

More actors, different play: sphenothmoid cell intimately related to the maxillary nerve canal and cavernous sinus apex

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Abstract

The sphenoid sinus is one of the most morphologically variable and surgically important structures of the skull base. Located below the *sella turcica*, neighbored by parasellar regions, such as the orbital apex, pterygopalatine fossa and lateral sellar region (cavernous sinus), it is clinically related to these and surgically relevant as corridor for various approaches. Moreover, at the sphenothmoidal junction, important variations occur, most of these related to the presence of the Onodi cells and the intrasinus protrusions of the optic nerve. That is why any identified and previously undescribed morphological variation at that level must be added to the well-established protocols, clinical and surgical. During a retrospective CT study of the sphenoid sinus anatomical features a previously unreported morphology was encountered and is reported here. It refers to a unilateral sphenothmoid cell (SEC), Onodi-positive, not only overriding the superior aspect of the sphenoid but also its lateral side to get intimately related to the maxillary nerve. As that SEC expanded medially to the cavernous sinus apex, it altered the usual endosinus morphological correlations and also added itself within the limits of the Mullan's triangle. It appears so that such postero-infero-lateral extended pneumatization of an Onodi cell alters the surgical landmarks and also can blur clinical pictures, by adding maxillary and pterygopalatine signs and symptoms.

Keywords: sphenoid sinus, parasellar region, pterygopalatine fossa, trigeminal nerve, CT.

Introduction

Trans-sphenoidal surgery, either microscopic or endoscopic is a safe procedure. Combination of the trans-sphenoidal route with the endoscope or neuro-navigation may improve the effectiveness of the operation. Sphenoid sinuses are the most inaccessible paranasal sinuses and are surrounded by a series of anatomic structures [1], already "classical" as regarding their exposure to risk during inadequate maneuvers (e.g. the optic nerve, internal carotid artery).

The sphenoid sinus is one of the most individually variable morphological structures and so the anatomical landmarks vary in a wide range from patient to patient [1].

Even though computer tomography (CT) opened the era of detailed morphological studies, the human substrate still offers new, undocumented yet, proofs of anatomic variation as it is the one reported here.

In the traditional anatomy, the maxillary nerve (MN) is described as leaving the middle cranial fossa (MCF) through the *foramen rotundum* to get within the pterygopalatine fossa (PPF). In that course, it may traverse a canal of individual length at the level of the

greater wing of the sphenoid bone. The maxillary nerve canal (MNC) is anatomically related with the lateral wall of the sphenoid sinus (SphS) and in well-pneumatized sinuses, it may protrude within the sinus cavity, offering for endoscopists a valuable landmark on the lateral sinus wall. The outer part of lateral wall of the SphS in well-pneumatized sinuses contains four bony protuberances (determined by the optic nerve, cavernous sinus apex, maxillary and mandibular nerves) and three depressions (carotico-optic, ophthalmomaxillary, and maxillo-mandibular) [2]. The carotico-optic recess may expand within the optic strut and further, within the anterior clinoid process. The removal of the bone covering the lateral wall of the sphenoid sinus and the carotid protuberance permits the exposure of the neurovascular structures that form the anterior part of the cavernous sinus [3].

Even though a large amount of studies were published on the maxillary nerve relations, as related to the lateral wall of the SphS, none of these described yet the morphological possibility of a posterior ethmoid cell – sphenothmoid cell (SEC) to get intimately related with the MN, although the presence of a SEC is well

documented in the PPF supero-medial limit. Most of the related studies on the SECs refer to the Onodi-positive SECs that, if present, it places at risk the optic nerve [4, 5].

Materials and Methods

During a retrospective CT study of the SphS morphology, performed on 150 CT scans of adult patients, a new morphological pattern (SEC expanded posterior to the orbital apex) was identified at the level of the right SphS wall on the scan of a 59-year-old male patient. Informed consent was obtained, if the identity of patients was kept anonymous. For the present case, axial scans were evaluated and also multiplanar reconstructions (MPR) were evaluated and so, the eventual misdiagnosis due to some degree of the head inclination was prevented.

Abbreviations

ACP – anterior clinoid process;
 CS/LSC – cavernous sinus/lateral sellar compartment*;
 ICA – internal carotid artery;
 MN – maxillary nerve;
 MNC – maxillary nerve canal;
 MS – maxillary sinus;
 OPEC – overriding posterior ethmoid cell;
 OSR – optic strut recess;
 PPF – pterygopalatine fossa;
 PPG – pterygopalatine ganglion;
 SEC – sphenoidal cell;
 SOF – superior orbital fissure;
 SphS – sphenoid sinus;
 VC – vidian canal (pterygoid canal).

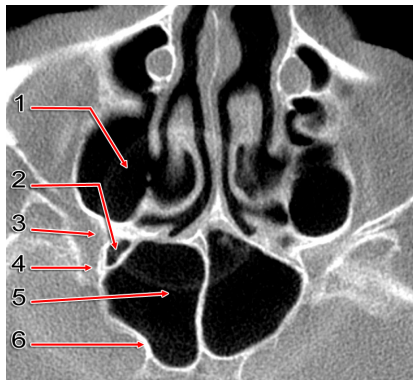
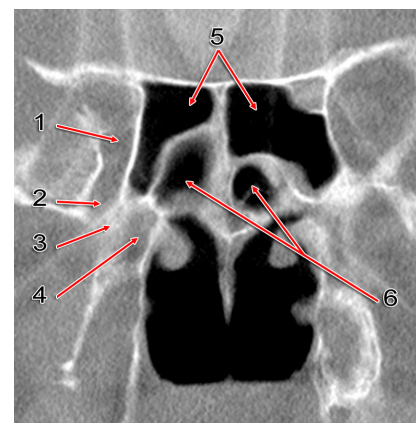


Figure 1 – Axial CT slice at the level of the maxillary nerve canal (MNC) demonstrating a distinctive pneumatization at the antero-infero-lateral angle of the right sphenoidal sinus intimately related to the MNC, that it would prove to be a sphenoidal cell (SEC). 1. Maxillary sinus; 2. Right SEC; 3. Pterygopalatine fossa – the outer part of the upper compartment; 4. MNC; 5. Right sphenoidal sinus; 6. Mild intrasinusal protrusion of the right internal carotid artery.

Figure 2 – Coronal CT reconstruction, at the level of the orbital apex, demonstrating the bilateral presence of Onodi-positive sphenoidal cells (SECs); on the right side, the SEC was expanded inferiorly to the pterygopalatine fossa (PPF) and laterally was bordering the apex orbitae. 1. Orbital apex; 2. Outer part of the superior compartment of the PPF, in front of the anterior opening of the maxillary nerve canal (MNC); 3. Positive relief on the maxillary surface of the greater wing of the sphenoid bone, between the MNC and vidian canal anterior openings; 4. Inner part of the superior compartment of the PPF, it lodges the pterygopalatine ganglion and is located in front of the anterior opening of the vidian canal; 5. Bilateral, Onodi-positive SECs, overriding the sphenoid sinuses (SphSs); 6. Anterior ends of the SphSs.



* As Dwight Parkinson noted, based upon its tremendous and unanimously recognized work, the use of the term “cavernous sinus” remains the greatest single obstacle to understanding the anatomy of this area [6]. He suggested the term “lateral sellar compartment” to refer to the space, and its contents should be labeled for what they are – the parasellar veins. Based upon my personal evidences we agree to this reform of the terminology. However, we must take into account the evaluation of Rhoton Al Jr (2009) who considers that both concepts, that of an unbroken, trabeculated, venous cavern and that of a plexus of various sized veins are partly correct [7]. We will use so in the text, from now on, both terms, „cavernous sinus/lateral sellar compartment”, abbreviated CS/LSC.

Results

From the CT study of the 150 patients, a single case (0.67%) presented unilaterally a sphenoidal cell expanding behind the orbital apex and intimately associated with the MNC and LSR/CS.

In that case, it resulted that the sphenoidal sinuses were relatively symmetrical: (a) sagittally, due to comparable pneumatizations of sellar type and (b) transversally, if taking into account the relative median position of the intersinus septum (Figure 1).

The axial slices at the level of the MSs evaluated unilaterally, on the right side, the presence of a distinctive pneumatization at the inner border of the MNC, coating the SphS at that level (Figure 1). As that pattern needed an accurate identification, multiplanar reconstructions were examined, coronal (Figures 2 and 3), sagittal (Figures 4 and 5) and oblique (Figure 6).

Figure 3 – Coronal CT reconstruction at the level of the anterior opening of the maxillary nerve canal (MNC) and optic canal (*) that demonstrates the ethmoidal “coat” of the right sphenoid sinus (SphS). 1. Superior orbital fissure (SOF); 2. Anterior root of the greater wing of the sphenoid bone, separating the MNC and the SOF; 3. MNC; 4. Vidian canal – separated to the MNC by a discrete pterygoalar recess of the right SphS (gray arrowhead); 5. Right SEC, with an indentation due to the posterior superposition of the optic strut recess (black arrowhead) of the right SphS; 6. Left SEC; 7. SphSs.

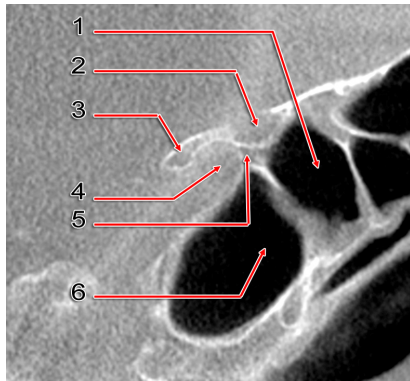
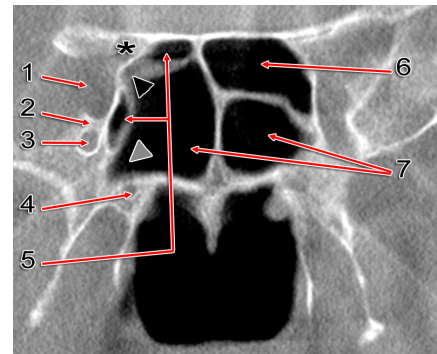


Figure 4 – Sagittal CT reconstruction on the left side, demonstrating the Onodi characteristic of the left sphenothmoidal cell (SEC). 1. Left SEC; 2. Optic canal; 3. Anterior clinoid process; 4. Anterior loop of the internal carotid artery; 5. Optic strut; 6. Left sphenoid sinus.

Figure 5 – Sagittal CT reconstruction on the right side, at the level of the sphenothmoidal junction; both cavities, of the sphenoidal sinus (SphS) and the sphenothmoidal cell (SEC) are closely related to the optic canal. 1. Anterior clinoid process; 2. Anterior loop of the internal carotid artery; 3. Right SphS; 4. Pterygopalatine fossa – the inner part of its superior compartment, where the pterygopalatine ganglion is lodged; 5. Optic strut, optic strut recess of the SphS; 6. Optic canal; 7. SEC, positive for a recess of the anterior root of the lesser sphenoidal wing; 8. The posterior inferior lateral extension of the SEC determines a protrusion of the SphS outer wall; 9. Maxillary sinus.

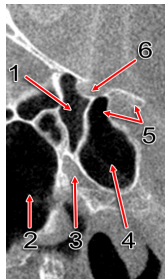
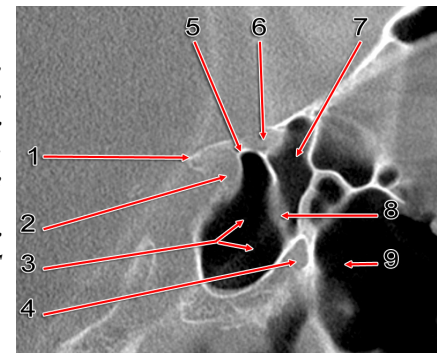


Figure 6 – Oblique CT reconstruction, demonstrating the topography of sinuses neighboring the upper compartment of the pterygopalatine fossa, on the right side. The sinusal origin of the lesser wing pneumatization around the optic canal is double, sphenoidal and ethmoidal. 1. Right SEC; 2. Maxillary sinus; 3. Pterygopalatine fossa – the inner part of its superior compartment, where the pterygopalatine ganglion is lodged; 4. SphS; 5. Optic strut recess, anterior clinoid process; 6. Optic canal.

On the coronal reconstructions the bilateral presence of SECs, overriding the SphSs, was diagnosed. So, OPECs were identified, the left one being larger than the right one (Figure 2). Then, those OPECs were evaluated for the relation with the optic canals: both were positive for the protrusion of the optic canal (Figures 2 and 4–6) in the respective cavity and so were considered as Onodi-positive OPECs. The left optic canal was only protruding within the OPEC on that side, the respective optic strut, bony and not pneumatized, being inserted on the bone at the sphenothmoid junction, between the SphS and the OPEC on that side (Figure 4). On the right side, the relations of the optic canal were more complex and different (Figure 6):

- the SphS sent an OSR located posterior, inferior and lateral to the optic canal, separating that canal to the ICA anterior loop (Figure 5);

- the OPEC sent a recess of the anterior root of the lesser wing, antero-medial to the optic canal;
- none of these two recesses pneumatized the anterior clinoid process on that side.

Further evaluation of the right OPEC on multiplanar reconstructions evaluated the following:

- that cell was medial to the orbital apex and extended on the side of the SphS towards the PPF (Figure 2);

- within the roof of the PPF it was supero-medial to the outer part of the upper compartment of the PPF but superior to the medial part of that compartment (Figures 2, 5 and 6) – within the later is lodged the PPG.

The appearance of the pneumatization on coronal slices, at the level of the anterior ends of the MNC and VC, immediately posterior to the PPF, could have been easily misdiagnosed for multiple intrasinus septa of the

SphS, but on various multiplanar serial slices, it was finally evaluated that the SphS and its OSR indented posteriorly that OPEC (Figure 3).

So, the postero-lateral extension of the right OPEC reached the medial wall of the apex of the CS, with the following relations (Figure 3):

- it was medial and supero-medial to the MNC and to the anterior root of the greater wing of the sphenoid bone;

- a discrete pterygoalar recess of the SphS first passed below the OPEC before being engaged in the corridor between the maxillary and vidian nerves:

- usually the lateral extension of the SphS is described as lateral recess, but we consider that term as general; the inferolateral recess of the SphS is first engaged, on coronal slices, within the corridor between the maxillary and vidian nerves and then it may evolve under the maxillary nerve within the greater wing of the sphenoid and/or inferiorly, below the level of the vidian nerve, within the pterygoid process. So, when simply engaged in the maxillary-vidian nerves corridor it is better to be termed as pterygoalar recess that further can continue as lateral/alar recess and/or pterygoid recess.

Located between the OSR, superiorly, and the pterygoalar recess, inferiorly, on coronal slices, the postero-lateral extension of the right OPEC protruded within the SphS (Figure 3).

Discussion

Radiologic reports of computed tomography (CT) scans of the paranasal sinuses often omit key information necessary for the surgeon to plan the procedure. The radiologist, unaware of what may be important to the surgeon, often includes in his reporting information of little value [8]. It is our opinion that, being aware of these, surgeons to assist the scan and/or to demand specific morphologies of interest to be evaluated. But, even though a consensus is reached, previously undescribed morphologies that alter a constant topography may escape undetected at CT scans and put additional risk on the surgical procedures. Apart the surgical relevancy of some rare and risky morphologies, an altered topography can modify a traditional clinical picture and so, some diagnostics might be obscured.

That is why the present report pleads for an accurate and open-minded CT evaluation at the level of the sphenothmoidal junction. This evaluation was described as a distinctive step (“*Note sphenothmoid interface configuration*”) in a seven steps protocol defined by Meyers and Valvassori in 1998 for radiologists, in order to have them focused on the surgically relevant details.

Clinically, the direct relations of such a SEC, as the right OPEC reported here, with the orbital apex, maxillary nerve and pterygopalatine (sphenopalatine) ganglion may determine, in pathologic states, clinical syndromes (such as the orbital apex syndrome, maxillary/trigeminal neuralgia and sphenopalatine neuralgia) that can mix symptoms and so can blur the diagnostic.

CS/LSC surgery presents a high grade of difficulty

because of its intrinsic anatomic complexity. Tremendous effort has been expended during the past 30 years by numerous authors to improve the surgical techniques to minimize mortality and morbidity rates. Surgery in this area requires a very detailed anatomic knowledge and excellent surgical skills [9]. However, focusing my referential upon authoritative modern references that review a large amount of papers, neurosurgically oriented, we could not get a description of the possible presence of a SEC inner to the medial wall of the CS/LSC, neither closely related to the maxillary nerve. Rhoton AL Jr (2009) described that some of the posterior ethmoid air cells, located in front of (but not outer to, my comment) the upper part of the “*lateral wing of the sphenoid sinus*”, often have to be removed to gain the lateral exposure in the sphenoid sinus needed to see the wall of the CS/LSC [7]. As related to the CS/LSC and middle fossa surgery, the presence of a postero-inferolateral extension of a SEC, apart its Onodi-positive characteristic, it distorts the well-known landmarks by coating the SphS:

- in such cases, the protrusion of the CS apex on the lateral sinus wall is replaced by the protrusion of that SEC and will be identified below the carotico-optic recess;

- consequently, the inferior limit of the carotico-optic recess changes from the CS apex in the protrusion of the respective SEC;

- being located superior and medial to the maxillary nerve it projects within the anteromedial middle fossa triangle, as described by Rhoton AL Jr (2009), or the anterolateral triangle of Mullan, as described by Fukushima T (2009) [7, 10]. The triangle of Mullan is the neurosurgical corridor between the opthalmic nerve, running to the SOF and the maxillary nerve running to the *foramen rotundum* and contains the confluence of the superior and inferior opthalmic veins; this triangle can be used for the packing obliteration of a carotid cavernous fistula or for the exposure of the abducens nerve [10]. Removing the bone in this area will allow the access in the SphS, as Rhoton AL Jr (2009) described, only if the sinus is not provided with an ethmoidal “coat”.

- as the pterygoalar recess expands between that SEC and the vidian nerve, before reaching the level of the MN, the respective cell also modifies the limit of that pneumatic corridor.

A recent study [11] pointed me the attention on the DeLano types of the optic nerve as related to the posterior paranasal sinuses.

According to DeLano MC et al. (1996), who found in all their specimens that the optic nerves were “*intimately related to the sphenoid sinus*”, in type I (76%) the optic nerves course adjacent to the sphenoid sinus but do not indent the sinus wall, type II comes with the protrusion of the optic nerve within the SphS, in type 3 nerves course through the SphS and in type 4 (3%) the optic nerves course immediately adjacent to the sphenoidal sinus and posterior ethmoidal cells [12].

In the case reported here there were bilaterally different situations of the optic canal topography:

- on the left side the optic canal was distanced and

not “intimately related” to the SphS and only protruded within the respective OPEC; if I take *ad litteram* the statements of DeLano MC *et al.*, this type in my report could be considered somehow a type 0; if not, we can refer it as type I DeLano;

▪ on the right side there was a rare type 4 DeLano topography of the optic canal, that one being kept as in a claw between the OSR of the SphS and the anterior root of the lesser wing pneumatization expanded from the OPEC on that side.

Both the right SphS and OPEC in the case reported here were expanding pneumatizations towards, but not reaching within the anterior clinoid process (ACP); the OPEC expanded *via* the anterior root of the lesser wing and the SphS *via* the optic strut. This pattern of pneumatization corresponds to the type III of ACP pneumatization, as defined by Mikami T *et al.* in 2007 and identified in 10.9% of 600 sides examined by CT [13]. Even though in the present case, the ACP was not pneumatized, its base, represented by the optic strut, it was and so, in such situations, a degree of risk for pneumocephalus or rhinorrhea may be considered during an anterior clinoidectomy [1, 13].

During various surgical approaches at this level, compression or contusion to the optic nerve should be avoided and, moreover, the anesthesiologist should be informed and prepared for arrhythmia or even for cardiac arrest for a while due to trigeminal nerve stimuli [14]. In cases such as this reported here, the OPEC is closely related not only to the optic nerve but also to the maxillary nerve and so, both nerves have to be identified during surgery, in order to avoid devastating neurological complications.

☐ Conclusions

As conclusive remark, it must be stated that practitioners, clinicians and surgeons, must be familiar with the topographic anatomy, not only in what regards the pathological deviations as stated Yonekawa Y (2009), but also in what concerns the variant morphologies.

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