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ORIGINAL STUDY

Challenges of endoscopic approach in sphenoid sinus surgery for beginners

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ABSTRACT

The sphenoid sinus and related anatomy should be known considering the intimate relationships with vital surrounding structures, such as the internal carotid artery, the optic canal, the maxillary and the vidian nerves. The sphenoid sinus has numerous variations regarding the pneumatization, the septation and the relation with the neurovascular structures. Multiplanar sinus CT scan is mandatory in the preoperative evaluation of the patient to avoid injury during endoscopic sphenoidotomy.

In this article, we review and describe the importance of the anatomical landmarks of the sphenoid sinus on the CT scan, the anatomic findings that augment the risk of complications during sphenoid sinus endoscopic surgery. Moreover, we discuss about the appropriate type of endoscopic approach of the sphenoid sinus depending on the localization of the pathologic process and the experience of the surgeon, as well as the endoscopic surgery challenges. We analysed 100 patients who addressed to our clinic in the last 6 months and who underwent CT of the paranasal sinuses and we studied the pneumatization type and the anatomic variations of the optic nerve and the internal carotid artery.

A variety of sphenoid sinus anatomy variations were found, and we emphasize the value of imagining evaluation before performing functional endoscopic sinus surgery.

KEYWORDS: sphenoid sinus, anatomy landmarks, endoscopic sphenoidotomy.

INTRODUCTION

When we approach the anatomy of the sphenoid sinus, we start from the premise that the sphenoid bone is described as one of the most complex structures of the human body. The sphenoid sinus has numerous variations regarding the pneumatization, the septation and the relation with the neurovascular structures. Imagistic studying methods, such as CT, MRI, offer an accurate view of the sphenoid sinus relationship with the vital structures (internal carotid artery, optic nerve, vidian canal, anterior and middle cranial fossa). This is why preoperative evaluation of the sphenoid sinus anatomical relation plays a major role in preventing intraoperative complications (e.g., cerebrospinal fluid leak, visual loss, extraocular muscles palsy, intracranial haemorrhage)[1].

The sphenoid sinus pathology can be categorized into inflammatory (90%)[2] and neoplastic causes.

The sphenoid rhinosinusitis represents the most common type of sphenoid sinus involvement characterized by clinical presentation with nonspecific symptoms and signs, making paraclinical evaluation of utmost importance[2].

Endoscopic nasal examination may reveal leakage of mucopurulent secretions, polyposis or edema at the level of the sphenoethmoidal recess, but a normal appearance of the sphenoethmoidal recess does not exclude the possibility of a sphenoid sinus pathology. Nasal endoscopy does not replace the radiologic imaging studies, these being the gold-standard investigations for establishing the diagnosis, and determine the therapeutic strategy[3] thorough analysis of patient's imaging diagnosis before procedures is still of great necessity for the operators. This study aimed to explore the morphological changes of sphenoid sinus lesions as observed on computed tomography (CT).

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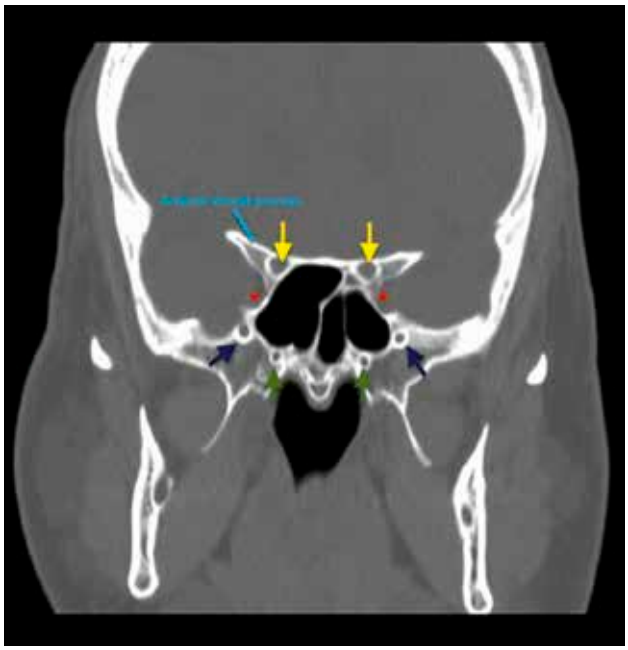


Figure 1. Cranio-facial CT scan, coronal slice, illustration of the critical anatomic landmarks: the optic canal (yellow arrows); the carotid canal (red *); foramen rotundum (blue arrows); the vidian canal (green arrows).

The supine position of the patient during endoscopic sphenoid intervention increases the risk of accidental perforation of the clivus[4]. Dehiscence of the optic nerve and carotid canals, best evaluated on CT scans in axial and coronal planes, can occur when an excessive pneumatization of the sphenoid bone has developed towards the skull base and anterior clinoid processes. This anatomoclinical particularity puts them at additional risk during sphenoid surgery[1]. Also, the dehiscence of the optic nerve is often found in cases where Onodi cells are present[5].

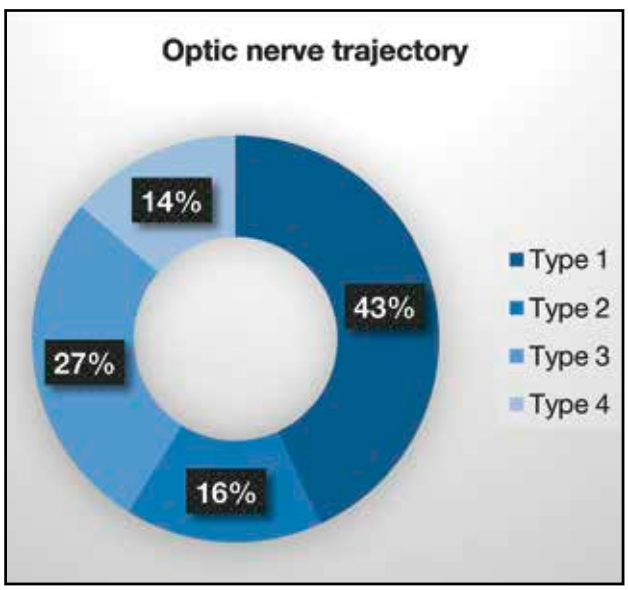
In order to avoid the injury to the vital structures in the area and prevent the complications that can occur during endoscopic sphenoidotomy, it is very important to know the individual anatomy of the patient.

ANATOMICAL LANDMARKS

Sphenoid sinus and sphenoid bone anatomy should be known considering their intimate relationships with vital surrounding structures, such as the internal carotid artery, the optic canal, the maxillary and the vidian nerves. Depending on the degree of sinus pneumatization, this structure may protrude into these air cavities, sometimes without any bone separation, making them susceptible to iatrogenic damage during endoscopic surgery. These structures are the internal carotid artery and the optic nerve in the superolateral wall, the maxillary nerve in the lateral wall, the posterior ethmoidal cell (the Onodi cell) in the anterosuperior wall and the vidian nerve in the floor of the sphenoid sinus[6] (Figure 1).

Sella turcica is considered one of the most important surgical elements, being a landmark in the classification of the sphenoid pneumatization[7], with an important impact in the surgical approach.

The prominence of **the optic nerve** usually extends horizontally to the superolateral wall of the sphenoid sinus from posterior to anterior and dis-



Graph 1. Distribution of sphenoid sinus anatomical relation with the optic nerve.

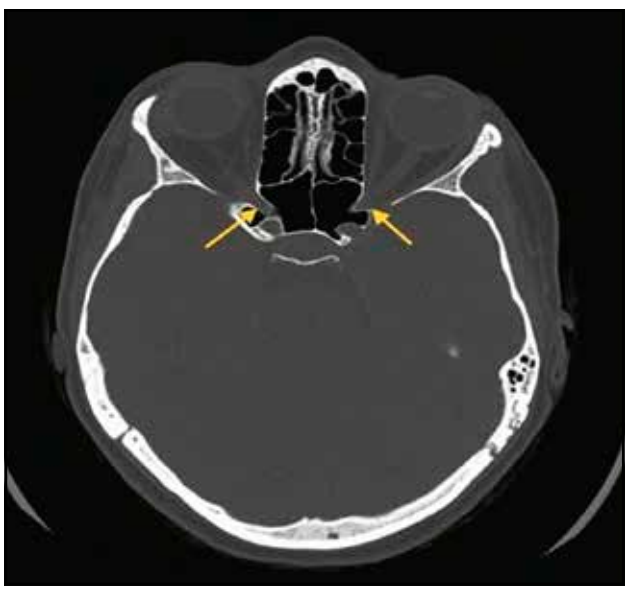


Figure 2. Transsphenoidal sinus trajectory of the optic nerve (Type 3) (cranio-facial CT scan, axial view) (yellow arrows).

appears gradually in the anterior direction. The bony covering of the optic nerve is dehiscent in 4 to 6% of cases[8].

The trajectory of the optic nerve, in relation to the posterior paranasal sinus, can be classified into 4 types according to DeLano et al.[9]:

- Type 1: adjacent to the lateral or superior wall of the sphenoid sinus.
- Type 2: makes an impression on the lateral sphenoid sinus wall.
- Type 3: course through the sphenoid sinus (Figure 2).
- Type 4: course immediately lateral to the posterior ethmoidal air cells and sphenoid sinus.

We evaluated the anatomic and imagistic landmarks of the sphenoid sinus on the cranio-facial CT scans of 100 patients, aged between 18 and 89 years old, who referred to the ENT&HNS Department, "Sfanta Maria" Hospital, between May 2021 and October 2021. All CT images were viewed and analysed using the Syngo FastView® program. For all 200 sphenoid sinuses we analysed the following parameters: the trajectory of the optic nerve, of the internal carotid artery; presence of intrasinusal septa; pneumatization types.

The trajectory of the optic nerve was evaluated in relation to the posterior paranasal sinus, based on DeLano et al.[9] classification. In our study, Type 1 was present in 43% of the cases, Type 2 in 16% the cases, Type 3 in 27% and Type 4 in 14% of the cases (Graph 1). Our findings are similar with those found in the literature, Type I being related over 55%, Type II over 14%, Type III between 6-23% and Type IV 3-11%[9-11].

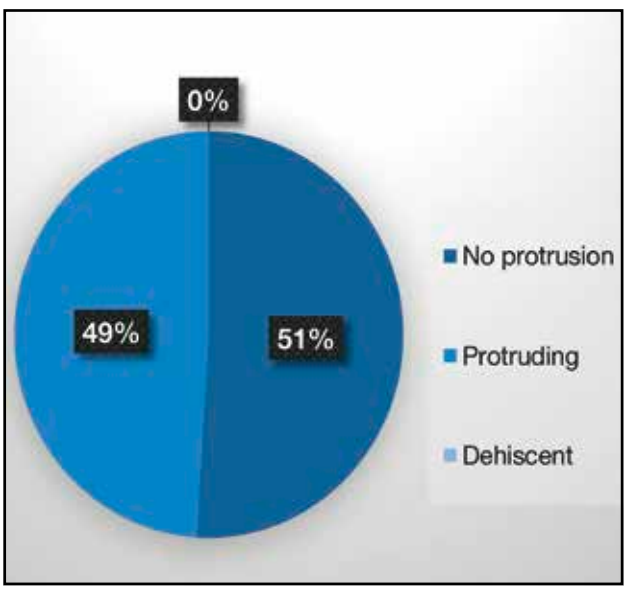
The internal carotid artery

The most important relations of the sphenoid sinus are with the internal carotid artery and the optic nerve, located on the superior and lateral walls. In cases of extensive pneumatization, the surrounding vessels and nerves are seen in the sinus cavity as irregularities or ridges[12].

Given these anatomical relations, instrumental palpation of the posterosuperior wall of the sphenoid sinus during endoscopic surgery or postoperative period should be avoided in order to prevent injury to these structures that can result in blindness and fatal hemorrhage[13].

The internal carotid artery (ICA) originates from the common carotid artery in the cervical region and has an ascending path to the brain. It has four portions: cervical, petrous, cavernous and cerebral. ICA enters the carotid canal in the petrous portion of the temporal bone. The cavernous portion of the internal carotid artery is located in the cavernous sinus. In its trajectory through the cavernous sinus, it can leave a prominence on the side wall of the sphenoid sinus cavity (Figure 3). It has a path from the bottom to the top of the side wall. The internal carotid may be partially dehiscent in approximately 2.5% of cases or can be entirely exposed without a bony covering[5,7,13].

Evaluating the trajectory of the internal carotid artery canal on 100 cranio-facial CT scans included in our study, we noticed that a protruding internal carotid artery was present in 49% of the cases, no protrusion of the artery was observed in 51% of the cases and none of the CT scans revealed total dehiscence of ICA (Graph 2). In the literature, the



Graph 2. Internal carotid artery relation with the sphenoid sinus.

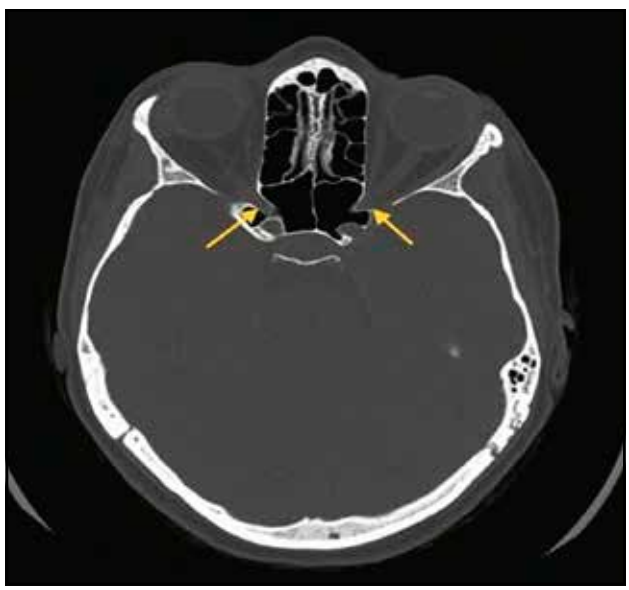


Figure 3. Aspect of protruding internal carotid artery (cranio-facial CT scan, axial slice) (yellow arrows).

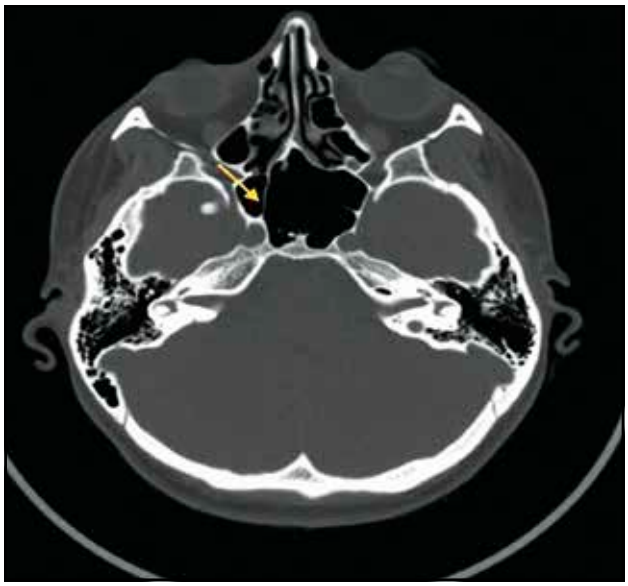


Figure 4. Insertion of asymmetrical median septum onto the internal carotid canal (cranio-facial CT scan, axial slice) (yellow arrow).

Figure 5. Intrasinusal septa inserted bilaterally on the internal carotid canal (cranio-facial CT scan, axial slice) (yellow arrows).

protrusion of ICA varies between 8 to 70% and no protrusion of ICA is found in almost 40% of the cases[14,15]. Our findings are similar to the ones reported by other authors.

The vidian canal

The vidian canal is found on the lateral wall of the pterygopalatine fossa. Its anatomical relation with the internal carotid artery makes it a reliable landmark to identify the petrous part of ICA in the endoscopic approach of the skull base surgery[16]. The vidian canal is usually located inferiorly and laterally of the ICA. The ostium of the vidian canal is found bellow the foramen rotundum. Most commonly, the vidian nerve terminates inferiorly to ICA.

Extensive pneumatization of the pterygoid process influences anatomical relations and size of the surrounding structures including the vidian canal, being associated with protrusion of the vidian canal[12,13].

In the literature, there are insufficient studies about the anatomic variations between the sphenoid sinus and the vidian canal; so, this topic is not fully clarified. Lee et al. described the location of the vidian canal according to the location of the sphenoid corpus and the sphenoid sinus floor[12].

The CT detection of the dehiscence of the bony roof of the vidian canal requires the surgeon to take additional precautions during the surgical procedure, in order to avoid injury to the content of vidian canal[12].

The identification of the vidian canal is highly important in endoscopic surgery of the skull base, not only for avoiding lesions of its content (vidian nerve and vidian artery), but also due to the fact that it represents an important landmark for the location of the internal carotid artery, which is consistently sited on the lateral part to the vidian canal[16].

Intrasinusal septa

The cavity of the sphenoid sinus is usually divided in two parts by a median septum. There is a high anatomic variability regarding septation of the sphenoid - multiple septa, different locations of insertion to the walls of the sphenoid sinus. Due to the position, number and site of insertion of the septum, the cavity of the sphenoid sinus can be divided in two or more parts that are uneven (Figure 4). The crucial insertions are the carotid canal and the optic canal (Figure 5). The preoperative CT scan visualized in axial section is the optimal method to identify the septum insertion[7,17].

From the 100 CT scans evaluated in our study, none of them revealed the absence of the intrasinusal septa.

IMAGISTIC EVALUATION OF SPHENOID SINUS LANDMARKS

Multiplanar sinus CT scan is mandatory in the preoperative evaluation of the patient. Each imaging plane is important in evaluation of anatomic variants, that can make the patient susceptible for recurrent disease and interfere with the surgical approach, and of critical variants that can put the patient's life at risk[3].

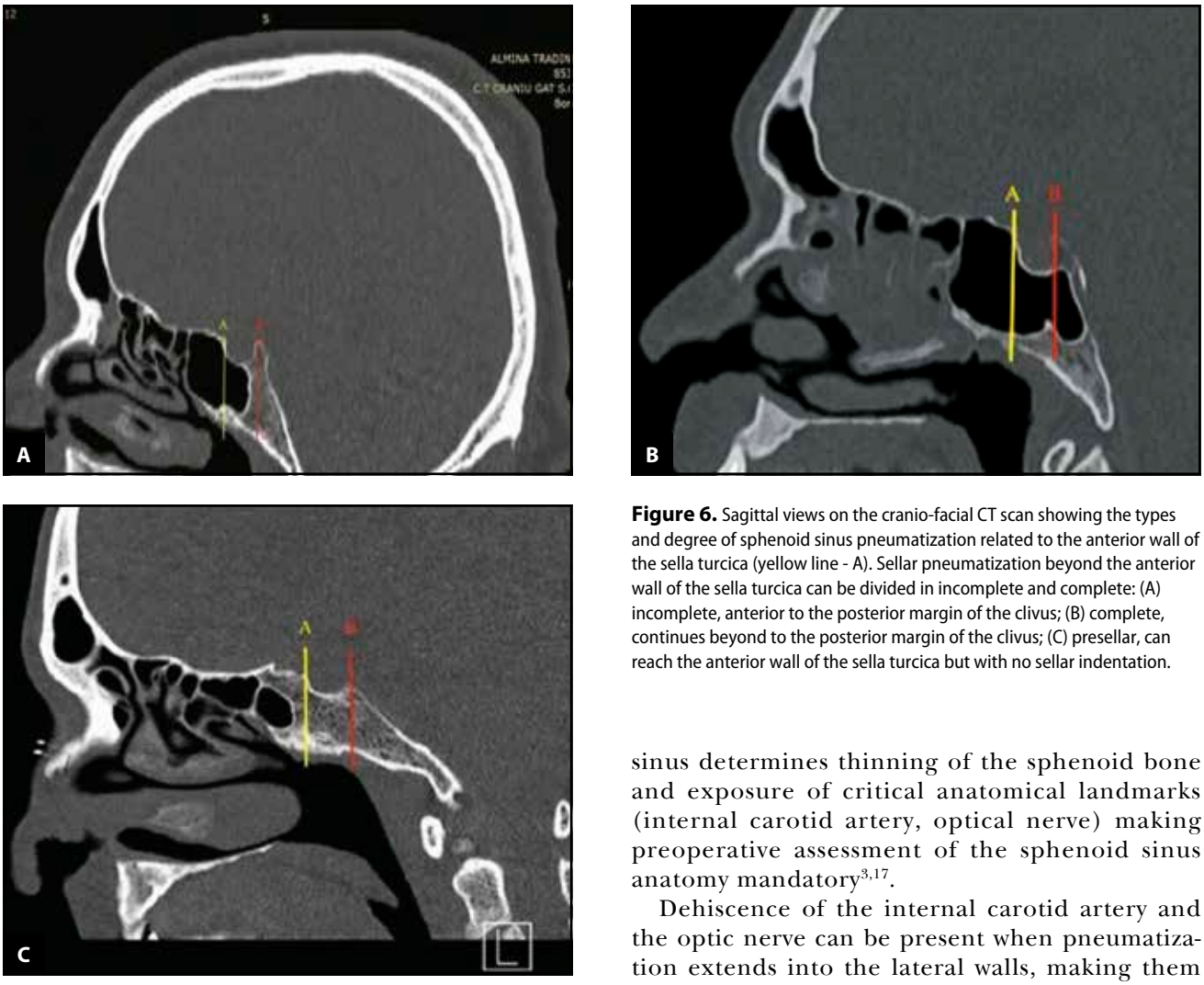


Figure 6. Sagittal views on the cranio-facial CT scan showing the types and degree of sphenoid sinus pneumatization related to the anterior wall of the sella turcica (yellow line - A). Sellar pneumatization beyond the anterior wall of the sella turcica can be divided in incomplete and complete: (A) incomplete, anterior to the posterior margin of the clivus; (B) complete, continues beyond to the posterior margin of the clivus; (C) presellar, can reach the anterior wall of the sella turcica but with no sellar indentation.

The key point in identifying the natural sphenoid ostium is the location of the superior turbinate on the CT scan. The CT also indicates when it is necessary to do an MRI exam.

The MRI exam is recommended when there is a suspicion of local complications (extension in the adjacent spaces, e.g., intracranial or orbital), also playing an important role in the differential diagnosis between proliferative processes, internal carotid artery aneurysm or encephaloceles[18].

Depending on the extent of the pneumatization into the sphenoid bone in relation with the sella turcica, the sphenoid sinus can be classified into: conchal, presellar and sellar[19].

Sellar pneumatization is the most common type in which the pneumatization surpasses the tuberculum sella and can extend as far as the clivus and can be divided in incomplete (Figure 6 - A) and complete sellar pneumatization (Figure 6 - B) in relation with the posterior wall of the sella turcica. Excessive pneumatization of the sphenoid sinus determines thinning of the sphenoid bone and exposure of critical anatomical landmarks (internal carotid artery, optical nerve) making preoperative assessment of the sphenoid sinus anatomy mandatory[3,17].

Dehiscence of the internal carotid artery and the optic nerve can be present when pneumatization extends into the lateral walls, making them prone to injury during the endoscopic surgery.

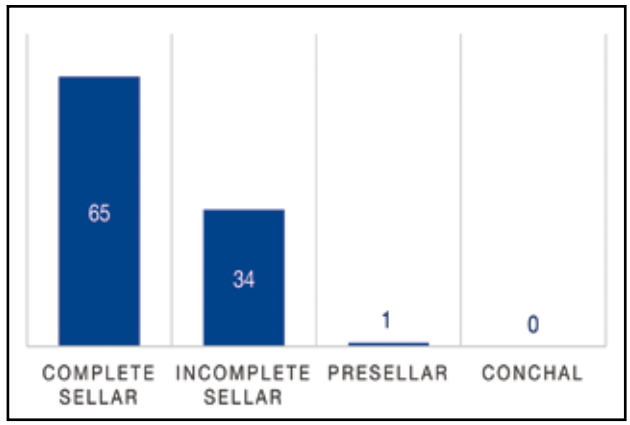
Pneumatization of the sphenoid bone that reaches the anterior wall of the sella turcica represents the presellar type (Figure 6 - C). A distance greater than 10 mm between the posterior wall of the sphenoid sinus and the anterior wall of the sella represents the conchal pneumatization.

Based on the types of pneumatization of the sphenoid sinus, we analysed the CT scans of the 100 patients. The extension of pneumatization was analysed in sagittal sections by drawing an imaginary line along the anterior and posterior walls of the sella.

From 100 patients included in the study, none of them presented the conchal type, 1% of them presented presellar pneumatization and sellar pneumatization was found in 99% of the patients, of which 65% complete sellar and 34% incomplete sellar pneumatization (Table 1, Graph 3). No significant differences were found regarding the pneumatization patterns between genders. Reviewing the literature, the sellar type of sphenoid sinus pneumatization was found between 83% and 98%,

Table 1. Distribution of sphenoid sinus pneumatization.

TYPE		Number of patients	Percentage
Conchal		0	0%
Presellar		1	1%
Sellar	Incomplete	34	34%
	Complete	65	65%



Graph 3. Distribution of the sphenoid sinus pneumatization.

presellar type 2 to 5%, while the conchal type was reported in less than 1% of the cases[20-22].

Identifying the anatomic location of the pathological process and the preoperative imagistic examination to identify possible variations of the sphenoid sinus and of the vital surroundings structures are the mandatory requirements that must be met in order to choose the appropriate type of endoscopic sphenoidotomy.

ENDOSCOPIC APPROACHES TO THE SPHENOID SINUS

The exact localization of the pathological process guides the surgeon in selecting the appropriate technique and to fulfil the main goal of the surgical act – a safe sphenoid sinus approach with a long-term patency that allows satisfactory ventilation and drainage of the sinus[23].

The sphenoid sinus can be endoscopically approached by 3 main routes: transnasal, transethmoidal and transseptal. Locating the anatomical ostium is the principal step in approaching the sphenoid sinus. The sphenoid ostium is located in close proximity to the skull base; at approximately 1.5-2 cm inferiorly to the ostium is located the choanal arch and septal branch of the sphenopalatine artery (Figure 7). The ostium is situated at approximately 7 cm from the base of the columella, having medially the posterior septum[4,23].

The endoscopic approaches can be performed directly, medial to the middle turbinate, or through the ethmoids, lateral to the middle turbinate. For selection of the most appropriate technique, Gibbons and Sillers developed an algorithm based on the anatomically location of the pathologic process[24].

Identification of the sphenoid ostium is essential regardless of the endoscopic type of approach. The sphenoid ostium is located superiorly to the choanal arch and medially to the superior turbinate, but there are situations when the ostium cannot be visualized, making essential the identification of landmarks on the CT scan - orbital walls, the level of orbital floor (it is below the sphenoid roof, indicating the level of the sphenoid ostium), the medial orbital wall (corresponding to the lateral wall of the sphenoid sinus, it also indicates the location of the internal carotid artery and the optic nerve)[4,23].

Also, skull base injury can accidentally happen, especially because it often has a descending trajectory from the posterior ethmoidal sinus to the sphenoid sinus.

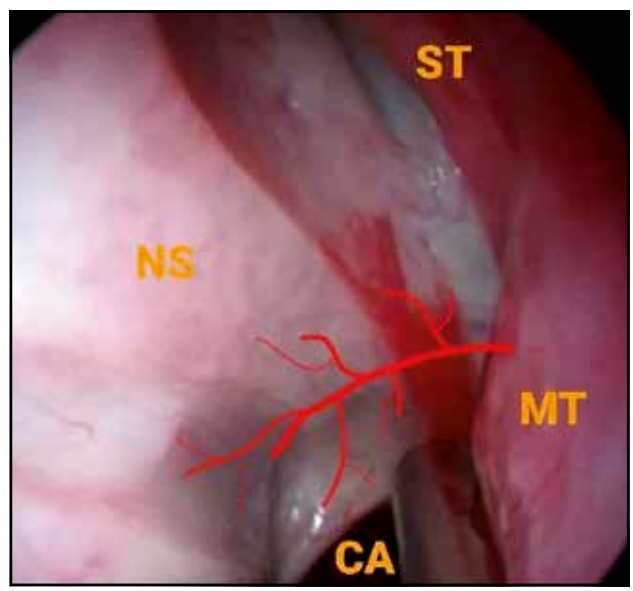


Figure 7. Trajectory of the septal branch of the sphenopalatine artery (Abbreviations: NS, nasal septum; MT, middle turbinate; CA, choanal arch; ST, superior turbinate).

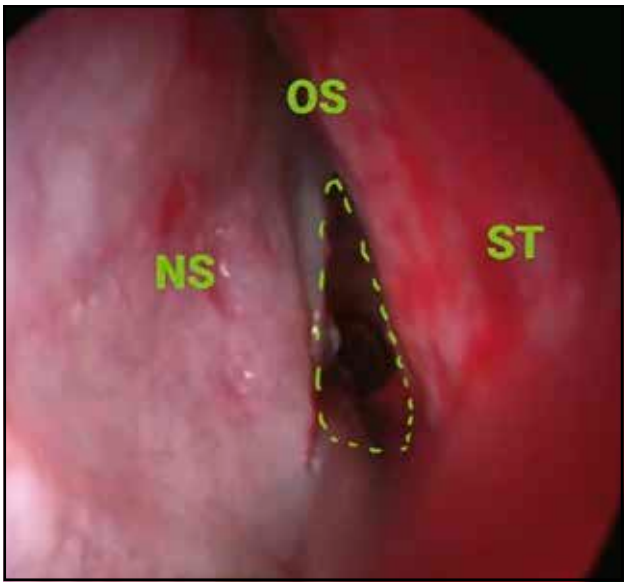


Figure 8. Endoscopic view of sphenoid ostium sphenoidalis (Abbreviations: NS, nasal septum; OS, ostium sphenoidalis; ST, superior turbinate).

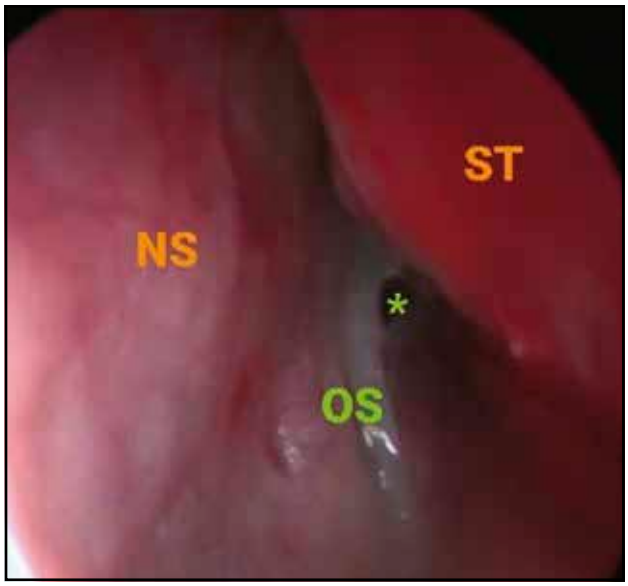


Figure 9. Enlarged sphenoid ostium (Abbreviations: NS, nasal septum; OS, ostium sphenoidalis; ST, superior turbinate).

The gold standard intervention for chronic sphenoid disease is the *endoscopic transnasal sphenoidotomy* by approaching directly the natural ostium of the sphenoid sinus, which is why it is considered to be a "physiological" intervention[4,5,23]. The first step in identifying the natural ostium is dislocating the middle turbinate laterally in order to visualize the superior turbinate that needs to be displaced medially to find the sphenoid ostium (Figure 8).

The natural ostium is identified by palpating with a blunt instrument upwards from the choana until bone absence is felt – at the level of the natural ostium only mucosa is present. At this point, with a microdebrider or a spoon curette, the enlargement of the ostium is made in a medial and inferior direction, in order to reduce the risk of injury to the optic nerve, carotid artery or skull base (Figure 9).

In order to minimize the risk of failure due to insufficient drainage or injury to important structures, the sphenoidotomy must be done as much as needed and as little as possible to be patent. It should be done medially and inferiorly to reduce the risk of injury to the carotid artery and the optic nerve[18].

Increased caution is needed to avoid injury to the sphenopalatine artery which runs by the posterior part of the middle turbinate. The septal brunch of the sphenopalatine artery runs horizontally along the inferior and anterior face of the sphenoid sinus and distributes on the nasal septum[12].

Inside the sphenoid sinus, the use of the microdebrider is not recommended due to the possibility of injury to the elements found in the lateral wall of the sphenoid – the optic nerve, the internal carotid artery[18].

For patients with concomitant ethmoidal involvement, or who went through a previous ethmoidectomy, the appropriate approach is endoscopic *transethmoidal sphenoidotomy*[23,25]. The risk of this approach increases when the Onodi cells are extended laterally to the sphenoid sinus[23].

Onodi cells are sphenoethmoidal cells. While performing sphenoid sinus surgery, a surgeon might expect to encounter the optic nerve. Not looking for it while performing posterior ethmoidectomy raises the chance of iatrogenic injury to the optical nerve. It is important to identify the presence of Onodi cell on the CT scan because it can encase the optic canal when it pneumatizes laterally and superiorly to the sphenoid sinus – considering that a preoperative imaging evaluation is mandatory because the risk of skull base penetration translate into cerebrospinal fluid leak. The anterior sphenoidal approach through the Onodi cells is not allowed due to their position (Figure 10).

Also, during the endoscopic approach of the sphenoid sinus, the probability to confuse a pneumatized Onodi cell with the sphenoid sinus is not uncommon.

Endoscopic transseptal sphenoidotomy is used when a good bilateral exposure for the approach of the pituitary gland and related areas is needed. The

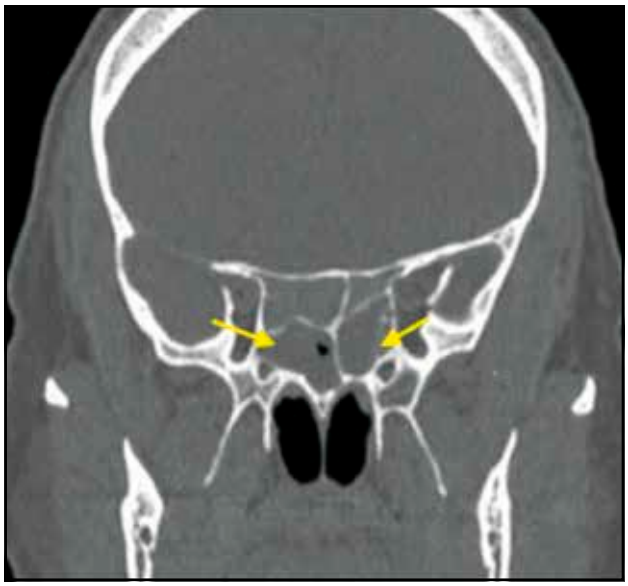


Figure 10. Coronal view of Onodi cells on cranio-facial CT scan.

technique is similar to the one used in the transnasal approach. The vomer is resected, and the inferior portion is saved, representing the landmark for the medial line. The anterior wall of the sinus is excised and the intersinus septum is also removed. This kind of approach is considered to be the safest for the surgeons who do not perform endoscopic sphenoid surgery very often[18,23].

Endoscopic pituitary and sphenoid sinus surgery are technically difficult, even for an experienced surgeon, due to the complex anatomical relationships of the sphenoid sinus with vital neurovascular structures such as the cavernous sinus, optic nerve and internal carotid artery (ICA). According to the literature, internal carotid artery injury is a rare complication, more commonly found in skull base transsphenoidal surgery, compared to functional endoscopic sinus surgery (FESS) which has an incidence ranging from 1.3-3.9%[26].

CONCLUSIONS

In this paper, in line with the literature, a variety of sphenoid sinus anatomy variations were found, and we emphasize the value of imagining evaluation before performing function endoscopic sinus surgery.

Sphenoid surgery must be done only with a solid knowledge of local anatomy, and preoperative imagistic examinations should be routinely done in order to assess the risk of injury to critical structures and to avoid surgical errors, like the confusion of the Onodi cells with the sphenoid sinus. Based on imagistic evidence of the pathology and anatomical relationships, the appropriate technique must be chosen.

Transnasal endoscopic sphenoidotomy is the safest and the least invasive mean of approaching sphenoid sinus intrinsic pathology because, by approaching the medial part of the anterior sphenoid wall, a safe distance is kept up to critical neurovascular elements that surrounds the sphenoid sinus. However, for surgeons who have not performed endoscopic sphenoid surgery very often, the transseptal approach is considered to be the safest due the midline approach.

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