Variations in sphenoid sinus anatomy with special emphasis on pneumatization and endoscopic anatomic distances

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ABSTRACT

Objectives: The purpose of this study was to present the morphometry and pneumatization of the sphenoid sinus in detail for the neurosurgeon for transnasal approach to the hypophyseal tumors and especially for functional endoscopic sinus surgery.

Methods: One hundred and eighty midsagittal magnetic resonance images, 48 bones and 29 hemi-sectioned cadaveric heads obtained from Ege University, Faculty of Medicine, Departments of Anatomy and Radiology were used in 2003. The sphenoid sinuses were classified into sellar, pre-sellar, conchal and post-sellar types according to the extent of their posterior limits. Different measurements based on the surgical approach and sinus size were performed.

Results: Conchal type sinus was observed in 1.9%, pre-sellar type 9%, sellar type 52.9% and post-sellar type 36.2% of the specimens. Conchal type sphenoid sinus was not observed in males, but in 1.7% of females. Pre-sellar type was observed in 5.6% of males and 2.8% of females. Sellar type was found in 24.4% of males and 23.9% females, and post-sellar type in 19.5% of males and 22.2% of females. The sphenoid sinus length at the upper and lower parts was 13.51±3.25mm and 24.57±6.65mm. The sphenoid sinus height at the anterior and posterior parts was 21.27±4.25mm and 14.5±4.07mm. Distance from the ostium to limen was 56.6±5.6mm and from ostium to sill was 64.6±6.11mm in cadaveric specimens. In MR images, distance from the ostium to the sill was 68.7±5.9mm and from sella to sill 82.8±6.2mm.

Conclusion: Sphenoid sinus variations observed in pneumatization, size, localization and shape are important in providing a better surgical approach and avoiding surgical complications.

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Sphenoid sinus is one of the paranasal sinuses subject to remarkable inter- and intra-subject variations in shape and localization. It consists of 2 unequal parts separated by a bony septum, and is normally contained within the body of the sphenoid occasionally extending laterally into the greater and lesser wings and pterygoid plates of the sphenoid bone and posteriorly to the clivus.[1] The overall size varies from 0.5-30 ml, with an average of 6-7.5 ml.[2-4] The degree of pneumatization of the sphenoid sinus varies considerably, and 3 main types are recognized, first described by Hamberger et al.[5] In the sellar type, a sellar floor bulges into a well-developed sinus, pneumatization extending beyond the tuberculum sellae. Pneumatization extends only as far posteriorly as the tuberculum sellae in the pre-sellar type, where the sphenoid sinus is usually small and sometimes rudimentary.

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In the conchal type, the sphenoid sinus is characterized by a very small sinus, separated from the sella turcica by a wall approximately 10 mm thick. Another pattern of pneumatization is the post-sellar (occipito-sphenoid) type, where the sinus is over pneumatized and the posterior border extending beyond dorsum sellae, even across the occipital synchondrosis.[6] The anatomical relations of the sphenoid sinus are important to neurosurgeons, especially as the sinus forms the most accessible approach to the pituitary gland. Lateral to the sphenoid sinus lays the superior orbital fissure anteriorly, and the cavernous sinus posteriorly.[7] Functional endoscopic sinus surgery has become of particular importance for the otorhinolaryngologist and is preferred for the treatment of non-neoplastic pathologies of paranasal sinuses, especially for chronic infective and polypoid sinusitis. Clear understanding of sphenoid sinus anatomy and anatomical variants provides a better surgical approach in functionally endoscopic sinus surgery and also in endoscopic endonasal transsphenoidal approach for treatment of lesions involving the region of tuberculum sellae, planum sphenoidale, supradiaphragmatic intradural space, and medial cavernous sinus. The present work was designed to study the anatomy of the sphenoid sinus in detail for the neurosurgeon to provide a better surgical approach and avoid operative complications.

Methods. The sphenoid sinus was examined in 48 mid-sagittal adult dried bones, 29 mid-sagittal male adult cadaveric heads and MRI of 180 patients without apparent indications of sinus disease and surgery (mean age 36, range 20-75; 89 males, 91 females) obtained from Ege University, Faculty of Medicine Departments of Anatomy and Radiology, in 2003. The MR images were taken using a standard head coil applicator of a GE Vectra (General Electric, USA) operating at 0.5 Tesla T1-weighted midsagittal images (TR: 500 msec., TE: 20 msec., NEX: 1-2, and matrix: 160X224, slice thickness: 5 mm) were used for evaluation. The sphenoid sinus was measured using a caliper with magnification correction. For bony and cadaver specimens, measurements were taken using a steel caliper. The sphenoid sinus length at the upper and lower portion of the sinus and the sinus height at the anterior and posterior portion of the sinus were measured on bony and cadaveric and MR specimens. The distances from limen nasi and the sill to the sinus ostium were measured in cadaveric specimens, and the distance from the sill to the anterior wall of the sphenoid sinus and to the anterior sellar wall were measured in MR images (**Figure 1**). Extent of sphenoid sinus pneumatization types were determined using 2 perpendicular lines A and B running through tuberculum sellae and dorsum sellae (**Figure 1**). The posterior border of the sinus reaches the line A in pre-sellar type, but not in conchal type. In sellar type, the sinus is well pneumatized and the posterior border of the sinus reaches the line B. The sinus is over pneumatized, the posterior border encroaching the clivus in post-sellar type (**Figure 2**).

Results. Variability in the shape and size of the sphenoid sinus was observed in bony, cadaveric and MRI image specimens. The sphenoid sinus length at the upper and lower parts of the sinus and sinus height for bony and cadaveric specimens and MR images, and the distances from limen nasi and the sill to the sinus ostium for cadaveric specimens and from the sill to the anterior sinus wall and to the anterior sellar wall for MR images are shown in **Tables 1 & 2**. The sphenoid sinus length at the upper and lower parts in bony, cadaveric and MR imaging specimens was 13.51±3.25 mm (min. 7.13-max. 30.7) and 24.57±6.65 mm (min. 7.13-max. 39.05). The sphenoid sinus height at the anterior and posterior parts was 21.27±4.25 mm (min. 7.4-max. 29.06 mm) and 14.5±4.07 mm (min. 7.04-max. 29.06 mm). Four different types of sphenoid sinus pneumatization were observed (**Figures 3 & 4**). These pneumatization types in bony, cadaveric and MR imaging specimens are shown in **Table 3**. Sex differences in the pneumatization of sphenoid sinus were assessed in MR images. Conchal type sphenoid sinus was not observed in males, but was present in 3 (1.7%) females. Pre-sellar type was observed in 10 (5.6%) males and 5 (2.8%) females. Sellar type was found in 44 males (24.4%) and 43 (23.9%) females, post-sellar type in 35 males (19.5%) and 40 (22.2%) females. Sphenoid sinus septation was investigated in bony specimens. A single major septum was observed in 22 (46%) specimens, 14 (64%) of these being off the midline. The incidence of accessory septae within the sinus was 52% (25 specimens).

Discussion. There is a wide range of normal variation in the pneumatization, size and the septation of the sphenoid sinuses. These variations may affect its relations to surrounding structures, especially the pituitary gland, the carotid artery, the cavernous sinus and the optic nerve. Some normal variations may mimic disease and cause misdiagnosis, and in some cases impede the surgical approach.[6] A highly pneumatized sphenoid sinus may attenuate the bone over the lateral wall placing the optic nerve and carotid artery at greater risk.[8] Pre-sellar type sphenoid sinus with no obvious bulge of the sellar floor into the sphenoid sinus is disadvantageous to transsphenoidal approach.[9] When the sinus is too small the operation is strongly contraindicated.[3]

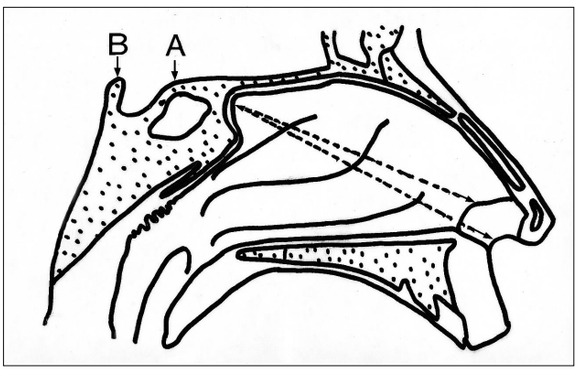

Figure 1 - Distance from limen nasi to sinus ostium/anterior sinus wall and from the sill to the sinus ostium. A - line running through tuberculum sellae. B - line running through dorsum sellae.

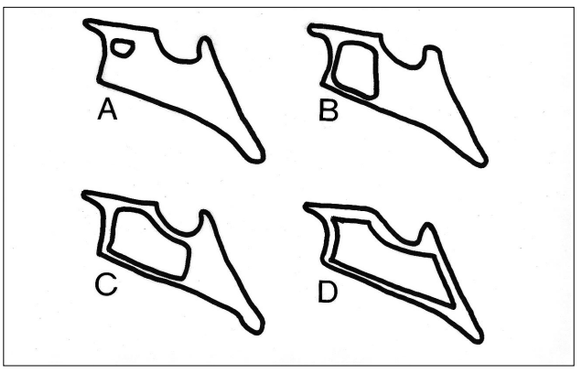

Figure 2 - Pneumatization types of the sphenoid sinus. A – conchal, B - pre-sellar, C – sellar. D - post-sellar.

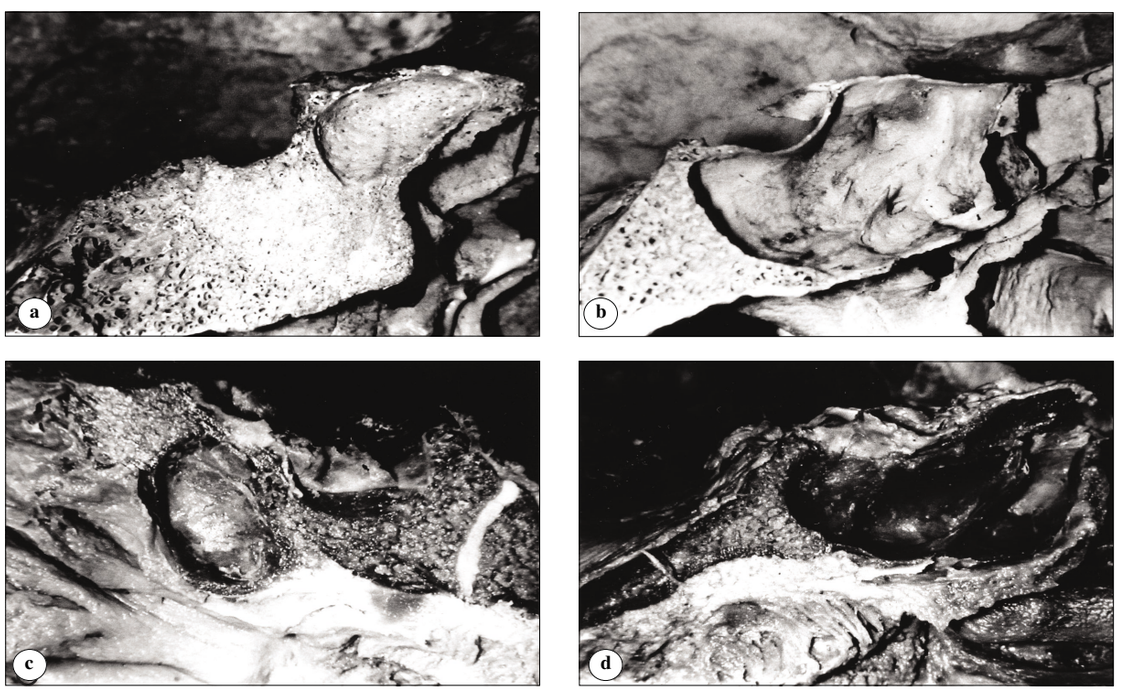

Figure 3 - Sphenoid sinus pneumatization types in bony and cadaveric specimens. **a)** pre-sellar type in bony specimen. **b)** sellar type in bony specimen. **c)** pre-sellar type in cadaveric specimen. **d)** sellar type in cadaveric specimen.

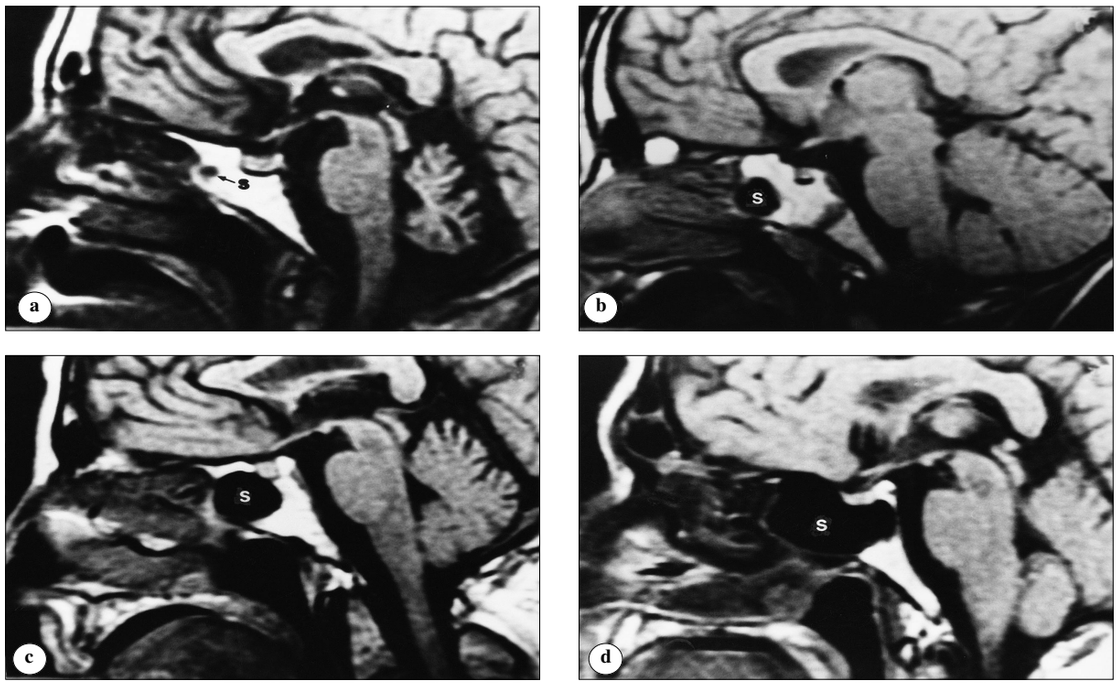

Figure 4 - Sphenoid sinus pneumatization in MR images. **a)** conchal type. **b)** pre-sellar type. **c)** sellar type. **d)** post-sellar type. S - sphenoid sinus.

Table 1 - Length and height of the sphenoid sinus on bony and cadaveric specimens, and the distances from limen nasi and the sill to the sinus ostium in cadaveric specimens.

Measurements	Specimens	Mean ± SD (mm)	Min-Max (mm)
Length (upper)	bones	14.7 ± 2.6	11.2-18.1
	cadavers	11.5 ± 1.9	9.2-14.1
Length (lower)	bones	26.4 ± 7.9	11.2-36.8
	cadavers	24.1 ± 6.8	11.7-35.4
Height (anterior)	bones	19.6 ± 3.5	14.6-24.7
	cadavers	17.8 ± 4.3	10.7-26.2
Height (posterior)	bones	12.6 ± 1.9	9.6-15.1
	cadavers	12.4 ± 1.8	10-14.7
Distance from ostium to limen	cadavers	56.6 ± 5.6	48.6-67.2
Distance from ostium to sill	cadavers	64.6 ± 6.11	55-82

Table 2 - Length and height of the sphenoid sinus and the distances from the sill to the anterior wall of the sphenoid sinus and to the anterior sellar wall on MR images.

Measurements	Gender	Mean ± SD (mm)	Min-Max (mm)
Length (upper)	male	14.1 ± 3.8	7.1-30.7
	female	13 ± 2.7	8.4-25
	total	13.6 ± 3.3	7.1-30.7
Length (lower)	male	24.8 ± 6.7	7.1-36.3
	female	24.6 ± 6.5	9.3-39
	total	24.5 ± 6.6	7.1-39
Height (anterior)	male	21.8 ± 4.5	7.9-33.6
	female	21.5 ± 3.8	9.3-30.2
	total	21.6 ± 4.2	7.9-33.6
Height (posterior)	male	15.1 ± 4.1	7.0-24.8
	female	14.5 ± 4.4	7.1-29.1
	total	14.8 ± 4.3	7-29.1
Distance from ostium to limen	male	71.2 ± 5.7	56.8-82.7
	female	66.2 ± 5.2	47.7-79.5
	total	68.7 ± 5.9	47.7-82.7
Distance from ostium to sill	male	85.6 ± 5.8	67.2-100.6
	female	80.2 ± 5.5	67.1-96.5
	total	82.8 ± 6.2	67.1-100.6

Table 3 - Sphenoid sinus types in bony, cadaveric specimens and MR images.

Sinus types	Bones	Cadavers	MR images	Total
Conchal	2 (4.2%)	-	3 (1.7%)	5 (1.9%)
Pre-sellar	4 (8.3%)	4 (13.8%)	15 (8.3%)	23 (9%)
Sellar	29 (60.4%)	20 (69%)	87 (48.3%)	136 (52.9%)
Post-sellar	13 (27.1%)	5 (17.2%)	75 (41.7%)	93 (36.2%)

The sellar type is the ideal anatomic configuration when the sella turcica is approached from below, since the floor bulges into direct view of the operative field.[10] On the other hand, post-sellar type with roomy sinuses, long intercarotid distance and thin anterior wall and floor of sella turcica, offers optimum conditions for trans-sphenoid hypophysectomy.[3] The conchal type presents an obvious difficulty to surgery because a bony barrier obliterates the view of the sella turcica, although it is not a contraindication to a transsphenoidal approach to the sella.[10] The incidence of various types of pneumatization, as found by different authors, is summarized in **Table 4**. The classification of pneumatization of the sphenoid sinus varies in these studies. In some of the previous studies[3,5,6,9,11,12] sellar type corresponds to sellar and post-sellar types, and in other studies[3,9,12,13] the designation pre-sellar largely covers the conchal and pre-sellar types.

The length and height of the sinus were measured 4-44 mm and 5-33 mm, by Van Alyea.[2] Elwany et al[3] measured the length as 1.2-1.8 mm (mean 1.6 mm) for the pre-sellar type and 2.6-3.9 mm (mean 3.1 mm) for post-sellar type and the height as 1-1.6 mm (mean 1.4 mm) for the pre-sellar type and 2.4-2.9 (mean 2.6 mm) for the post-sellar type. Ouaknine and Hardy[10] measured the sphenoid sinus length as 10-22 mm (mean 15 mm). The distance from the limen to the sinus ostium was measured as 56.5 mm.[14] Measurements of these studies are in accordance with the findings of our study.

The bony septum separating the 2 sinuses is rarely in the midline, therefore, it should not be used as a reference of midline. Sphenoid sinus with no major septum or with the major septum well off midline is considered disadvantageous to transsphenoidal approach.[9] Ouaknine and Hardy[10] observed a single major septum in 75% of 100 cadavers and off the midline in 55% which, is close to our findings. Accessory septae may also be present which partially divide the sinus into several large, intercommunicating cells. The incidence of accessory septae is 52% in our specimens, 30% in the study of Dharambir et al,[12] and 56% in the study of Ouaknine and Hardy.[10]

The anatomical relations of the sphenoid sinus are of utmost importance. Superiorly, the sphenoid sinus is related to sella turcica, causing sphenoid lesions which erodes the skull base and extends into the sella, and sellar lesions such as pituitary adenomas inferiorly into the sphenoid sinus. Inferiorly, sphenoid sinus is in close proximity to the nasopharynx, so sphenoid lesions can invade the nasopharynx and nasopharyngeal lesions can invade the sphenoid sinus. The cavernous sinuses and optic nerve are intimately related to the lateral wall, infections of the sinuses can spread to the cavernous sinus. The relationship of the sphenoid sinus is a prerequisite to safe and effective surgical treatment of lesions of the region, and lack of orientation during dissection may cause surgical complications.[3,15]

In conclusion, sphenoid sinus variations observed in pneumatization, size and localization are important in providing a better surgical approach in functional endoscopic sinus surgery and endoscopic endonasal transsphenoidal approach and for avoiding surgical complications. This study provides anatomy of the sphenoid sinus on a large series of bony, cadaveric and MR specimens as a guide for neurosurgeons and otorhinolaryngologists to reduce mortality and morbidity.

Table 4 - Pneumatization types of sphenoid sinus studied by various authors.

Reference	Conchal	Pre-sellar	Sellar	Post-sellar
Renn and Rhoton (1957), n=50	-	20%	80%	-
Hamberger (1961), n= 163	3%	11%	86%	-
Hammer and Radberg (1961), n=161	2.5%	11%	86%	-
Bruneton et al(1979), n=200	-	5.5%	80.5%	14%
Elwany et al (1983), n=500	-	29%	71%	-
Banna and Olutola (1983), n=70	2.9%	11.4%	85.7%	-
Ouaknine and Hardy (1987), n=266	3%	12%	85%	-
Dharambir et al (1995), n=30	-	27%	73%	-
Liu et al (2002), n=45	2%	20%	78%	-
Kayalioglu et al (2003), n=257	1.9%	9%	52.9%	36.2%

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