Anatomic Variations of the Sphenoid Sinus and Their Impact on Trans-sphenoid Pituitary Surgery

Ossama Hamid, M.D.,¹ Lobna El Fiky, M.D.,¹ Ossama Hassan, M.D.,¹
Ali Kotb, M.D.,² and Sahar El Fiky, M.D.³

ABSTRACT

Introduction: The trans-sphenoid access to the pituitary gland is becoming the most common approach for pituitary adenomas. Preoperative evaluation of the anatomy of the sphenoid sinus by computed tomography (CT) scan and magnetic resonance imaging (MRI) is a routine procedure and can direct the surgical decision. **Purpose:** This work determines the incidence of the different anatomical variations of the sphenoid sinus as detected by MRI and CT scan and their impact on the approach. **Methods:** The CT scan and MRI of 296 patients operated for pituitary adenomas via a trans-sphenoid approach were retrospectively reviewed regarding the different anatomical variations of the sphenoid sinus: degree of pneumatization, sellar configuration, septation pattern, and the intercarotid distance. **Results:** There were 6 cases with conchal pneumatization, 62 patients with presellar, 162 patients with sellar, and 66 patients with postsellar pneumatization. There was sellar bulge in 232 patients, whereas this bulge was absent in 64 patients. There was no intersphenoid sinus septum in 32 patients, a single intersphenoid septum in 212 patients, and an accessory septum in 32 patients. Intraoperatively, the sellar bulge was marked in 189 cases and was mild in 43 cases. **Discussion:** The pattern of pneumatization of the sphenoid sinus significantly affects the safe access to the sella. A highly pneumatized sphenoid sinus may distort the anatomic configuration, so in these cases it is extremely important to be aware of the midline when opening the sella to avoid accidental injury to the carotid and optic nerves. The sellar bulge is considered one of the most important surgical landmarks, facilitating the access to the sella. The surgical position of the patient is also a crucial point to avoid superior or posterior misdirection with resultant complications. It is wise to use extreme caution while removing the terminal septum. **Conclusion:** Different anatomical configurations of the sphenoid sinus can seriously affect the access to the sella via the nose. The surgeon should be aware of these findings preoperatively to reach the sella safely and effectively.

¹Department of Otorhinolaryngology, ²Department of Neurosurgery, ³Department of Radiodiagnosis, Ain Shams University, Cairo, Egypt.

Address for correspondence and reprint requests: Lobna El Fiky, M.D., Assistant Professor of ORL, Ain Shams University, 48 Ibn El Nafees Street, 6th District, Madinet Nasr, 11371 Cairo, Egypt (e-mail: lfiky@entainshams.com).

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The trans-sphenoid route is considered the standard approach for surgery of pituitary adenomas.¹ The different routes to the sella: transthemoid, transnasal, trans-septal, whether microscopic or endoscopic, ultimately pass through the sphenoid sinus to reach the sella. Therefore the anatomical variations of the sphenoid sinus have major impact on the surgical access and the possibility of complications. Knowing the details of the anatomy of the sphenoid sinus and the extent of pneumatization can guide the surgeon through difficult corners of the approach.

The wide availability of computed tomographic scanning (CT) as well as magnetic resonance imaging (MRI) makes it easy to study the sphenoid sinus anatomy preoperatively.

The aims of this study are to evaluate the incidence of the different anatomical variations of the sphenoid sinus that are relevant to trans-sphenoid pituitary surgery as detected by preoperative MRI and CT scans and to highlight the impact of these variations on this type of surgery.

MATERIALS AND METHODS

A retrospective cross-sectional study was done on 296 patients operated for pituitary adenomas at Ain Shams University hospitals, Cairo, Egypt, in the period between January 1995 and April 2004. There were 160 males and 136 females, with an age range of 18 to 63 years (mean, 48 ± 14.7 yrs). The size of the tumor ranged from 7 mm to 7 cm. Nonfunctioning pituitary adenomas represented 107 cases and functioning adenomas represented the remaining 189 cases. Before surgery, all patients had complete clinical and neurological examinations and hormonal and ophthalmologic evaluations, including visual acuity and field of vision examina-

tions. No patient had previous sinus surgery or craniofacial trauma.

A preoperative contrast-enhanced CT scan, in both axial and coronal planes, was obtained in all cases. A preoperative MRI was routinely done using a standard head coil of a 1.5-T scanner, contiguous 3 mm thick in axial, coronal, and sagittal planes. In every patient T1-weighted pre- and postcontrast sequences and fast spin-echo T2-weighted sequences were obtained. In cases of Cushing's disease and microprolactinoma, the tumor was only visualized during a dynamic contrast MRI. This was done in 11 cases. The CT scan and MRI of these patients were reviewed retrospectively for the following four anatomical variations.

Degree of pneumatization: Conchal, presellar, sellar, and postsellar.^{2,3} Type of sphenoid sinus pneumatization depends on the position of the sinus in relation to the sella turcica. This was best seen in the sagittal films of MRI.

Sellar configuration: To evaluate the prominence (well defined) or absence (ill defined) of sellar bulge. This was determined according to the degree of pneumatization of the sinus in relation to the floor of the sella. The pneumatization of the planum sphenoidale and the Dorsum sellae, namely in the sagittal MRI, were also noted.

Septation: The presence or absence of an intersphenoid septum: a single intersinus septum and the place of its insertion, whether it is in the sellar floor, at the carotid canal, or at the optic canal. The same was done if there was more than one septum (accessory septum). This was best evaluated on both axial and coronal CT scans.

The intercarotid distance: was measured in mm between the signal void intracavernous ICA in midsellar coronal MRI.

All these patients underwent trans-sphenoid pituitary surgery via a team of otolaryngologists and neurosurgeons. The different anatomical variations were analyzed preoperatively and evaluated intra-operatively to assess their effect on the surgical exposure.

RESULTS

Radiological Findings

Regarding the degree of pneumatization of the sphenoid sinus, there were 6 cases with conchal pneumatization (2%) (Fig. 1), 62 patients with presellar pneumatization (21%) (Fig. 2), 162 patients with sellar type (54.7%), and 66 patients with postsellar pneumatization (22.3%) (Fig. 3). The lateral pneumatization of the greater wing of the sphenoid, leading to a capacious sinus, was found in 47 cases (15.9%) (Fig. 4).

There was prominent sellar bulge in 222 patients (75%) (Fig. 3), whereas this bulge was ill defined and inappreciable in 74 patients (25%) (Fig. 2). Dorsum sella pneumatization was visualized in 40 patients (60%) out of 66 with postsellar

Figure 2 T1-weighted magnetic resonance imaging of the sella, sagittal cuts, showing presellar pneumatization of the sphenoid sinus with absent sellar bulge.

pneumatization (Fig. 3), whereas planum sphenoidale pneumatization was evident in 108 patients (48.2%) out of 224 patients having sellar and presellar pneumatization (Fig. 5).

The evaluation of axial cuts of these patients revealed no septum in 32 patients (10.8%) and a single intersphenoid septum in 212 patients (71.6%) (Fig. 6). The insertion of the septum was at the

Figure 1 Computed tomography scan of the sella, coronal cuts, bone window, showing conchal or absence of pneumatization of the sphenoid sinus.

Figure 3 T1-weighted magnetic resonance imaging of the sella, showing postsellar pneumatization of the sphenoid sinus, with prominent sellar bulge (arrow) and a pneumatized dorsum sellae (arrowhead).

Figure 4 Computed tomography scan of the sella, coronal cuts, bone window, showing lateral pneumatization of the greater wings of the sphenoid sinus and multiple sphenoid sinus septa.

lowest point in the sellar floor, in a central point, in 198 patients (66.9%). The intersphenoid septum pointed toward the carotid canal in 14 patients (4.7%, right = 8 patients, left = 6 patients) (Fig. 6). An accessory septum was also seen in 32 patients (10.8%). This accessory septum was attached to the sellar floor in 12 patients and extended into the carotid canal in 20 patients (right = 4 patients, left = 16 patients). Multiple intersphenoid septa were found in 20 patients (6.8%) (Fig. 4). These were transverse, medial, or lateral septa. The intercarotid distance ranged from 12 to 30 mm (mean, 23 mm).

Figure 5 T1-weighted magnetic resonance imaging of the sella, showing a postsellar pneumatization of the sphenoid sinus and a pneumatization of the planum sphenoidale (arrowhead).

Figure 6 T1-weighted magnetic resonance imaging of the sella, showing an intersphenoid septum pointing toward the left internal carotid artery.

Surgical Implications

The degree of pneumatization of the sphenoid was the prime preoperative concern for accessing the sella. Extremes of pneumatization were carefully assessed. The six cases with conchal type or non-pneumatized sphenoid were accessed safely using a C-arm fluoroscope intraoperatively together with initial burring of the sellar floor, followed by total removal with the punches, which is a safer procedure than using a chisel.

Intraoperatively, the sellar bulge was seen in all the cases diagnosed by CT scan and MRI. However, this bulge was well defined in 179 cases and was less apparent in 43 cases. The access to the sella was straightforward in these cases and was further facilitated when the pathology caused thinning or breaching of the sellar floor; this occurred in 86 cases. In 74 cases, the bulge was ill defined, necessitating the use of a C-arm fluoroscope intraoperatively. It is worth mentioning that most of these cases ($n = 47$) were a hyperpneumatized sphenoid sinus.

All intersphenoid and accessory septa were carefully removed under vision, until the sellar bulge was clearly seen. Care was taken in removing the lateral attachment of these septa, especially

when the preoperative imaging showed that it ended on the carotid prominence.

We had 21 cases of cerebrospinal fluid (CSF) leak. In 5 cases, the leak was during exposure of the sellar floor. Three cases were from the anterior cranial fossa and 2 were from the posterior cranial fossa. An additional 16 cases developed CSF leak intraoperatively through the diaphragma sellae. In all these cases, packing of the sella using muscle, fat, and fascia lata was done. The leak was stopped by conservative postoperative treatment. Only in 3 cases of CSF leak from the diaphragma sellae was reoperation needed. In our series, we had no vascular compromise of the carotid artery nor any accidents related to the optic nerve.

DISCUSSION

Trans-sphenoid surgery has become the standard approach for the surgical removal of pituitary adenoma. The versatility of the trans-sphenoid approach is based on solid foundations: it is the least traumatic route to the sella turcica, it avoids brain retraction, and it provides excellent visualization of the pituitary gland and related lesions. It also offers a lower morbidity and mortality rate when compared with a transcranial procedure.¹

High-resolution CT scan may show pneumatization of the sphenoid sinuses as early as 2 years of age. Pneumatization progresses in an inferior and posterolateral direction. The pneumatized basiphosphoid plate often extends to, but not past, the spheno-occipital synchondrosis in the mature sphenoid sinus. The sinus attains its mature size by the age of 14 years.⁴ The degree of pneumatization of the sphenoid sinus varies considerably. The sella turcica is seen as a prominence in the roof of a well-pneumatized sphenoid sinus and is known as the sellar bulge.⁵ This is considered one of the most important surgical landmarks to the sellar floor.

The conchal nonpneumatized sphenoid was always considered to be a contraindication to the trans-sphenoid approach to the sella. It usually

makes this approach less favorable.⁶ However, with the surgeon informed in advance, different tools can make such an approach feasible. The availability of intraoperative fluoroscopic imaging or intraoperative navigational devices can be used to confirm surgical landmarks, making it possible to access the sella through the sphenoid sinus safely even in these poorly pneumatized cases.⁷ In our series, the 6 conchal or nonpneumatized sphenoid sinuses were accessed safely. The bone was cancellous and easily removed with punches after initial drilling of the sellar floor. The operative time was, of course, longer. In these cases, the surgeon should consider the size of the tumor: small and intrasellar tumors can be completely removed, but with larger tumors, transcranial approaches should be considered to allow safe and adequate removal.

On the other hand, a highly pneumatized sphenoid sinus may distort the anatomic configuration and may attenuate the bone over the lateral wall, placing the optic nerve and carotid artery at greater risk.⁸ In our experience, these cases may show minimal if any sellar bulge. In addition, the large cavity is in large part related to the irregular thin middle cranial fossa bony floor that can be mistaken for the sellar floor and can be easily traumatized during surgery. The C-arm can even be misleading in such cases, as it allows only craniocaudal localization, without any lateral perspective. In the absence of the sellar bulge, especially with a hyperpneumatized sinus, it is extremely important to accurately determine the midline when opening the sella. This can be confirmed from the base of the sphenoid inferiorly (rostrum-vomer) or from the remaining anterior sphenoid wall-septum attachment superiorly. One can also follow the floor of the nasal septum as an indication of the midline.⁹

The postsellar pneumatization of the sphenoid and that of the Dorsum sella may result in penetrating the posterior wall of the sphenoid, with resultant CSF leak. This occurred in two cases in our series. This can result from excessive dissection along the nasal floor, as the speculum will tend to slide downward, directing the surgeon to the posteriorly pneumatized recess.

Table 1 Different Findings in Different Studies

Reference	Finding					
	Conchal Pneumatization	Sellar Pneumatization	No Intersphenoid Septum	Single Intersphenoid Septum	Accessory Septum	Multiple Septa
Liu et al ¹⁰	2%	78%	—	—	—	—
Banna and Olutola ¹¹	2.8%	85.7%	11.4%	—	14%	—
Szolar et al ¹²	—	—	—	77%	—	—
Present Study	2%	77%	10.8%	71.6%	10.8%	8.7%

The surgical position of the patient is also a crucial point for proper visualization. The pneumatization of the planum sphenoidale, together with the flat position of the patient and minimal neck flexion, will direct the speculum anterosuperiorly. This can result in breach of the anterior cranial fossa with resultant CSF leak.

In the current study, the most common type of pneumatization of the sphenoid sinus was the sellar type (54.7%). The conchal pneumatization was the least frequent (2%) and this agrees with different studies (Table 1).^{10–12}

The sellar bulge, planum sphenoidale pneumatization, and dorsum sellae pneumatization were found in an incidence of 78.3%, 80.4%, and 60% respectively. To our knowledge no previous studies commented on these findings.

There is usually an intersphenoid septum. This septum must be removed to expose the floor of the sella. The septum usually deviates to one side, dividing the sinus into two unequal cavities, thereby resulting in an asymmetrical appearance of the sella turcica floor. In 32 to 40% of patients the septum deviates quite laterally and terminates on the carotid artery.¹³ In this situation it is wise to use extreme caution while removing the terminal septum in order to prevent accidental and disastrous injury to the carotid artery.¹⁴ The terminal septa are usually inserted lateral to the sellar floor and may not require complete removal for adequate exposure.⁹

The septa of the sphenoid sinus were found to be variable (Table 1). Multiple septa were found in only 8.7% of cases; these septa could have been transverse or vertical and some were difficult to remove. The intercarotid distance was found to be

12 to 30 mm. In cases of large macroadenoma extending outside the sella, this distance was usually enlarged, making the dural exposure enough to access the entire tumor and at the same time avoiding exposure of the carotid artery. The mean of this distance in our study was 23 mm, which is higher than in most of the literature.¹⁵ This can be explained, as the majority of our cases were large macroadenomas. However, in small intrasellar adenomas, this distance was found to be less than 20 mm. In cases approaching 12 mm, caution should be taken not to extend the dural incision laterally to avoid injuring the carotid artery. If the intercarotid distance is small and a large suprasellar or parasellar tumor is present, one should consider a transcranial approach to avoid complications and ensure rather complete removal of the tumor.¹⁶

Careful planning of trans-sphenoid access to the sella is possible with modern imaging modalities. Different anatomical variations can be detected and problems can be anticipated. In order to avoid morbid consequences during surgery, it is imperative that clinicians determine the location and extent of the walls of the sphenoid sinus and its relationship to adjacent vital structures whenever trans-sphenoid pituitary surgery is contemplated. The few surgical tips related to the anatomical configuration of the sphenoid sinus are important to keep in mind during such an approach.

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