Anatomical Considerations of the Endonasal Transsphenoidal Approach

Considerações anatômicas na abordagem transesfenoidal endonasal

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ABSTRACT

The sellar contents are separated from the sphenoidal sinus by a thin sheath of bone that comprises the sellar floor, making the transsphenoidal approach the most used surgical route to intrasellar lesions. The transsphenoidal approach can be initiated in three different ways: 1) cutting the mucosa over the alveolar part of maxilla (sublabial transsphenoidal), 2) cutting along the anterior nasal mucosa adjacent to the columella (transseptal transsphenoidal), and 3) cutting the mucosa over the sphenoidal rostrum (endonasal transsphenoidal). Each cavernous sinus has four dural walls. The lateral, superior and posterior walls are composed of endosteal and periosteal dura leaflets. Unlike the other dural walls, the medial wall is formed of a single, thin dural sheath, an anatomical fact that helps explain the lateral expansion of a pituitary adenoma. In the center, the diaphragm sellae has an opening through which the infundibulum courses, linking the pituitary gland to the floor of the third ventricle. The morphology of this opening is quite variable among individuals. On average, the anteroposterior distance of the diaphragm opening was 7.26 mm + 1.99 mm, varying from 3.4 mm up to 10.7 mm. The lateral distance of the diaphragm opening was 7.33 mm + 2.79 mm, varying from 2.8 mm up to 14.1 mm.

Key-words: anatomy, diaphragma sellae, pituitary gland, sphenoid sinus, transsphenoidal approach.

RESÚMEN

Los contenidos de la silla turca se encuentran separados del seno esfenoidal por una delgada lámina de hueso que es el piso selar, haciendo que la vía transesfenoidal sea la ruta quirúrgica más utilizada para lesiones intraselares. El abordaje transesfenoidal puede ser iniciado de tres diferentes maneras: 1) cortando la mucosa sobre la parte alveolar del maxilar superior (sublabial transesfenoidal), 2) cortando la mucosa nasal anterior, adyacente a la columella (transseptal transesfenoidal), y 3) cortando la mucosa sobre el rostro del esfenoides (endonasal transesfenoidal). Cada seno cavernoso tiene 4 paredes durales. Las paredes lateral, superior y posterior están compuestas por dos hojas (endosteal y periostea), mientras que la pared medial posee una sola hoja dural, muy delgada, un hecho anatómico que podría explicar la expansión lateral de los adenomas hipofisarios. En el centro, el diaphragma selar tiene una abertura a través de la cual el infundíbulo transcurre, uniendo la glándula pituitaria con el tercer ventrículo. La morfología de dicha abertura es muy variable. En promedio, la distancia anteroposterior de la abertura es de 7.26 mm + 1.99 mm, variando desde 3.4 mm hasta 10.7 mm. La distancia lateral de la abertura del diafragma es de 7.33 mm + 2.79 mm, variando desde 2.8 mm hasta 14.1 mm.

Palabras-clave: abordaje transesfenoidal, anatomía, diafragma selar, glándula hipófisis, seno esfenoidal.
INTRODUCTION

The pituitary gland and sella are located below the center of the brain in the center of the cranial base\textsuperscript{1}. The sellar contents are separated from the sphenoidal sinus by a tiny sheath of bone that comprises the sellar floor, making the transsphenoidal approach the most used surgical route to intrasellar lesions. Herman Schloffer, in Austria, was the first in operate a patient with a pituitary tumor by a transsphenoidal approach\textsuperscript{2}. After a period in disuse, the transsphenoidal approach resurfaced in the second half of the last century\textsuperscript{3, 4}. Thus, over the last 30 years, the transsphenoidal approach became the first choice approach to sellar lesions, being a relatively safe route with low risk of complications, which reach up to 4% in major series\textsuperscript{5}. The transsphenoidal approach can be initiated in three different ways: 1) cutting the mucosa over the alveolar part of maxilla (sublabial transsphenoidal), 2) cutting along the anterior nasal mucosa adjacent to the columella (transseptal transsphenoidal), and 3) cutting the mucosa over the sphenoidal rostrum (endonasal transsphenoidal). The aim of this paper is to study the anatomical landmarks for the endonasal transsphenoidal approaches.

ANATOMICAL CONSIDERATION

NASAL CAVITY (FIGS. 1A-D)

The nasal cavity is limited above by the anterior cranial fossa, laterally by the orbits and maxillary sinuses and inferiorly by the hard palate. Its walls are covered by respiratory mucosa. It is wider inferiorly and communicates with frontal, ethmoidal, maxillary and sphenoidal sinuses by way of the nasal meati which open under cover of the superior, middle and inferior nasal concha. The cavity is divided along midline by the nasal septum, whose anterior part is septal cartilage. The bony septum is comprised by the perpendicular plate of ethmoid anteriorly-superiorly and by vomer postero-inferiorly. The posterior border of the perpendicular plate attaches to the sphenoid rostrum and it is at this level that fracture of the bony septum is produced during endonasal transsphenoidal approach to reach midline. The aspects of the anterior nasal apertures vary among individuals. Their edges are formed by a U-shaped cartilage and fibrous tissue, making them flexible enough to accept the introduction of the endonasal speculum, even in small, delicate-featured individuals. The lateral wall of the nasal cavity has the superior, middle, and inferior nasal conchae, bellow each of which is a corresponding superior, middle, or inferior nasal meatus.

SPHENOID BONE AND SPHENOID SINUS (FIGS. 2A-D)

The sphenoid bone is located in the center of the skull base, in front of the temporal and occipital bones and posterior to the frontal and ethmoid bones. Its anterior aspect resembles a bat with wings outstretched. It has a body, and paired greater and lesser wings and pterygoid processes. The pituitary gland lies under the sphenoid bone and pituitary gland above has led to the transsphenoidal route being the operative approach of choice for most sellar tumors. The sphenoid sinus is a space created by pneumatization of the sphenoid body anterior and inferior to the sella. The sphenoid sinus is subject to considerable variation in size, shape and degree of pneumatization and, in the adult, can be divided by multiple bony septae, which are often located off midline. The ostia for the sinus are located in a superior position related to the floor of the sinus, at each side of midline, at the level of the posterior portion of the superior concha and both are used as landmarks during the performance of the endonasal transsphenoidal approach.
noidal approach. However, in some cases the finding of the os-
tia is difficult. Kim et al. suggest that the ostium should ideally
be searched from a superior and medial aspect in relation to the
posteroinferior end of the superior turbinate.

Figure 2 - The Sphenoid Bone and Sphenoid Sinus. A, anterior view. The right
half of the anterior wall has been removed. The sphenoid has a body and paired
lesser wings, greater wings and pterygoid processes. During development, the
sphenoid body is pneumatized to form the sphenoid sinus, which open to the
nasal cavity through paired ostia. The sphenoidal ostia are located on the superior
portion of the anterior wall and are partially hidden by the superior nasal concha.
B, the sphenoid sinus has been opened. The sinus is partially divided by multiple,
incomplete septa. The anterior bend of the internal carotid artery can be seen as
a protrusion on the superior portion of the lateral wall of the sinus, covered by
a thin plate of bone and mucosa. In some specimens, no bony cover exists and
the artery is separated from the sinus by mucosa only. C, the anterior wall of the
sphenoid sinus has been removed, preserving the mucosa and ostia. D, sagittal
cut through the head. The lateral wall of the sphenoid sinus has been dissected to
expose the relationship of the horizontal portion and anterior carotid bend to the
sella.
A., artery; Car., carotid; CN, cranial nerve; Mid., middle; Pit., pituitary; Proc.,
process; Sphen., sphenoid, sphenoidal; Sup., superior.

The cavernous segment of the internal carotid artery, the ma-
xillary, mandibular and optic nerves are in intimate contact with
each lateral wall of the sphenoid body. The cavernous carotid
course is marked on the cerebral surface of the sphenoid body
by a groove of bone, the carotid sulcus. This sulcus produces
a prominence within the sinus wall below the anterior margin
of sella. The bone separating the artery and the sphenoid sinus
is thinner over the anterior portion of the carotid prominence
and bone defects are not uncommon. The intracranial surface
of the sphenoid is covered by endosteal layer, and this and the
sinus mucosa can be the only structures separating the air cavi-
ity from the carotid arteries if no bone is present.

CAVERNOUS SINUS AND MEDIAL
WALL (FIGS. 3A-D)

The cavernous sinuses are paired structures located at each
side of the sella, pituitary gland and sphenoid sinuses. Each
cavernous sinus has four dural walls that comprise a set of ve-
nous plexus, the cavernous segment of the carotid artery and
its intracavernous branches, the abduces nerve, the sympathetic
branches and a variable amount of fat. Each superior wall
combines along midline to form the sellar diaphragm, which,
by its turn, forms the roof of the sella and partially covers the
pituitary gland, except by an opening through which the pitui-
tary stalks courses. Laterally to the diaphragm is located the
oculomotor triangle, the space where the oculomotor nerve en-
ters the cavernous sinus. The oculomotor cistern, an arachno-
idal and dural cuff, accompanies the oculomotor nerve through
the cavernous sinus roof to the area just below or anterior to the
lower edge of the tip of the anterior clinoid process. The
lateral, superior and posterior walls are composed of endosteal
and periosteal dura leaflets. Unlike the other dural walls, the
medial wall is formed of a single, thin dural sheath, an anato-
mical fact that help explains the lateral expansion of a pituitary
adenoma.

The medial wall of the cavernous sinus has two parts: sellar
and sphenoidal. The sellar part separates the sella and the
pituitary gland from the venous spaces in the sinus. The sphen-
oidal part is formed by the dura lining the carotid sulcus on the
lateral aspect of the sphenoid body. The medial wall is lo-
cated lateral to the sella and carotid sulcus on the body of the
sphenoid bone. Its anterior limit extends along a line that starts
at the junction of the optic strut with the body of the sphenoid
bone and passes downward along the medial edge of the super-
ior orbital fissure to the superior edge of the foramen rotundum.
The superior limit is located at the level of the diaphragm
sellae and is formed by a line extending backward from the
superior edge of the junction of the optic strut with the body of the
sphenoid bone to the posterior clinoid process. Inferiorly, the
lower edge of the medial wall extends backward from the
superior edge of the foramen rotundum across the anterior por-
tion of the lingula of the sphenoid bone to reach its posterior
limit at the superior end of the petroclival fissure. Its posterior
dge is located along a line connecting the posterior clinoid
process and the superior limit of the petroclival fissure. Two
areas, sellar and sphenoidal, are easily recognized.
**THE SELLAR PART**

The sellar part of the medial wall of the cavernous sinus forms the lateral wall of the sella. In all specimens, it was in direct contact with but easily separated from the capsule of the pituitary gland. The dura forming the medial wall is very thin and cannot be separated into two layers, as can the thicker dura lining the superior, inferior, anterior, and posterior walls of the sella. With the exception of both lateral aspects of the pituitary gland, which are covered by just one very thin layer of dura, the other four surfaces of the gland (superior, inferior, anterior, and posterior) are covered by dura that can be separated into two layers and between which the intercavernous sinuses course. The pituitary capsule, which is separate from the medial wall of the cavernous sinus, is a very thin, semitransparent membrane that is tightly attached to the gland. The average superior to inferior length of the sellar part of the medial wall at its center was $7.24 \pm 1.23$ mm, and the average anterior to posterior length at the center was $8.52 \pm 1.25$ mm (Fig. 4) (Table 1).

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**Table 1 - Measurements of the medial wall of the cavernous sinus**

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Average (mm)</th>
<th>Standard Deviation (mm)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from the diaphragm to the sella floor</td>
<td>7.24</td>
<td>1.23</td>
<td>4.83-9.33</td>
</tr>
<tr>
<td>(A-B)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between the anterior and posterior limit of the sella (C-D)*</td>
<td>8.52</td>
<td>1.25</td>
<td>6.21-10.57</td>
</tr>
</tbody>
</table>

* See Figure 4.

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**PITUITARY GLAND (FIGS. 5A-D)**

The pituitary gland is a red-grey structure that measures around 12 mm laterally and 8 mm anterio-posteriorly. It is composed of two embryological and functionally distinct areas: the anterior and posterior lobes. The inferior surface of the gland is usually round to accommodate to the floor of the sella, while the superior and lateral have a variable form according to the flexible walls they are in contact with.

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**Figure 3** - The Cavernous Sinus and Medial Wall. A, the inner and outer layers of dura have been removed from the lateral wall and roof of the cavernous sinus, to expose the cranial nerves and cavernous carotid. B, right parasellar area. The vascular and neural elements of the cavernous sinus have been resected to expose its medial wall. The medial wall of the cavernous sinus at the sellar level is composed of a thin dural layer. C, superior view of the sellar region. The diaphragm is continuous with the dura covering the tuberculum and anterior fossa, anteriorly and the dura covering dorsum and clivus, posteriorly. Laterally, the diaphragm is continuous with the dura over the roof and lateral wall of cavernous sinus. D, superior view of the sellar region. The medial wall of cavernous sinus separates the pituitary gland from the cavernous sinus contents.

A., artery; Ant., anterior; Car., carotid; Cav., cavernous; Clin., clinoid; Diaph., diaphragm; Falc., falciform; CN, cranial nerve; Pit., pituitary; Tuberc., tuberculum.

**Figure 4** - Diagram showing measurements of the medial wall of the CS (see Table 1 for definitions). V2, second division of the trigeminal nerve; V3, third division of the trigeminal nerve.

**Figure 5** - The Pituitary Gland. A, superior view of the middle fossa. The pituitary...
gland is located inside the sella turcica. B, the pituitary gland is formed by two lobes: anterior and posterior. C, posterosuperior view. The posterior clinoid processes and the dorum sellae were removed in order to see the posterior aspect of the pituitary gland. D, anterior view. The bone forming the sellar floor and the lateral walls of the sphenoid sinus were removed in order to see the anterior aspect of the pituitary gland.

A., artery; Car., carotid; Ant., anterior; Clin., clinoid; Hyp., hypophyseal; Inf., inferior; Intercav., intercavernous; Ophth., ophthalmic; Pit., pituitary; Post., posterior.

**Pituitary Fossa and Diaphragma Sellae**

A combined wall of dura mater and bone protects the anterior, inferior and posterior surfaces of the pituitary gland, while the lateral and superior portions are protected by dura mater only. The dural layer facing the lateral portion of the gland is single, but a double-layered dura cover all other surfaces. The diaphragm is the dural sheath that partially covers the superior surface of the gland, having a medial opening to transmit the pituitary stalk.

The diaphragma sellae is composed of two layers. Anteriorly, these layers form the dura mater that covers the sphenoid planum and the anterior cranial fossa. Posteriorly, they are continuous with the dura mater covering dorsum sellae and clivus. The superficial or meningeal layer is continuous laterally with the superficial layer of the roof and lateral wall of cavernous sinus, the upper dural ring and the optic sheath. The deeper or periorbital layer is continuous with the inner layer of the lateral wall of the cavernous sinus, the lower dural ring and the periorbita. The diaphragma sellae extends from the tuberculum sellae anteriorly to the dorsum sellae posteriorly. Laterally, its limits correspond to the area where the medial and superior walls of cavernous sinus meet. In the center, the diaphragm has an opening through which the infundibulum courses, linking the pituitary gland to the floor of the third ventricle. The morphology of this opening is quite variable among individuals. On average, the anteroposterior distance of the diaphragm opening was 7.26 mm + 1.99 mm, varying from 3.4 mm up to 10.7 mm. The lateral distance of the diaphragm opening was 7.33 mm + 2.79 mm, varying from 2.8 mm up to 14.1 mm. The distance of the dural portion of the diaphragm anterior to its opening (between the opening and the insertion in the tuberculum sellae) was 1.89 mm + 1.49 mm, varying from zero up to 5.1 mm. The distance of the dural portion of the diaphragm posterior to its opening (between the opening and the insertion in the dorsum sellae) was 1.35 mm + 1.03 mm, varying from zero to 2.8 mm. The distance of the dural portion of the diaphragm on the right side of its opening was 4.55 mm + 2.08 mm, varying from 1.3 mm up to 8.8 mm. The distance of the dural portion of the diaphragm on the left side of its opening was 4.65 mm + 2.42 mm, varying from zero up to 8.2 mm (Fig. 6) (Table 2).

It is remarkable that, the largest the diaphragm opening, the greater the amount of pituitary tissue in direct contact with the arachnoid of the chiasmatic cistern (Fig. 7).

**Table 2 - Measurements of diaphragma sellae**

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Average (mm)</th>
<th>Standard Deviation (mm)</th>
<th>Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteroposterior distance of the diaphragm opening (A-B)*</td>
<td>7.26</td>
<td>1.99</td>
<td>3.4-10.7</td>
</tr>
<tr>
<td>Lateral distance of the diaphragm opening (C-D)*</td>
<td>7.33</td>
<td>2.79</td>
<td>2.8-14.1</td>
</tr>
<tr>
<td>Distance of the dural portion of the diaphragm anterior to its opening (A-E)*</td>
<td>1.89</td>
<td>1.49</td>
<td>0-5.1</td>
</tr>
<tr>
<td>Distance of the dural portion of the diaphragm posterior to its opening (B-F)*</td>
<td>1.35</td>
<td>1.03</td>
<td>0-2.8</td>
</tr>
<tr>
<td>Distance of the dural portion of the diaphragm on the right side of its opening (C-G)*</td>
<td>4.55</td>
<td>2.08</td>
<td>1.3-8.8</td>
</tr>
<tr>
<td>Distance of the dural portion of the diaphragm on the left side of its opening (D-H)*</td>
<td>4.65</td>
<td>2.42</td>
<td>0-8.2</td>
</tr>
</tbody>
</table>

* See Figure 6.
tuberculum sellae; B-F: distance of the dural portion of the diaphragm posterior to its opening (between the opening an the insertion in the dorsum sellae); C-G: distance of the dural portion of the diaphragm on the right side of its opening; D-H: distance of the dural portion of the diaphragm on the left side of its opening. Yellow dotted line: limits of the diaphragma sellae. (See Table 1).

**Figure 7** - Specimen with a big Diaphragm Opening and an Empty Sella. The pituitary gland is displaced inferiorly and laterally (green arrows). A, posterior view. B, superior view. Note that the opening starts at the level of the tuberculum sellae and finishes at the level of the dorsum sellae. A., artery; Car., carotid; Clin., clinoid; CN, cranial nerve; Pit., pituitary; Post., posterior; Tuberc., tuberculum.

**CLASSIFICATION OF THE DIAPHRAGMA SELLAE**

According with the results, the authors propose a classification of the diaphragma sellae in relationships of the diameter of its opening:

- **Group A**: when the diameter of the opening is lesser than 4 mm. Twenty percent of the heads studied.
- **Group B**: when the diameter of the opening is between 4 and 8 mm. Forty percent of the heads studied.
- **Group C**: when the diameter of the opening is bigger than 8 mm. Forty percent of the heads studied.

**REFERENCES**


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