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Sphenoid Sinus Pneumatization and Its Relation to Bulging of Surrounding Neurovascular Structures

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Objectives: We investigated the bulging and dehiscence of neurovascular structures in the sphenoid sinus and their relationships to the pneumatization of the sphenoid sinus.

Methods: One hundred sagittally hemisected cadaveric heads were examined. The degree of pneumatization of the sphenoid sinus was determined. Bulging and dehiscence of the internal carotid artery (ICA), optic nerve, maxillary nerve, and vidian nerve were examined, and the distances between these structures and the anterior or superior wall of the sphenoid sinus were measured. Additionally, the degree of bony thickness over these structures was determined.

Results: The prevalences of bulging of the optic nerve, segments 1 and 3 of the ICA, and the maxillary and vidian nerves were 56%, 34%, 65%, 41%, and 52%, respectively. The greater the degree of pneumatization, the more frequently did the structures bulge into the sphenoid sinus. The optic nerve was found to be in close proximity to the anterior and superior walls of the sphenoid sinus. The bone over the surrounding structures was very thin, especially for the complete sellar type.

Conclusions: The prevalence of bulging of the optic nerve, the ICA, and the maxillary and vidian nerves increased in proportion to the degree of sphenoid sinus pneumatization.

Key Words: internal carotid artery, maxillary nerve, optic nerve, sphenoid sinus, vidian nerve.

INTRODUCTION

The sphenoid sinus is located in the center of the head and is surrounded by several neurovascular structures, including the optic nerve, the internal carotid artery (ICA), the maxillary nerve, and the vidian nerve. Since the development of endoscopic equipment and navigational systems, it has become much easier to access the sphenoid sinus and to treat resident diseases directly. However, even minimal damage to surrounding structures during an operation can lead to an irrevocable outcome such as blindness or massive bleeding.[1] Therefore, careful preoperative evaluation of the sphenoid sinus and its relation to the surrounding structures is critical.

When evaluating the sphenoid sinus, particular attention should be paid to the bulging and dehiscence of surrounding structures. The more the optic nerve and the ICA bulge into the sphenoid sinus or the greater their dehiscence, the greater is the chance of accidental damage. Bulging and dehiscence of related structures are likely to be closely related to the extent of sphenoid sinus pneumatization. Logically, the optic nerve and carotid artery should be able to bulge out easily when the sphenoid sinus is extensively pneumatized, and dehiscence should only occur when these surrounding structures bulge significantly. Therefore, both pneumatization of the sphenoid sinus and bulging or dehiscence of the surrounding structures should be considered. However, most studies of the anatomy of the sphenoid sinus and its surrounding structures have dealt with these subjects separately.[1-10] The purpose of this study was to investigate bulging and dehiscence of the neurovascular structures located in the sphenoid sinus and to evaluate their relationships to the pneumatization of the sphenoid sinus.

METHODS

One hundred eighteen sagittally hemisected fresh cadaveric heads from 59 Korean adults were examined. For simplicity of analysis, we excluded 18 hemisected heads with Onodi cells. Once all of the mucosa in the sphenoid sinus had been carefully removed, the degree of pneumatization of the sphenoid sinus was determined according to the classi-

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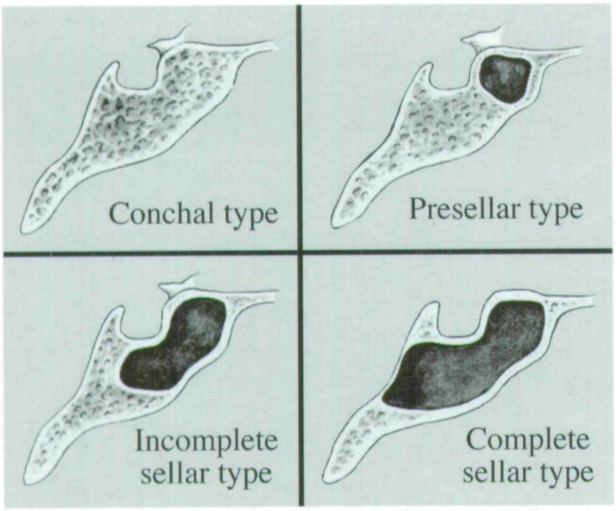

Fig 1. Four types of sphenoid sinus pneumatization. In conchal type, there is no air cavity in sphenoid sinus. In presellar type, air cavity does not expand beyond vertical plane passing through anterior clinoid process. Sellar type is subdivided into complete and incomplete types. In complete sellar type, air cavity extends to clivus, and in incomplete type, it does not.

fication of Hammer and Radberg.[6] Bulging and dehiscence of the ICA, optic nerve, maxillary nerve, and vidian nerve were measured. Bulging was noted when the impression of a structure was clearly identifiable, and dehiscence was documented when any bony defect was observed in the bulge. The distances between these structures and the anterior or superior wall of the sphenoid sinus were determined with steel vernier calipers. To determine the bony thickness over these structures, we first identified the bone segment at the point of maximal bulging and then measured its thickness using calipers. Three experienced rhinologists performed the examinations, with the cases evenly allocated among them. When the degree of sphenoid sinus pneumatization or the existence of a bulge or dehiscence was ambiguous, all 3 rhinologists discussed the case to arrive at a unanimous conclusion. The internal review board of Yonsei University Hospital exempted this study, because it did not come within the purview of their regulations.

Pneumatization of Sphenoid Sinus. We classified the sphenoid sinuses into sellar, presellar, and conchal types, as proposed by Hammer and Radberg.[6] The sellar type was subdivided into complete and incomplete types. The complete type was identified when the pneumatization reached the clivus, and the incomplete type included cases in which the pneumatization did not reach the clivus (Fig 1).

Optic Nerve. Bulging and dehiscence of the optic nerve were examined. The distances between the most anterior bulging point of the optic nerve and the superior and anterior walls of the sphenoid sinus were measured separately. Finally, the bony thickness of the point of maximum bulging of the optic nerve was measured (Fig 2).

Internal Carotid Artery. The ICA around the sphenoid sinus was divided into 3 segments. Segment 1 was defined as the portion of the ICA from the posteroinferior part of the lateral wall to the posterior clinoid process. Segment 2 was the short horizontal portion inferior to the pituitary fossa. Segment 3 was the vertical portion between the pituitary fossa and the optic nerve. The bulging and dehiscence of each segment were examined separately. The distances between the anterior wall of the sphenoid sinus and the most anterior bulging points of segments 1 and 3 were measured separately. Finally, the bony thicknesses of the points of maximum bulging on segments 1 and 3 were measured (Fig 2).

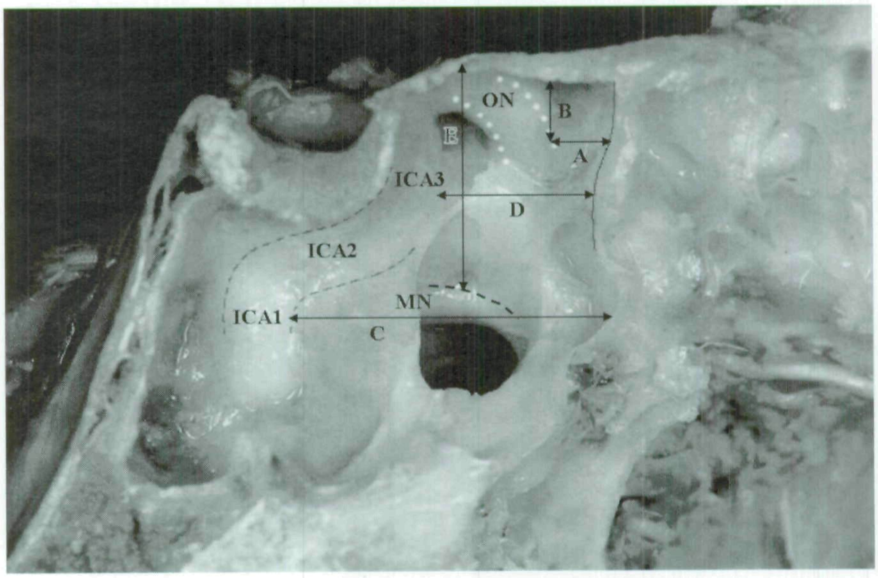

Fig 2. Lateral wall of sphenoid sinus (right side). A, C, and D indicate distances between anterior wall of sphenoid sinus and most anterior bulging part of optic nerve (ON; A), segment 1 of internal carotid artery (ICA1; C), and segment 3 of internal carotid artery (ICA3; D). B and E indicate distances between superior wall of sphenoid sinus and most anterior bulging part of optic nerve (B) and between superior wall of sphenoid sinus and most superiorly bulging part of maxillary nerve (MN; E).

Maxillary and Vidian Nerves. The bulging and dehiscence of the maxillary and vidian nerves were also examined. The distance between the most superiorly bulging point of the maxillary nerve and the superior wall was measured. The bony thicknesses of the points of maximum bulging on the maxillary and vidian nerves were measured separately (Fig 2).

RESULTS

Pneumatization of Sphenoid Sinus. The sellar type was the most predominant type (90%) and comprised almost equal numbers of incomplete (47%) and complete (43%) types. The presellar type was found in 9% of cases, and the conchal type was found in only 1% of cases. These results are summarized in Table 1.

Bulging and Dehiscence of Surrounding Structures. Overall, the incidence of bulging in the optic nerve, segments 1 and 3 of the ICA, the maxillary nerve, and the vidian nerve were 56%, 34%, 65%, 41%, and 52%, respectively. The presence of bulging depended mainly on the degree of pneumatization of the sphenoid sinus. The more pneumatized the sphenoid sinus, the more frequently the structures bulged out into the sphenoid sinus. For example, the optic nerve bulged in 72.1% of complete sellar-type cases, in 49.0% of incomplete sellar-type cases, and in only 20.0% of presellar- and conchal-type cases. Similar results were observed for the other structures.

Theoretically, dehiscence should occur only in cases in which bulging is present; the prevalence of dehiscence was therefore only calculated for cases in which bulging was present. The dehiscence rates were quite low for all structures: 3.6% for the optic nerve, 0% for segment 1 of the ICA, 1.5% for segment 3 of the ICA, 2.2% for the maxillary nerve, and 9.6% for the vidian nerve. These results are summarized in Table 2.

Distances Between Surrounding Structures and Sphenoid Sinus Walls. Segment 3 of the ICA was fairly distant from the anterior wall of the sphenoid sinus, whereas the optic nerve was quite close to both the anterior and superior walls. For the complete sellar type, the average distance from segment 3 of the ICA to the anterior wall was 9.5 ± 3.1 mm, whereas the distance from the optic nerve to the anterior wall was only 1.9 ± 2.2 mm and that to the superior wall was 3.7 ± 3.4 mm. The optic nerve was in contact with the anterior wall in 45% of cases and with the superior wall in 34% of cases. These results are summarized in Table 3.

TABLE 1. PREVALENCE OF SPHENOID SINUS PNEUMATIZATION

Type	*Number (%)*
Conchal type	1 (1)
Presellar type	9 (9)
Sellar type	90 (90)
Incomplete	47 (47)
Complete	43 (43)

TABLE 2. PREVALENCES OF BULGING AND DEHISCENCE OF SURROUNDING STRUCTURES

	Bulging		*Dehiscence*	
Structure and Type	*Yes (%)*	*No (%)*	*Yes (%)*	*No (%)*
Optic nerve	56 (56.0)	44 (44.0)	2 (3.6)	54 (96.4)
Complete sellar	31 (72.1)	12 (27.9)	2	0
Incomplete sellar	23 (49.0)	24 (51.0)	0	0
Presellar and conchal	2 (20.0)	8 (80.0)	0	0
Segment 1 of ICA	34 (34.0)	66 (66.0)	0 (0)	34 (100)
Complete sellar	31 (72.1)	12 (27.9)	0	0
Incomplete sellar	3 (6.4)	44 (93.6)	0	0
Presellar and conchal	0 (0)	10 (100)	0	0
Segment 3 of ICA	65 (65.0)	35 (35.0)	1 (1.5)	64 (98.5)
Complete sellar	38 (88.4)	5 (11.6)	1	0
Incomplete sellar	24 (51.1)	23 (48.9)	0	0
Presellar and conchal	3 (30.0)	7 (70.0)	0	0
Maxillary nerve	41 (41.0)	59 (59.0)	1 (2.2)	40 (97.8)
Complete sellar	26 (60.5)	17 (39.5)	1	0
Incomplete sellar	14 (29.8)	33 (70.2)	0	0
Presellar and conchal	1 (10.0)	9 (90.0)	0	0
Vidian nerve	52 (52.0)	48 (48.0)	5 (9.6)	47 (90.4)
Complete sellar	29 (67.5)	14 (32.5)	4	0
Incomplete sellar	23 (49.0)	24 (51.0)	1	0
Presellar and conchal	0 (0)	10 (100)	0	0

ICA — internal carotid artery.

Bony Thicknesses Over Surrounding Structures. Overall, the bone over the surrounding structures was very thin. For the complete sellar type, the average bone thickness was only 0.2 to 0.3 mm for all structures. For the incomplete sellar type, the bone

TABLE 3. DISTANCES BETWEEN SURROUNDING STRUCTURES AND SPHENOID SINUS WALLS

	Complete Sellar	*Incomplete Sellar*	*Presellar*
Optic nerve to anterior wall	1.9 ± 2.2	3.1 ± 3.7	0
Optic nerve to superior wall	3.7 ± 3.4	3.1 ± 3.4	2.62
Segment 1 of ICA to anterior wall	19.3 ± 3.3	18.6 ± 6.2	
Segment 3 of ICA to anterior wall	9.5 ± 3.1	9.2 ± 3.3	3.5 ± 2.8
Maxillary nerve to superior wall	17.1 ± 3.1	14.3 ± 4.2	4.4

Data are mean ± SD in millimeters.

TABLE 4. BONY THICKNESSES OVER SURROUNDING STRUCTURES

	Complete Sellar	*Incomplete Sellar*	*Presellar*
Optic nerve	0.2 ± 0.1	0.6 ± 0.5	0.3
Segment 1 of ICA	0.3 ± 0.2	0.2 ± 0.2	
Segment 3 of ICA	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.4
Maxillary nerve	0.2 ± 0.2	0.4 ± 0.3	
Vidian nerve	0.2 ± 0.2	0.3 ± 0.1	

Data are mean ± SD in millimeters.

over the optic nerve was marginally thicker than that found for the complete sellar type: 0.6 ± 0.5 mm versus 0.2 ± 0.1 mm, respectively.

For the remaining structures, the thicknesses were nearly identical between the complete and incomplete sellar types. These results are summarized in Table 4.

DISCUSSION

The sphenoid sinus is rarely pneumatized at birth. The sinus begins to pneumatize after 4 years of age and completes its pneumatization between the ages of 6 and 12 years.[10] As mentioned previously, the degree of sphenoid sinus pneumatization varies between the conchal and complete sellar types; this fact is very important when one is approaching the pituitary gland via the transsphenoidal route.[8] For the conchal and presellar types, access via the transsphenoidal route is very difficult, whereas access is much easier for the sellar type. There is also a difference in ease of access between the complete and incomplete sellar types. It is possible to expose the entire floor of the pituitary gland only for the complete sellar type.

This classification of the sphenoid sinus is important not only for pituitary surgery, but also for evaluation of the structures surrounding the sphenoid sinus. As the sphenoid sinus becomes better pneumatized, it is more likely that the surrounding structures will bulge into the sphenoid sinus; if this occurs, the probability that these structures will be damaged during surgery increases. Therefore, the overall prevalence of bulging and dehiscence in the surrounding structures is less meaningful than is the individualized prevalence based on sphenoid type. However, few studies have investigated this idea. This lack of literature was the major impetus for the present study.

The sphenoid sinuses were classified into 4 types in this study. However, the conchal and presellar types were so rare that we considered them together for analysis. As we predicted, the prevalence of bulging of the surrounding structures differed according to sphenoid sinus type. Bulging was frequently observed for the complete sellar type, whereas bulging was seldom found for the presellar and conchal types. It is much easier to uncover the sphenoid sinus once it has been well pneumatized, although the risk of damage also increases proportionally to the extent of pneumatization.

The optic nerve has been reported to bulge into the sphenoid sinus in 88% to 100% of cases[2,5,8]; however, we observed bulging of the optic nerve in only 56% of cases in the present study. This discrepancy may be due to ethnic differences, as most of the previous studies were based on Caucasian populations. Sethi et al[8] reported that the ICA bulged out in 93% of cases, whereas Tan and Ong[9] reported ICA bulging in 67.7% of cases. We subdivided the ICA into 3 segments and analyzed each segment separately. The overall bulging prevalence for segment 1 was 34%, and that for segment 3 was 65%. The results for segment 3 are nearly identical to the results reported by Tan and Ong.[9] The prevalences of bulging in the maxillary and vidian nerves were 41% and 52%, respectively; these results are similar to those reported previously.[7,9]

Attention should be paid to potential dehiscence, because neurovascular structures may be damaged more easily during an operation if they have undergone dehiscence. However, the prevalence of dehiscence was very low for all structures in our study: 3.6% for the optic nerve, 1.5% for segment 3 of the ICA, and 0% for segment 1 of the ICA. These results are very different from those reported by Stammberger,[11] who found that in cadavers, the ICA had a rate of dehiscence of 25% and the optic nerve had a rate of dehiscence of 6%. Unal et al[1] reported dehiscence rates of 5.3% for the ICA and 8% for the optic nerve, and Davoodi et al[4] reported rates of ICA dehiscence of 39% in male subjects and 44.9% in female subjects, with optic nerve dehiscence rates of 28.5% in male subjects and 46% in female subjects. That both of these studies were based on computed tomography scans is likely the reason dehiscence was observed so frequently. Because thin bone is rarely detected on a computed tomography scan, it may easily be mistaken for dehiscence.

The most anterior bulging point of the optic nerve is typically very close to the anterior and superior walls of the sphenoid sinus. In many cases, we observed that the most anterior bulging point of the optic nerve was in direct contact with the walls; careful attention should therefore be focused on not damaging the optic nerve in removing the anterior wall of the sphenoid sinus. Segment 3 of the ICA was remote from the anterior wall. The bone over the surrounding structures was very thin: 0.2 to 0.3 mm for the complete sellar type and 0.2 to 0.6 mm for the incomplete sellar type. As such, the bony wall over the structures cannot act as a reliable physical shield.

In addition, great attention should be paid to the Onodi cell in performing endoscopic sphenoid sinus surgery. The Onodi cell is a sphenoethmoidal air cell that is positioned posterolateral to the sphenoid sinus. The optic nerve is commonly exposed in this cell and is therefore at great risk of being damaged. Because the prevalence of Onodi cells is higher among Asians (47.9%) than in Caucasians (9% to 12%),[9] much more attention is needed in operating on patients of Asian origin. We also found Onodi cells in 18 hemisected heads among the 118 (15.3%). The reason we excluded Onodi cells in this study was that our focus was on the inside of the sphenoid sinus, and we were interested in determining the association between the degree of pneumatization and the bulging of the surrounding structures.

CONCLUSIONS

The prevalence of bulging in the optic nerve, the ICA, and the maxillary and vidian nerves depends on the degree of sphenoid sinus pneumatization. Bulging in the surrounding structures increases in proportion to the degree of pneumatization. Furthermore, the bony wall over these structures is very thin. During surgery, careful attention must be paid so as not to damage these structures during manipulation of the sinus; this is especially true for the optic nerve, which is very close to the anterior wall of the sphenoid sinus.

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