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Endoscopic anatomy of sellar region

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Abstract The transsphenoidal approach is the preferred access used in surgical treatment of most sellar region pathologies. The use of endoscopy is advantageous, and it is considered a good alternative to the traditional microsurgical technique. The purpose of this study is to recognize and describe anatomical variations of the sphenoid sinus and the sellar region, mainly describing the anatomy of the posterior wall of the sphenoid sinus and analyzing intercarotid distances in 3 regions. Thirty sphenoid blocks treated with formaldehyde were injected and dissected. Using endoscopy, anatomical variations were studied and the intercarotid distances were measured at the tuberculum sellae, sellar floor and clivus. The types of sphenoid sinus found were: conchal in 1 (4.76 %), pré-sellar in 2 (9.52 %) and sellar in 19 (85.7 %) specimens. The mean distance found from the sphenoid sinus ostium to the sella turcica was 19 mm (±6.5) mm. The mean intercarotid distances found at the tuberculum sellae, sellar floor and clivus were respectively 13.32, 18.00 and 18.90 mm. Endoscopy, with its magnification and lighting provide a panoramic view of deep fields. The anatomical variations described in this study support the need for a careful evaluation of preoperative images in each case.

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Introduction

Transsphenoidal surgery (TS) has been the favorite approach to most intrasellar lesions since it was popularized by Dott [1], Hamlin [2], Guiot [3] and Hardy [4]. It provides excellent visualization of the lesions involving the pituitary gland, avoiding brain retraction, and is considered the least traumatic route to the sella [5, 6].

In the time from the first procedure performed in 1907 up to the present TS underwent an evolutionary process. The introduction of fluoroscopy, microscopy and, recently, endoscopy, and their technical advantages increased procedure safety [7].

Endonasal endoscopy was developed and disseminated during the last 20 years, and it is currently considered a safe, effective alternative to microsurgery in the treatment of pituitary tumors [8–10].

The main advantages described for its used are, besides the absence of a sublabial incision comparing with some conventional approaches, the availability of resources such as modern optics providing high magnification, excellent lighting and a greater angle of view than the microscope [11–14]. The use of angulated optics makes it easier to inspect the lateral parasellar spaces, suprasellar and retrosellar regions, and allows removing tumor residues under visual control [5, 15–17].

The relationship between SS and vital structures such as the carotid artery, optic nerve and hypophysis renders this surgery challenging and difficult. Anatomical variations of the SS have been studied since the last century [18] and in recent decades there has been a renewed interest [19–23].

Anatomical studies of the sphenoid sinus and sellar region are relevant because they can improve spatial orientation to the landmarks helping the surgeon to avoid transoperative complications.

The general purpose of this study is to describe the endoscopic anatomy of the sellar region and its variations in 30 cadavers. The specific purpose is to measure the following distances:

Distance between internal carotid arteries at the tuberculum sellae, sellar floor and paraclival segment.

Materials and methods

We evaluated 60 sides of 30 sphenoids blocks in the Department of Anatomy of the Federal University of Rio Grande do Sul. All blocks had been previously embalmed in a formaldehyde solution.

Both carotids were injected with Batson (940 ml monomer base, 2 × 100 ml catalyst, 50 ml promoter, 10 g pigment red (red pigment), 10 g pigment blue (blue pigment) Polysciences, Inc. Warrington, PA.

To study the sellar region we used an 18-cm long 4 mm diameter rigid microscope with an angled lens. A xenon light source and a single CCD digital video camera (Stryker) were connected to the endoscope. Digital pictures were printed by coupling the video images to a videocapture system.

For endoscopic dissection we used endoscopic sinus instruments and for bone resection a high- speed drill.

Each sphenoid block was inspected before dissection due to lack of uniformity of the coronal slices. In fact, the anterior wall of the SS had been previously removed in some cases, and they were excluded from part of the analysis.

The dissection was performed in three stages: nasal, sphenoid and sellar. The sphenoid ostium sinus is generally found 1.5 cm above the choana just below the superior turbinates [5]. After identification and enlargement of the ostium we inspected and recorded the extent of sinus pneumatization [24]. Therefore, when feasible or possible we measured the distance between the ostium and the nearest part of the sella (depth of the sphenoid sinus). After, posterior part of the septum, anterior wall of the sphenoid sinuses and inter sinus septa were removed, allowing the widest possible endoscopic view of the sphenoid sinus.

Then the inspection of the posterior and lateral wall began, aiming to identify highlights of the anatomical landmarks: sellar floor, clival indentation, carotid protuberances, optic nerve protuberances and opto-carotid recesses.

The next step was drilling the bone of the walls, tuberculum, upper clivus and removing dura mater exposing pituitary gland and cavernous segments of the carotid arteries. Afterwards the following measurements were performed utilizing plastified milimeter paper and under endoscopic visualization: Between the carotid arteries in the following regions:

A Tuberculum sellae
B Parasellar: sellar floor
C Paraclival. (trigeminal segment)

Data were analyzed using SPSS, comparing means found in present study with previous reports. Statistical significance was defined as a probability value <0.05.

Results

In 22 specimens we performed a step by step dissection reaching the sphenoethmoidal recess, lateralizing the middle turbinate and finding the sphenoidal ostium (Fig. 1b, c). After detaching the posterior region of the nasal septum we identified the anterior all of the sphenoid sinus (Fig. 1d).

Using plastified milimeter paper as a marker we measured the distance between the sphenoid sinus ostium and the nearest part of the sella turcica. The distance from the OS to the nearest part of the sella was measured in 21 heads. Mean depth found was 19 mm SD:6.5 mm (range 11–23 mm).

According to the Hammer and Radberg sphenoid sinus classification, we found in our study two (9 %) pre-sellar type, 19 (86 %) sellar type and one (5 %) conchal type [20]. In the sphenoid sinus, the septa and mucosa were removed allowing the identification of the consistent bony landmarks found in the midline of the posterior wall. In eight heads the sphenoidal anterior wall had been previously removed and septa intersinus disrupted, so they were included only to study the posterior wall as follows:

The posterior wall of the sphenoid sinus can be subdivided into five vertical compartments (Fig. 2b): Midline, bilateral paramedian and bilateral lateral. The planum sphenoidale, sella turcica and clivus are located in the midline compartment [25] while paraclival ICA, parasellar ICA and medial optic canal belong to the paramedian compartments. The maxillary branch of the trigeminal nerve (V2), cavernous sinus apex, carotid-opto recess and lateral portion of the optic canal belong to the lateral compartment (Fig. 2c) [25].

After identifying and recording the bony landmarks, the bone of the posterior wall of the sphenoid sinus was removed exposing the duramater (Fig. 3a). Once the dura was removed, the following structures were exposed: Pituitary gland and cavernous carotid artery (Fig. 3d). The cavernous segment of the carotid artery has two distinct divisions from the endoscopic perspective: paraclival and parasellar (Fig. 3d). The paraclival segment can be further subdivided into two segments: trigeminal and lacerum (Fig. 4b).

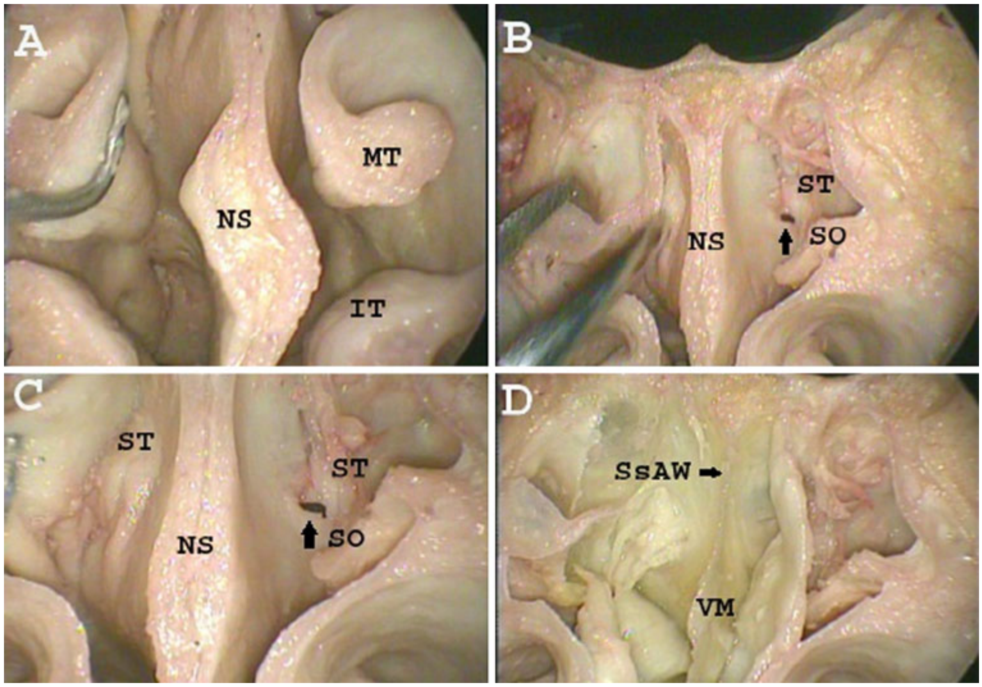

Fig. 1 **a** Endoscopic anterior view of a coronal section through the nasal cavity exposing the cartilaginous septum, middle turbinate and inferior turbinate. **b** Removal of left middle turbinate and tail of superior turbinate allowing exposition of *left* ostium sphenoidal sinus. **c** Closed view of *left* SS after removal of *middle* and tail of superior turbinate. **d** Removal of cartilaginous septum and exposure of vomer and anterior sphenoid wall. *IT* inferior nasal turbinate, *MT* middle nasal turbinate, *NS* nasal septum, *SO* sphenoid ostium, *SsAW* sphenoid sinus anterior wall, *ST* superior turbinate, *VM* vomer

The parasellar segment of the ICA is C-shaped with the convexity of the C facing anterolaterally when it is viewed from the medial aspect. It is subdivided into four parts in caudal-rostral order: The hidden segment, horizontal inferior, vertical anterior and horizontal superior (Fig. 4b) [25].

Then we performed the measurements. The mean distance found at the tuberculum sellae was 13.32 (range 8–17 mm) while at the sellar floor it was 18 mm (range 11–24 mm). The mean distance found at the paraclival segment was 18.90 mm (range 15–24 mm). Results are shown in Tables 1 and 2.

Discussion

The transsphenoidal approach has been the favorite approach to the sella turcica in the last 50 years [3, 26, 27]. With the introduction of the microscope in transsphenoidal surgery it became a procedure with low mortality and morbidity rates, and it provides enough exposure of the pituitary gland with the least amount of brain retraction [4, 28, 29].

The introduction of the endoscope together with intra-operative neuronavigation are considered important advances in pituitary surgery [30].

Anatomical variations of the sphenoid sinus were described in anatomical studies already during the first half of the twentieth Century [18, 31].

In the Sixties and Seventies the neurovascular relationships of the sphenoid sinus and sellar region were widely studied in anatomical studies that are still used as references [32–35].

When endoscopy was introduced, the sphenoid sinus and its important neurovascular relationships gained new attention. The panoramic view of the endoscope, together with the excellent magnification and lighting, more readily help the surgeon to recognize anatomical variations. This allows changing the technique or the approach according to the specific anatomical presentation [36].

Our series presents a significant number of endoscopic dissections compared to recently published anatomical studies [36–38]. However, the lack of data such as sex, age and race, prevented the comparative analysis of anatomical variations of the sphenoid sinus.

Considering Hammer and Radberg's classification [[24],] the sellar sinus is most frequently found (70 %) [19]. It is characterized by the presence of an extensive pneumatization where the air cavity extends through the sphenoid body below the sella and may reach the clivus. The pre-sellar sinus is the second most frequent (10–27 %)

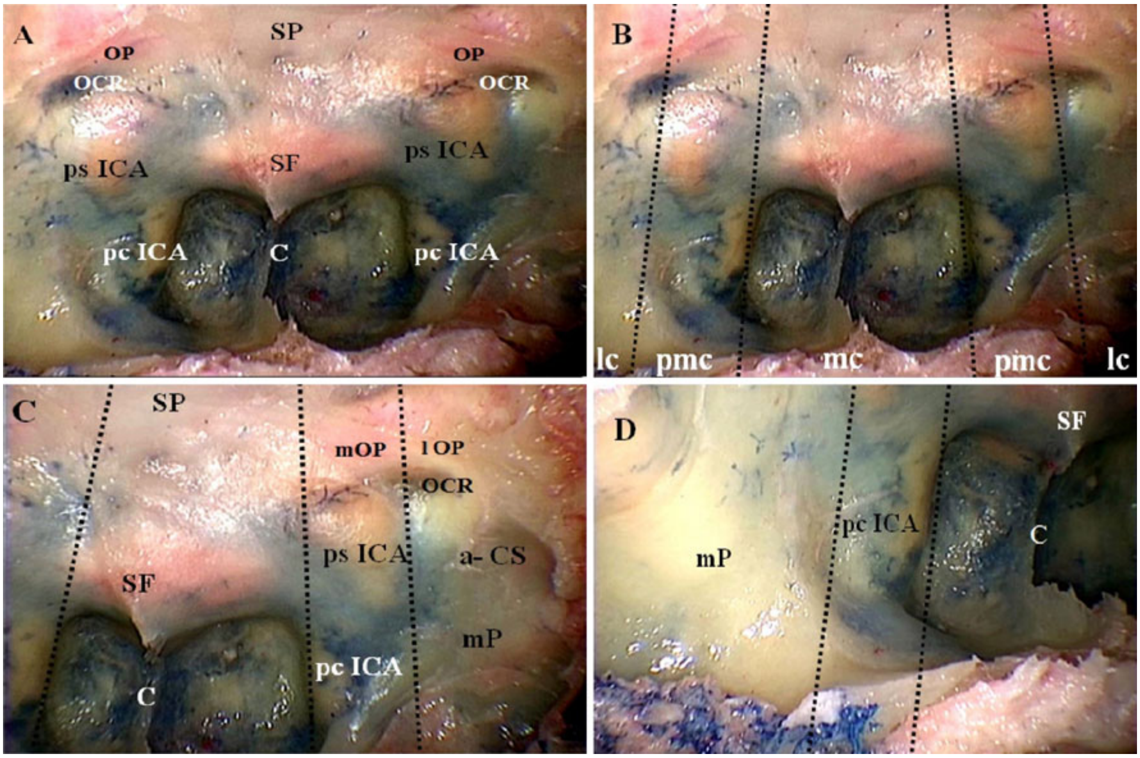

Fig. 2 Endoscopic view of sphenoid sinus. **a** Panoramic view of posterior wall exposing the sellar floor, optic and carotid protuberances, optic carotid recess, and clivus. **b** Subdivision of posterior wall of the sphenoidal sinus in five vertical compartments by *two lines* drawn vertically along the medial and lateral carotid protuberances: *midline* (m), paramedian *right* and *left* (pm) and lateral *right* and *left* (l). **c** Closed view of midline and the left side showing sphenoid planum, sella, clivus (*midline*), median optic protuberance, clival-parasellar carotid protuberances (paramedian compartment) and lateral optic protuberance, cavernous sinus apex, opto-carotid recess and trigeminal maxillary protuberance (lateral compartment). **d** *Right* side enlarged and angled view of posterior wall showing sella, clivus (median compartment), paraclival carotid protuberance (paramedian compartment) and maxillary protuberance (lateral compartment). *a-Cs* cavernous sinus apex, *C* clivus, *ICA pc* internal carotid artery paraclival, *ICA ps* internal carotid artery parasellar, *mP* maxillary protuberance, *OCR* opto-carotid recess, *OP* optic protuberance, *mOP* medial optic protuberance, *lOP* lateral optic protuberance, *SF* sellar floor, *SP* sphenoid planum

and it presents an air cavity that does not extend posteriorly to a plane perpendicular to the sellar wall. In the conchal sinus, the area below the sella is occupied only by bone, and there is no air cavity. The incidence found in our study of sellar, pre-sellar and conchal type sinuses agrees with the results from the literature.

The sphenoid sinus presents a variable antero-posterior dimension [35].

In our study, the depth of the sinus, considering the distance from the sphenoid sinus ostium to the sella turcica, presents a mean with a significant difference from previously described studies (Table 3), except for Fuji et al. (19 vs. 17.1) and Unlu et al.(19 vs. 20.6 mm) studies where the difference found was not significant [35, 36].

The relevance of this measure is that it indicates the extent of the route to be travelled within the sphenoid sinus until the sella turcica is reached [35].

The mean distance found between the internal carotids at the level of the 18 mm sellar floor can be considered a "safe zone" to access the hypophysis.

The value is similar to those reported by Fuji et al. (18 vs. 17 mm, $p = 0.202$) and Abuzayed e cols. [41] (18 vs. 18 mm, $p = 0.952$) (Table 4) [35, 38].

The minimum distance found in this region was 11 mm (Fig. 4f), different from Bergland [32] and Renn and Rhoton [33] who found a minimal intercarotid distance of 4 mm. In 23 cadavers (73.3 %) the mean distance observed in our study was between 15 and 20 mm. (Table 2).

Neither anatomical variations, such as kissing intracranial carotid arteries, where the medialization of the arteries promotes their physical encounter [39, 40], nor "tongue-like" projection of the pituitary gland were observed in this study [[41].].

The close anatomical relationships between the cavernous segment of the ACI and the hypophysis explain the

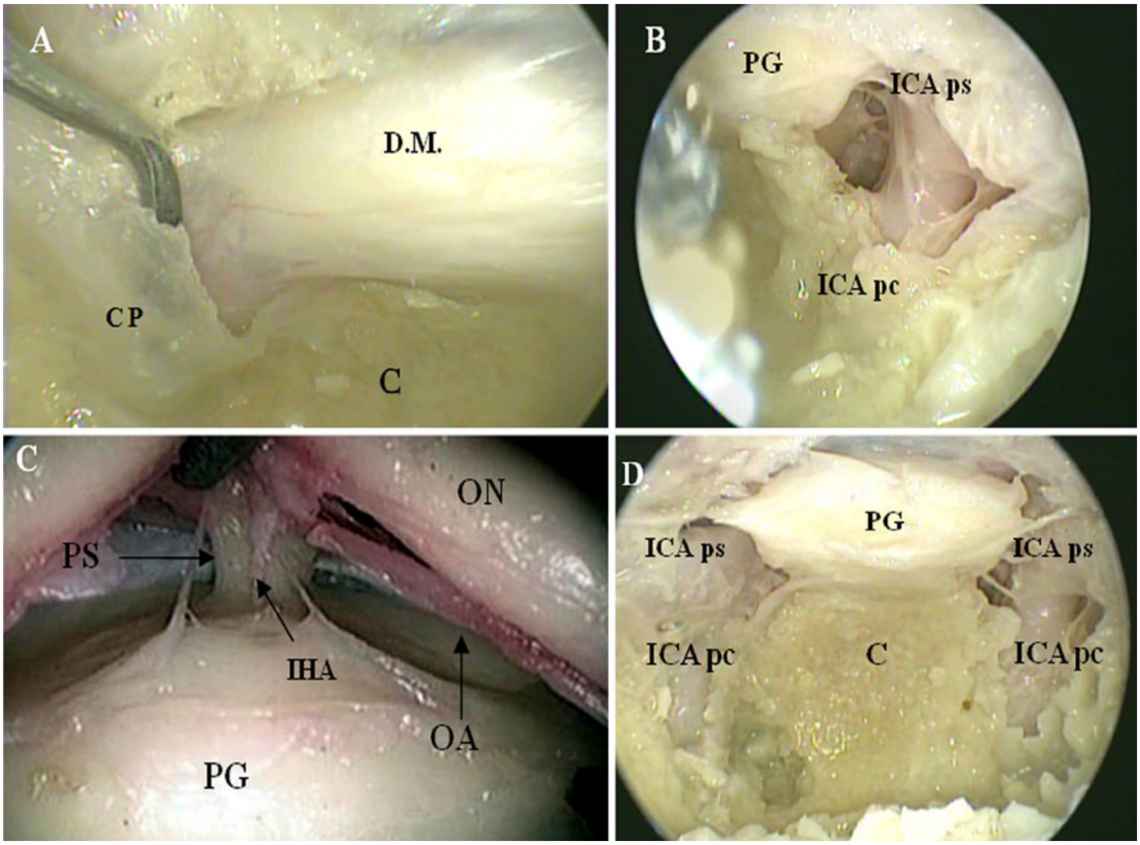

Fig. 3 **a** Removal of sellar floor and *upper* portion of carotid protuberance exposing periosteal duramater of sella and medial wall of cavernous sinus. **b** Removal of duramater exposing pituitary gland and the transition segments between paraclival and parasellar regions of the cavernous internal carotid artery. **c** Endoscopic view of pituitary gland, superior hypophyseal artery, pituitary stalk and optic nerve. **d** Removal of bone and dura exposing pituitary gland and both paraclival and parasellar segments of the ICA. *C* clivus, *CP* carotid protuberance, *DM* dura-mater *ICA pc* internal carotid artery paraclival, *ICA ps* internal carotid artery parasellar, *SHA* superior hypophyseal artery, *PG* pituitary gland, *PS* pituitary stalk, *OA* ophthalmic artery, *ON* optic nerve

possibility of vascular (carotid) lesion during transsphenoidal surgery [42]. Considering that the rate of carotid-lesion type vascular complications is 1.1 % in transphenoidal surgery [[28],] it is essential to study preoperatively, not only the anatomy of the paranasal sinuses of the base of the skull, but also of the anatomical relations between the carotid and the hypophysis [43]. Patients with acromegaly and SAH deserve more attention, since, besides having a statistically significant reduction of the distance between the carotid sulci [44], they may develop severe vascular ectasis, with the risk of protrusion into the sella [45, 46].

The anatomical distortion found in patients who have undergone a previous surgical procedure or radiation therapy increases the risk of losing the midline reference, with a consequently increased chance of vascular lesion [46].

In the region of the tuberculum sellae we find the shortest mean distances between the internal carotid arteries in this study (mean:13.3 mm). The value does not present a statistically significant difference in relation to the means described by Fuji et al. (13.3 vs.13.9 mm, $p = 0.153$) and Lang et al. (13.3 vs. 14 mm, $p = 0.102$). [21, 35].

The maximum distance found in this region in the study, 17 mm, is identical to that found by Fuji et al., but different from Lang et al., whose largest measure was 24 mm. [21, 35]. The fact that the internal carotid arteries in this segment are fixed by the bone and by the distal dural ring increases their vulnerability in this region during transsphenoidal surgery [47].

It is crucial to analyze this measure when planning access extended into the region of the tuberculum sellae and sphenoid plane, especially in patients with a normal-sized or small sella turcica [6, 48, 49] (Table 5).

As regards the distance of the internal carotids in the paraclival segment, the mean distance found in our study, 18.9 mm (variation: 15 and 24 mm) presents a significant difference from Fuji et al. findings (18.9 vs. 17.1 mm,

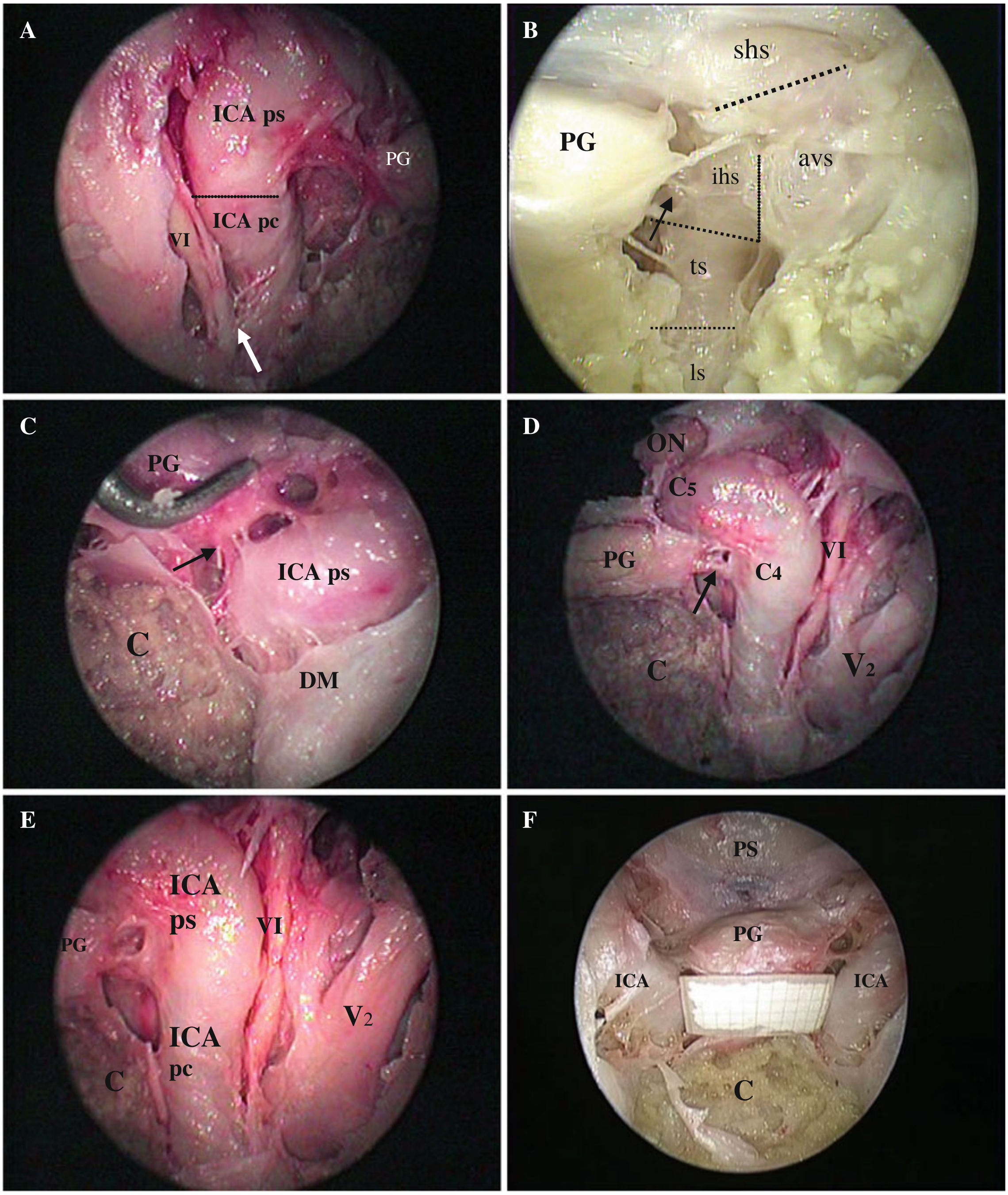

Fig. 4 **a** endoscopic view of under 0-degree lens. Exposure of two segments of ICA: paraclival (pc) and parasellar (ps) segment. A opening in the lateral wall of the cavernous sinus allows exposure of VI nerve and sympathetic plexus (*arrow head*). **b** endoscopic view of paraclival ICA (pc) two divisions: trigeminal (ts) and lacerum (ls)segments and C-shaped ICA parasellar (ps) four divisions :superior segment horizontal (shs), anterior vertical segment (avs), inferior horizontal segment (ihs) and hidden segment (*arrow head*). **c** endoscopic view of medial wall of cavernous sinus and the parasellar (ps) segment of ICA. When the adeno hypophysis is displaced medially the inferior hypophyseal artery is visualized (*arrow head*). **d** endoscopic view of ICA segments,VI nerve and second branch of trigeminal nerve. **e** closed endoscopic view of ICA segments,VI nerve and second branch of trigeminal nerve. **f** endoscopic view of intercarotid distance in sella region. The short distance found in sellar region in our study was 11 mm. *C* clivus, *DM* duramater, *ICA pc* paraclival segment of ICA, *ICA ps* parasellar segment of ICA, *VI* abducens nerve, *V2* second branch of the trigeminal nerve, *ON* optic nerve, *PG* pituitary gland, *PS* planum sphenoidale, *C4* fourth segment of ICA, *C5* fifth segment of ICA

$p = 0.038$), but no significant difference from the study by Wang et al. (18.9 vs. 17.5 mm, $p = 0.135$) and Unlu et al. (18.9 vs. 19.7 mm, $p = 0.063$) [35, 36, 50].

The paraclival intercarotid distance is the lateral limit of the clivus opening, and it is an anatomical reference for accesses extended into this region. [51]. The window made

Table 1 Results of the measurements of the carotid artery

Level of measurement	Distances between the internal carotid arteries of two sides		
	Range (mm)	SD	Mean (mm)
Tuberculum sellae	8–17	±0.25	13.32
Sellar floor	11–24	±3.0	18
Paraclival	15–24	±0.22	18.90

Table 2 Results of measurements of the carotid artery

Intercarotid distance (mm)	Tuberculum sellae	Sellar floor	Clivus
<10	3 (10 %)	0	0
10–15	18 (60 %)	2 (6.7 %)	0
15–20	9 (30 %)	23 (73.3 %)	24 (80 %)
>20	0	5 (16.7 %)	6 (20 %)

Table 3 Reported distances from the sphenoid sinus ostium to the sella floor (depth)

Author	Variation (mm)	Mean (mm)	Value expressing difference to the present study
Fuji et al. [35]	(12–23)	17.1	$p = 0.130$
Lang [21]	(9–23)	14.6	$p = 0.001$
Unlu et al. [36]	(18.9–23)	20.6	$p = 0.227$
Lazaridis et al. [23]	(7–24.9)	13.6	$p < 0.001$
Present study	(11–23)	19	

Table 4 Intercarotid distance, reported at the level of the sella

Author	Median (mm)
Fuji et al. [35]	Mean:17
Abuzayed et al. [38]	Mean:18
Present study	Mean:18

Table 5 Intercarotid distance reported at the level of the tuberculum sellae

Author	Range (mm)	Median (mm)
Fuji et al. [35]	10–17	13.9
Lang [21]	9–24	14
Present study	8–17	13.3

in the clivus to expose the tumor obeys the lateral distance of 16 mm in its upper portion, 20 mm at the level of the abducens nerves and 34 mm between the two hypoglossal canals [51] (Table 6).

Table 6 Intercarotid distance reported at the level of the clivus

Author	Range (mm)	Mean (mm)
Fuji et al. [35]	12–23	17.1
Wang et al [49]	15–20	17.5
Unlu et al. [36]	13.2–26.2	19.7
Present study	15–24	18.9

In our series, generally, we find the shortest distance between the carotids in the tuberculum sellae region in 86.6 %, in the sellar floor, 10.1 %, and in the clival region, 3.3 % of the specimens studied.

When the sphenoid sinus is highly pneumatized, there may be an anatomical distortion, making it difficult to identify the points of reference of the posterior wall, and increasing the risk of a neurovascular lesion [43].

The relations between the sphenoid sinus walls and major neurovascular structures lead the surgeon to value the clear identification of the midline and keep to this path until the sella turcica is reached [55]. The importance of recognizing the midline in transsphenoidal surgery has been emphasized since the beginning of last century [53].

Techniques, such as partial preservation of the vomer, location of the middle point between the carotid protuberances and the opto-carotid recess [54] and the identification of the dural filum in the sellar phase [52] help the surgeon maintain this reference and increase the safety of the procedure.

It is crucial to perform a careful evaluation of preoperative images, evaluating the course and distance between the internal carotid arteries, especially to plan anterior and posterior extended accesses [55].

The endoscopic visualization, with excellent magnification and lighting, allows the surgeon to perform an easier identification of the posterior wall structures, diminishing the risk of spatial disorientation and associated complications.

Conclusion

Considering that the sphenoid sinus reflects anatomical relationships in its walls, it is essential for the surgeon to recognize these structures, as well as their anatomical variations. Endoscopy provides a panoramic view of the sphenoid sinus and sellar region, and thus, with other tools, helps perform less invasive procedures, safely and effectively.

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