September 2003 were included in this study. Patients with any disease other than chronic or recurrent sinusitis were eliminated from the study group. All patients initially underwent routine workup for sinus disease, including history and physical examination, and standard sinus radiographs. After given medical treatment for 3 to 4 weeks, patients with persistent sinus disease were scanned with computed tomography. A detailed analysis of CT scans of the paranasal sinuses were reviewed by two authors (MK, YK) with consensus. Attention was directed toward identifying especially bony anatomic variations of the sphenoid sinuses, and mucosal abnormalities were also evaluated. Bony anatomic variations such as pneumatization of the pterygoid process (PP) and anterior clinoid process (ACP), protrusions of either the carotid canal (CC), optic canal (OC), vidian canal (VC) or foramen rotundum (FR) into the sinus, and dehiscence of either the carotid canal, optic canal or foramen rotundum were also recorded. When the pneumatization extends below a plane between VC and FR, it has been considered significant for PP pneumatization (Figure 1). It was regarded as 'protrusion' when more than 25% of the nerves were surrounded by the air. Meanwhile relationships of sphenoid septa with the carotid canal, optic canal or vidian canal were noted. Mucosal abnormalities such as mucosal thickening and cyst or polyp were also determined in the CT scans. The relationship between the bony anatomic variations, and mucosal abnormalities of the sphenoid sinus on CT was also investigated.

Paranasal sinus CT, on coronal plane and sometimes also with the transverse plane, examinations were performed using a SELECT Elscint scanner (Israel). Patients were not prescribed nasal decongestion before radiological examination. Coronal plane CT examination was performed while the patient was in the supine position with the neck hyperextended. Data were evaluated using technical properties of 120 kVp, 210 mAs and 3-mm slice thickness in the coronal plane (simultaneously with the axial plane in 75 patients) without using intravenous (iv) contrast material. CT scans were obtained with a 2340/ 425 H window width bone technique and a field of 160x160mm. While the coronal images were obtained from glabella to the posterior wall of the sphenoid sinus, axial images were performed from the level of the hard palate to the roof of the frontal sinus and the films were formatted at bony window width. The evaluation of CT slices was done regarding both sides of the sphenoid sinus as a separate cavity. The comparison of pneumatization of the PP and ACP with the protrusions of VC and FR, and protrusions of CC and OF respectively were tested with the logistic regression test. The chi-square test was used for testing the relationships between bony abnormalities and mucosal pathologies. Results were considered significant at $p < 0.05$.

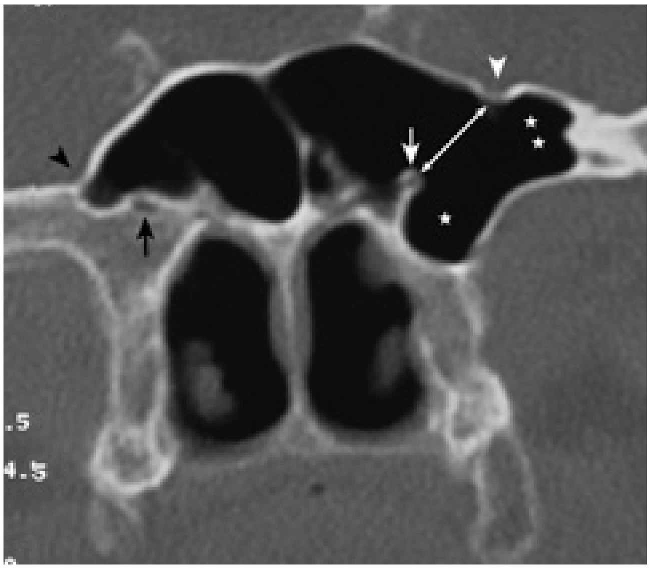

Figure 1a. The pneumatization of the left pterygoid process (star) and greater wing (double stars) of the sphenoid sinus on coronal CT. Note the the vidian canal protrusion (white arrow-eye on a stalk) and foramen rotundum protrusion (white arrowhead) on the left side. The normal vidian canal (black arrow) and foramen rotundum on the left side (black arrowhead) are seen.

RESULTS

A total of 267 patients (159 women, 108 men) were evaluated in this study. The mean age of the patients at the time of scanning was 39 (14-73 yrs). The examinations of the SS were performed separately regarding each cavity. The detailed data about bony anatomic variations as well as mucosal abnormalities are shown in Table 1. Pneumatization of the PP and ACP were detected in 39.7% and 17.2% of the patients respectively (Figures 1A, 1B and 2). In the evaluation of 534 sides of 267 CT images, vidian canal protrusion was found in a total of 158 sides and it was detected bilaterally in 60 patients (Figure 2). VC and FR protrusions were interestingly delineated mostly in a condition of which pneumatization of the PP occurred. CC and OC protrusions were found in 5.2% and 4.1% of the

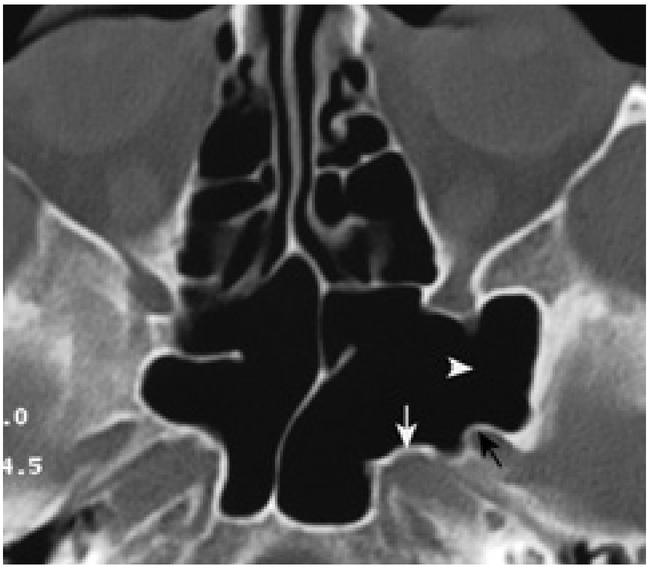

Figure 1b. Axial CT scan of the same patient. It is seen that the over pneumatization (white arrowhead) caused protrusion of both the carotid canal (white arrow) and mandibular nerve (black arrow) on the left side.

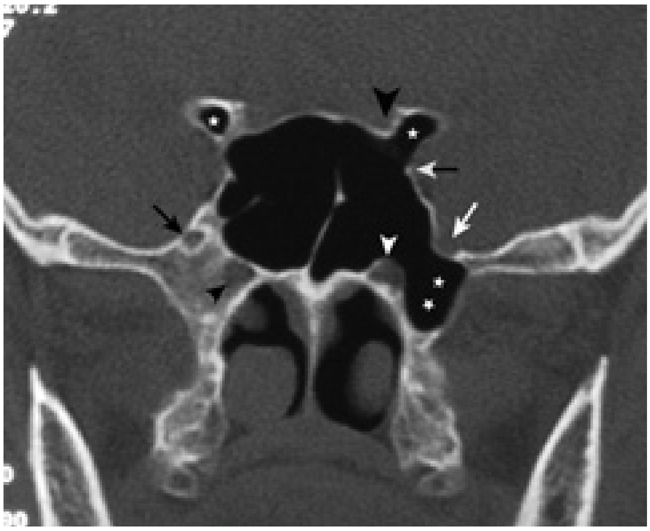

Figure 2. The coronal CT scan showing the pneumatization of the bilateral anterior clinoid processes (stars) and both protrusions of CC (black-white arrow) and OC (big black arrowhead). Note the pneumatization of the pterygoid process (double stars), vidian canal protrusion (white arrowhead) and foramen rotundum protrusion (white arrow) on the left side and the normal vidian canal (black arrowhead) and foramen rotundum on the right side (black arrow).

patients respectively (Figures 1B and 3). Both of these protrusions were usually detected when ACP pneumatization took place. The statistical data are shown in Table 2. There were statistically significant correlations between PP pneumatization and VC ($p < 0.001$), and FR protrusions ($p=0.004$). As optic canal protrusion was found significantly associated with the ACP pneumatization ($p < 0.001$), there was no statistically significant correlation between CC protrusion and ACP pneumatization ($p=0.250$). Mucosal thickening, and cysts or polyps in the sphenoid sinuses were found in 20.6% and 4.5% respectively, constituting a total of 67 patients and 25.1% overall. The presence of an air-fluid level in the pterygoid recesses was encountered in only 8 patients. Statistically important negative correlations between PP pneumatization, VC and FR protrusions and mucosal abnormalities were found ($p < 0.05$). On the other hand, negative correlations, but no statistically signifi-

Table 1. The prevalence of bony anatomic variations and mucosal abnormalities seen on sphenoid CT.

ANATOMIC VARIATIONS	**SIDES OF SINUS**				**PATIENTS**	
	BILAT	**UNILAT**	**TOTAL**	**%**	**No.**	**%**
onodi cell		4	4	2.6*	4	5.3*
pterygoid pneu	58 (116)	48	164	30.7	106	39.7
anterior clinoid pneu	23 (46)	23	69	12.9	46	17.2
vidian canal protr	60 (120)	38	158	29.6	98	36.7
carotid canal protr	7 (14)	7	21	3.9	14	5.2
carotid canal deh	1 (2)	3	5	0.9	4	1.5
optic canal protr	4 (8)	7	15	2.8	11	4.1
optic canal deh	1 (2)	1	3	0.6	2	0.7
f. rotundum protr	16 (32)	22	54	10.1	38	14.2
f. rotundum deh	2 (4)	4	8	1.5	6	2.2
sphenoid septa	33 (66)	38	104	19.5	71	26.6
septa (carotid canal)	8 (16)	19	35	6.6	27	10.1
septa (optic canal)	1 (2)	4	6	1.1	5	1.9
septa (vidian canal)	1 (2)	1	3	0.6	2	0.7
mucosal thickening	30 (60)	25	85	15.9	55	20.6
polyp or cyst	5 (10)	7	17	3.2	12	4.5

* They are evaluated on only 75 axial plane CTs.

PNEU: pneumatization, PROTR: protrusion, DEH: dehiscence, F: foramen

Figure 3. Carotid canal protrusions are seen on the axial CT scan. Note the dehiscent over the carotid canal on the right side (white arrow) and the crest inserting into the bony covering of the carotid artery on the left side (white arrowhead).

cant, were found between ACP pneumatization, OC and CC protrusions and mucosal abnormalities ($p > 0.05$).

DISCUSSION

The sphenoid sinuses show a parallel expansion in antero-posterior and lateral directions until age 10, and later on there might still be a slight trend to expand further, although there will be no significant further expansion in both directions after age 14 or 15. Their sizes differ considerably between different ages. It was stated that size and shape of SS show a high variability with a range of 200% or more in both directions [5]. The carotid artery, the optic nerve (ON), and the vidian nerve are present before the sinus development, so that they produce irregularities in the walls of the sinus as the cavity develops. Only a thin bony plate separates the sinus from adjacent structures in well-pneumatized cavities [6]. In other words, as the pneumatization of the sphenoid sinus extends far beyond the sphenoid body, air spaces will take place to form a large variety of recesses. This pneumatization may extends inside the clinoid processes, the greater wing, or downward into the pterygoid process. Therefore, the contour of the cavity appears irregular, with protrusions and recesses. When the pneumatization expands into the base of the pterygoid process and into the greater wings of the sphenoid, the cavity projects to form the pterygoid recess and lateral recess, respectively [1,6,7]. As far as we are concerned both pneumatizations of the greater wing and pterygoid process occur in the same time, whether one or another takes place predominantly. It is difficult to evaluate each other independantly and so we accept it as PP pneumatization when one or both of these structures pneumatized. We considered it significant when pneumatization extended over a plane constituted between VC and FR. In the literature, pneumatization of the PP was reported 25-57% [2-4,7,8]. Similarly, we found PP pneumatization in 39.7% of the patients of whom 54.7% were bilateral. Lewin et al. [7] reported pneumatization of the PP in 20 bilateral, and in 21 unilateral of a total of 72 healthy subjects. When pneumatization expands into the plates, the floor of the sinus shows a definite ridge that corresponds to the vidian (pterygoid) canal. The reported prevelance of VC protrusion into the sinus varies between 7.5 and 10% in different studies [2,9]. Van Alyea [10] reported a vidian canal protrusion in 36% of all cadavers in an anatomic study and he also mentioned that the nerve might have only a mucosal lining [10]. In contrast to the literature and similar to the findings of Van Alyea [10], we found this proportion in 36.7% of all the patients, and we noticed that as the size of the pterygoid recess increases, the VC protrusion occurs simultaneously. We detected statistically significant correlations between PP pneumatization and both protrusions of VC ($p < 0.001$) and foramen rotundum ($p=0.004$). FR was reported to indent the lower lateral wall of 24 sinuses (12.9%) [2]. Similarly, we found FR protrusions in 12.7% which is in accordance with the literature. We are in the opinion that the projection of vessels and nerves adjacent to the sinus wall yield to bulge into the cavity as the whole pneumatization of the sinus increases. The pterygoid process pneumatization might cause a potential space for occurrence of focal infection as it will have proponence, in order to gravity, to contain purulent exudates which is associated with sinusitis.

Table 2. The statistical data including comparisons of pneumatizations and protrusions.

ANATOMIC VARIATIONS	**OR (95% CI)**			
	Exp (B)	**Lower**	**Upper**	**p**
pp pneu - vc protr	180	83.7	387.2	<0.001
pp pneu - fr protr	12.5	2.3	68.7	0.004
acp pneu - oc protr	22.6	7	73.5	<0.001
acp pneu - cc protr	1.9	0.6	6	0.250

OR: odds ratio, CI: confidence interval, PP: pterygoid process, VC: vidian canal, FR: foramen rotundum ACP: anterior clinoid process, OC: optic canal, CC: carotid canal

We had 8 patients having air-fluid level in the pterygoid recesses. We found mucosal thickening, and polyps or cysts in 25.1% of all patients. Mucosal abnormalities seen on CT imaging may lead the surgeon to planning adequate treatment of the disease, even medical or surgical. The relation between the mucosal disease and the bony anatomic variations were not noted parallel to the severity of the disease. In the literature, pneumatization of the pterygoid process and anterior clinoid processes have not been implicated in the etiology of sinusitis [4]. In accordance with the literature, we could not detect any statistically significant correlation between mucosal disease and bony anatomic variations.

The sphenoid pneumatization may climb upward into the anterior clinoid process and it will result in an air cavity which will appear rear to the sinus in radiological examination [1]. When the ACP is pneumatized, the optic nerve protrudes against the superior lateral sinus wall, forming an OC protrusion [1,2,11,12]. OC is the place where the optic nerve is the least nourished throughout its course; therefore, it is very susceptible to injury through direct inflammatory invasion of the sinus diseases and additionally, there is a risk of blindness if the surgeon damages the nerve within the sinus [13]. In the literature, pneumatization of the ACP, and protrusion of the OC were noted in 6 to 17% [4,8,14] and 8 to 70.7%, respectively [1-3,7,11,12,15]. Similar to the literature, we found anterior clinoid process pneumatization in 17.2% of the patients. In contrast, OC protrusion was detected in 4.1% of the patients. The wide discrepancy in the reported prevalence of OC protrusion may be due to differences in criteria chosen by the authors. Nevertheless, there is no idea about the criteria for choosing this entity. The defined ON protrusion as a bulging of the OC into the cavity of the sinus more than half the circumference of the nerve was considered by Dessi et al. [16]. They noted that when pneumatization of the ACP was present OC protrusion took place in all of them [16]. Our lower rate of OC protrusion may be the result of defining eminence as we considered it completely protruded when it is clearly visible. The ON is at risk during sinus surgery when the posterior ethmoid anatomical variation exists, i.e., sphenoethmoid or Onodi cell (OnC). Although the accurate prevalence of OnC is unclear, it is estimated to range from 7% to 13% [2,9,14,17,18]. We determined OC in only 5.3% of the 75 patients whom underwent axial plane CT examination.

The internal carotid artery is critical owing its close proximity and bulging medially into the sphenoid sinus and this may create increased risk during surgery. The artery may occasionally protrude into the sphenoid sinus, especially when there is an overpneumatization in the sphenoid base [3]. The surgeon must know this variation on the sinus wall to avoid any fatal risk before surgical intervention. The percentage of CC protrusion was reported as 8-72% in the literature [1,2,14]. In contrast to these reports, we found this rate to be 5.2% (50% of them were bilateral) which is lower than the in the reported literature. Bony covering of the carotid canal and optic canal has been noted varying greatly in thickness in different anatomic studies. The optic nerve may be covered by thin bone or lack its bony covering as its courses within the sphenoid sinus. The average thickness of the bony covering of the optic canal was reported as 0.28 to 0.50 mm and it was noted that dehiscenses were present between 4% and 12% [1,11,15]. Our result is in accordance with the reports of Maniscalco et al. [19] and Fujii et al. [11] who noted optic eminence dehiscence in 3.6% and 4% of all their patients. Absolutely, these results might be considered more correct than ours, because these studies were anatomical. The thickness of bone separating the carotid artery from the sinus was found as 0.5-1 mm in 66-88% of the specimens [2,11]. In some cases the thin bony wall over the vessel may be dehiscent separated the internal carotid artery (ICA) from the sinus cavity by mucosa only. Dehiscences were noticed in the anatomic studies as 4-25% [2,9,11,20,21]. In our study we found the dehiscence rates of both the optic nerve and carotid artery as 0.7% and 1.5% of all the patients respectively. Although this is less then the rates reported in the literature, it is because these reports are from anatomic studies and it is very difficult to delineate them on CT. A dehiscence in the bone covering the artery may lead to direct contact of the artery with sinus mucosa which may lead infection occurring within the cavernous sinuses. On the other hand, if the surgeon is not aware of such variation, even fatal results, i.e. blindness and carotid injury, may happen. The surgeon should be forewarned, absolutely with radiological examinations, to recognize these variations in case not to do any iatrogenic trauma.

An accessory bony septa or crests may exist in the sphenoid sinus and occasionally they insert directly in to the bony covering of the ICA or ON. Trials to fracture the crest in these cases could lead to injury of these two major structures with serious consequences [12,18]. Bony septa or crests were seen in 68.8-69.6% of all the patients and while 39.1-47.8% were unilateral, 21-30.4% were bilateral [2,18]. The crests were inserted into the bony covering of the carotid arteries in 12.9-13%, and into the bony covering of the optic nerve in 5.9% [2,18]. In accordance with the literature we found bony septa inserting into the CA to be 10.1%. Additionally, we detected septa inserting into the optic canal and vidian canal as 1.9% and 0.7% respectively. During the surgery, it must be known that the septum may insert near to the vital structures like ICA and avoid fracturing the bony covering.

In summary, the complex anatomy and risky morphometry of the SS tend to give rise to a complexity of symptoms and potentially serious complications. Inadequate understanding of the exact anatomy, undoubtedly increases the possibility of serious or fatal iatrogenic surgical mishaps. In order to minimize risks during surgery, a cautious dissection should be coupled with a careful inspection of anatomic conditions on CT scans before any procedure. A detailed knowledge about anatomic variations preoperatively and evaluation of pathological findings within this cavity with gold standard CT may prove beneficial during FESS. The clearest understanding of the sinus morphology enhances identification of the limits of dissection and hence may help to reduce the possibility of complications.

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