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Sphenoid bone and its sinus — anatomo-clinical review of the literature including application to FESS

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Abstract: Authors paid attention to anatomy and clinical implications which are associated with the variations of the sphenoid sinus. We discuss also anatomical structure of the sphenoid bone implementing clinical application of this bone to different invasive and miniinvasive procedures (i.e. FESS).

Key words: sphenoid bone, sphenoid sinus, anatomy, computer tomography, FESS.

Introduction

Sphenoid sinuses are pneumatic spaces lined with mucosa, located in the body of the sphenoid bone. Their morphology is highly variable. Their variability concerns:

- Size
- Shape
- Number of septa
- Level of pneumatization

There is a lack of unequivocal pattern of the sinuses, which could have been supposed as anatomically normal.

Sphenoid sinuses neighbor through their walls with important anatomical structures, both nervous and vascular — this neighbourhood and anatomical composition of the sphenoid sinuses are extremely important for the surgery in these regions. Anatomical evaluation of different parameters of the sphenoid sinuses is essential before execution of any of the surgical procedures (including endoscopy) to minimize the risk of opearation and to avoid potential complication during the procedure [1–11].

Computer tomography (CT) is one of the most precise methods which helps to visualize paranasal sinuses. This method enables to recognize variations of the anatomical composition of the sphenoid sinuses, first of all because of precise visibility of the bone structures.

Anatomical composition of the sphenoid bone

Impaired sphenoid bone is placed in the middle of the cranial base and joins with 12 bones:

- single
  1. Vomer
  2. Ethmoid
  3. Frontal
  4. Occipital
- paired
  1. Parietal
  2. Temporal
  3. Zygomatic
  4. Palatine

One can distinguish in the sphenoid the body and three even processes: greater and lesser wings, and the pterygoid processes.

The body (corpus) is a middle part of the bone, it's shape is similar to a cube. This is why we distinguish six major surfaces: the anterior, the superior, the inferior and the two lateral. The posterior aspect of the body unites with the basal part of the occipital through the spheno-occipital synchondrosis. The anterior aspect of the body presents sphenoidal crest, that connects anteriorly with the perpendicular lamina of ethmoid and inferiorly continues as sphenoidal rostrum. On both sides of the sphenoidal crest

one can find the sphenoidal conchae. Lateral and superior to the conchae we can find the apertures of the sphenoidal sinuses, that lead into the sphenoidal sinuses located inside the body of the sphenoid. On the inferior surface of the body one can see sphenoidal rostrum that is embraced by the wings of vomer. Bilaterally on both sides of the body one can find the carotid sulcuses. There is sphenoid lingula, posterior and lateral to these sulcuses. Greater wings and medial pterygoid plates insert to lateral surfaces of the sphenoid body. The superior surface, faceing the cranial fossa shows a coronally arranged groove — sella turcica, with hypophysial fossa. The sella is bordered posteriorly by the dorsum sellae, that ends laterally with posterior clinoid processes. The clinoid processes may be united in the form of bony bridges that fuse together mentioned processes uni- or bilaterally [12–15]. Posteriorly dorsum sellae falls down, and together with the basilar part of the occipital forms clivus (of Blumenbach). The anterior portion of the superior surface of the body is occupied by the middle clinoid processes. Anterior to the sellar tubercle there is transversely oriented prechiasmatic sulcus, that bilaterally continues as the optic canals. Anterior border of this sulcus is sphenoidal limbus, followed next by sphenoidal plane. Anterior margin of this plane forms ethmoidal spine.

Greater wings, the largest sphenoid processes, are attached to lateral aspect of the body by radix (root). Posterior division of the wing forms the process named sphenoid spine. Two surfaces are distinguishable in the greater wing: cerebral (internal) and external. Cerebral surface is a fragment of the floor of the lateral part of the middle cranial fossa. The external surface can be subdivided into:

- Orbital
- Temporal
- Infratemporal
- Maxillary surfaces.

Three last surfaces are posterior walls of the temporal, infratemporal, and pterygopalatine fossae, respectively. The greater wing is pierced by foramen rotundum, ovale, and spinosum. The posterior border of the orbital surface of the greater wing of the sphenoid borders the superior orbital fissure from below, and its inferior margin borders the inferior orbital fissure.

Lesser wings begin medially in the supero-anterior part of the sphenoid body from two roots that embrace the optic canal. In the middle both lesser wings join with the sphenoid jugum. Superior surface of the lesser wings is a part of the floor of anterior cranial fossa. Posterior border is located at the anterior clinoid process.

Pterygoid processes originate bilaterally from the connection between body and the greater wing and they protrude downwards. They are composed of the medial and lateral pterygoid plates. These plates join anteriorly to form the pterygopalatine sulcus. Posteriorly both laminae embrace pterygoid fossa. \in the bottom the laminae are separated by the pterygoid notch. The base of the pterygoid process is pierced

by the pterygoid (Vidian) canal. There is a scaphoid fossa next to the base. The anterior wall of the process forms the posterior wall of the pterygopalatine fossa, while lateral surface of the lateral pterygoid plate forms a fragment of the medial wall of the infratemporal fossa. Inferior end of the medial pterygoid plate has a pterygoid hamulus, on its lateral surface one can find the groove of the pterygoid hamulus. A vaginal process separates from the root of the medial pterygoid plate. On the inferior surface of this process one can find the palatovaginal groove. There is a vomerovaginal groove between the body of the sphenoid and the vaginal process.

The body of the sphenoid is almost entirely composed of the compact substance. Small remnants of the cancellous substance are located in the posterior part of the body, in the roots of the pterygoid processes, in the thicker portions of the greater wings and along the posterior borders of the lesser wings.

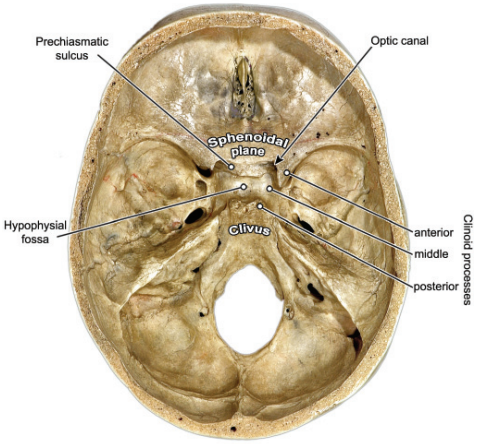

Fig. 1. Cranial fossae — view from above.

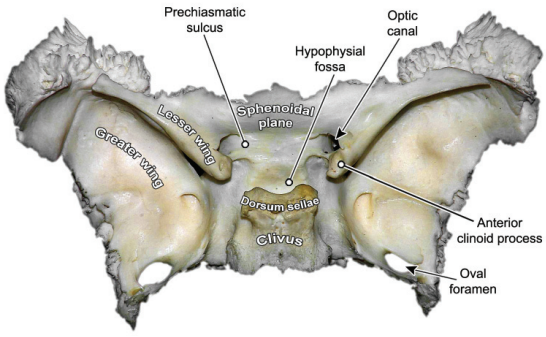

Fig. 2. Sphenoid bone (extracted) — view from above.

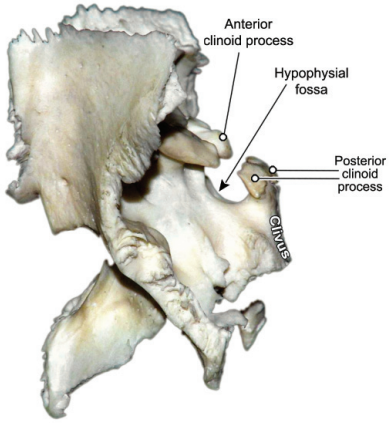

Fig. 3. Sphenoid bone (extracted) — view from lateral.

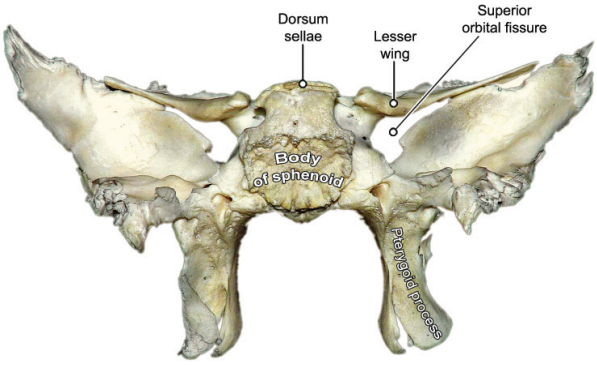

Fig. 4. Sphenoid bone (extracted) — view from behind.

The outline of the development of the sphenoid bone

Sphenoid bone develops from seven paired points of ossification, predominantly through endochondral method of bone growth. Only minimal foci of membranous ossification can be denoted.

Ossification point for the greater wing and the lateral pterygoid plate arises between the ovale foramen of foramen rotundum in the 8th week of gestation (alisphenoidale). In the 9th week one can find a point located in the lateral border of the optic canal that is designated for the lesser wing (orbitosphenoidale). The body ossifies based on two pairs of points arranged one by one: posterior pair forms so calles basisphenoidale and develops in the 3rd month of gestation in the floor of sella turcica, while the

anterior pair (that develops later than posterior) forms presphenoidale. A small point ossification for sphenoidal lingual and neighboring part of the carotid sulcus develops lateral to the basisphenoidale, and fuses soon with the basisphenoidale. Points of ossification of the basisphenoidale join with one another during the 4th month of fetal growth. Ossification point of the lesser wing and presphenoidale join together bilaterally at the same time, while both presphenoidale join together as well as with the basisphenoidale only during the 8. month (the cartilage placed between the anterior and the posterior pair of ossification points for the body regresses before delivery or soon after it). A separate ossification point of the medial pterygoid plate (pterygoid bone) appears during 2th month through membranous ossification. The membranous ossification is also a process of developments of a small point at the apex of the greater wing; all remaining points develop through the endochondral ossification.

Neonatal sphenoid bone consists of three parts: right and left, comprising the greater wing and the pterygoid process; and the central part, that develops from already united ossification points. These three portions united by a thin layer of cartilage unite during the first postnatal year. The sphenoid conchae develop from primary cranium from few ossification points, beginning with the fifth month of gestation [16]. To sum up the sphenoid bone develops from the following paired ossification points:

- For the greater wing and the lateral pterygoid plate (8th week of gestation; chondral background)
- For lesser wing (9th week of gestation, chondral background)
- For basisphenoidale (3rd month of gestation, chondral background)
- For presphenoidale (3rd month of gestation, chondral background)
- For sphenoidal lingual and adjoining part of the carotid sulcus (3rd month of gestation, chondral background)
- For medial pterygoid plate (2nd month of gestation; membranous background)
- For the apex of the greater wing (membranous background).

Anatomy of the sphenoid sinuses

Right and left sphenoidal sinuses are paired irregular pneumatic spaces that are lined with mucosa, placed inside the sphenoid body. They are divided by septum of the sphenoid sinus, that is rarely placed in the midsagittal plane; predominantly it is characterized by an oblique course — so the spaced are significantly asymmetrical. The volume of both sinuses is variable, mostly around 6 cm^3. They are variable both according to the shape, size and the level of pneumatization. Aeration of the sinuses may exceed beyond the level of the sphenoid body and may embrace it other parts (lesser and greater wings, pterygoid processes) and also bones neighboring to the sphenoid (vomer, ethmoid, frontal, occipital, parietal, temporal, zygomatic, and palatine bones).

Each of the sinuses has six walls: superior, inferior, lateral, medial, anterior, and posterior. The anterior wall of both of the sinuses presents the sphenoidal aperture, that is larger in the bone then in the lining mucosa (bony openings are surrounded by double layers of mucosal folds), about 0.5–5 mm large, located about 14 mm from the bottom of the sinus. Sphenoidal aperture leads on either side to the sphenoethmoidal recess, through which the sinus communicates with the superior nasal meatus.

The mucosal membrane of the sphenoid sinus is a continuation of the respiratory mucosal lining of the nasal cavity. Comparing to the mucosa of the nasal cavity, the mucosa of the sphenoid sinus is thinner, more pale and sparing of the glands, cuboid cells and cilia. Particular regions of the sinuses may completely do not have glands and cilia [16–18].

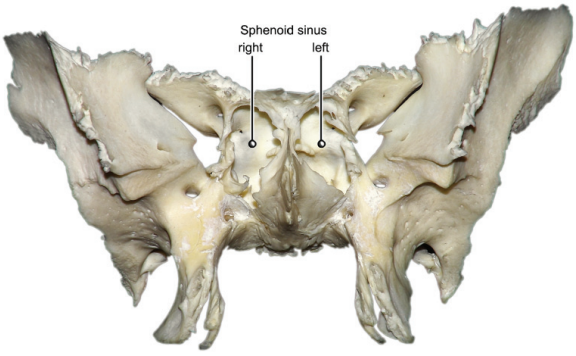

Fig. 5. Sphenoid bone (extracted). Sphenoid sinuses see — anterior view.

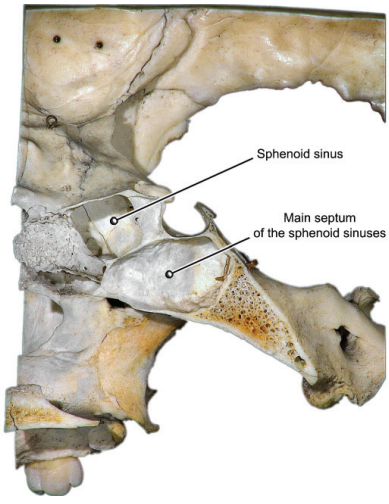

Fig. 6. Sphenoid bone (extracted). Sphenoid sinuses — view from lateral.

Outline of the development of the sphenoid sinuses

The sphenoid sinuses start their development around the 3–4 month of gestation [19, 20], through bilateral intussusception of the nasal mucosa toward the sphenoid bone. These intussusceptions of the mucosa have the form of recesses (sphenopalatine) and are adjacent to future sphenoidal apertures of the completely formed sphenoid sinuses. The sphenoid sinuses are present in a newborn, but they are not yet aerated. Their size does not exceed 2 mm in common [21] — at that stage of development they present as small cavities (size of a pea) — continuations of the spheno-ethmoidal recesses.

Process of aeration of the sinuses begins within postnatal period [22], around the 3–4 year and lasts until puberty — the moment of complete pneumatization is not precisely established and varies between 12–16 years of age.

Aeration begins in the front part of the sphenoid bone, bilaterally, within so called presphenoidal area, and next process continues posteriorly toward so called basisphenoidal area, until it reaches the level of anterior wall of clivus of Blumenbach [21]. During puberty period aeration of the sphenoid sinuses reaches its peak point: they achieve final form and shape, and further growth of the space beyond the sphenoid body, it means origin of sphenoid recesses can appear after maturation period [23]. The entire process may reach the base of occipital until the moment of ossification of the spheno-occipital synchondrosis, that occurs around the age of 20. Usually pneumatization of the sinuses ends in the third decade of life [22].

Process of development of the sphenoid sinus can be divided into two stages [24]:

1. Primary pneumatization — depression within the spheno-ethmoidal recess (neonatal period until age of 4)
2. Secondary pneumatization — connective tissue grows into skeletal framework of the viscerocranium (beginning of the pneumatization: around the age of 4; the end of pneumatization: around the age of 12–16).

Morphological difference of the aeration process enables to distinguish three main types dependent on the level of pneumatization [25, 26]:

1. Conchal (fetal) — minimal, rudimentary pneumatization, that involves the region of the sphenoid rostrum only, and does not reach the sphenoid body — this type is equal to sphenoid sinus aplasia or hypoplasia (underdevelopment),
2. Presellar — pneumatization is seen in the sphenoid body until the anterior wall of the hypophysial fossa and does not exceed the border of the sellar tubercle,
3. Sellar or postsellar — pneumatization involves the body, exceeds beyond the border of the anterior hypophysial fossa and the sellar tubercle.

Taking into consideration only fully formed sphenoid sinuses one can divide them into two main types: pre- and postsellar. The subdivision is based on the criteria involving the posterior borders. The border line between these two types is marked by

the vertical plane that goes through the sellar tubercle. This border is convergent with the place of junction of two pairs of fetal ossification centers (anterior and posterior) for the sphenoid body (basisphenoidale and presphenoidale [19].

The neighborhood of the sphenoid sinuses

The sphenoid sinuses through their walls are located next to important clinically, both nervous and vascular, anatomical structures. In the vicinity of the sphenoid sinuses one can find the following anatomical elements:

- Cavernous sinus (internal carotid artery; oculomotor, trochlear, ophthalmic, maxillary and abducens nerves; cavernous plexus)
- Optic nerve
- Optic chiasm
- Ophthalmic artery
- Olfactory nerve
- Nerve and vessels of pterygoid canal (Vidian nerve and vessels)
- Pituitary gland

Anatomical variations of the sinuses, especially their size and level of aeration influent anatomical relationships of the neighboring structures, that may impinge the sinuses (protrusion) or even partially traverse them [27, 28]. In case of strongly aerated sinuses, the structures located in the nearest vicinity of the sinus may be separated only by very thin bony lamina, that contains additionally bony dehiscenses (deficits).

Lateral walls of the sphenoid sinuses neighbor to the orbits (orbital surface of the sphenoid body is the medial orbital wall. Optic nerve bilaterally adheres to the lateral wall of the sphenoid sinus, while the optic chiasm adheres partially to the anterior and superior wall. Significant asymmetry of the sinus may cause the fact that both optic nerves are associated with one (dominant) sphenoid sinus [27]. Additionally the lesser wing of the sphenoid is traversed by the optic canal (that contains: the optic nerve and the ophthalmic artery).

The cavernous sinus is associated with the posterior and the lateral walls of the sphenoid sinus. The lumen of the cavernous sinus is traversed by the siphon of the internal carotid artery, internal carotid plexus (that in this particular region is named cavernous) and the abducens nerve (VI cranial nerve), while in the lateral wall of the sinus one can find the following nerves: oculomotor (III cranial nerve); trochlear nerve (IV cranial nerve), ophthalmic nerve (first division of the trigeminal nerve), maxillary nerve (second division of the trigeminal nerve). Lateral wall of the sphenoid sinuses are associated with the superior orbital fissure (lateral wall of the sphenoid body forms the medial border of this slot), and is traversed by the: oculomotor nerve, trochlear nerve, abducens nerve, orbital branch of the middle meningeal artery, superior ophthalmic vein, superior branch of the inferior ophthalmic vein, and

postganglionic sympathetic fibers of the cavernous plexus). Besides, the greater wings (attached to the lateral aspect of the sphenoid body) are pierced by foramen rotundum (traversed by maxillary nerve), oval foramen (traversed by the mandibular nerve and the venous plexus of foramen ovale), and foramen spinosum (that is pierced by the nervus spinosus and the middle meningeal vessels).

The posterior wall of the sphenoid sinuses may additionally relate to the structures positioned on the clivus of Blumenbach.

The superior wall of the sphenoid sinuses is located next to the pituitary gland. The Turkish saddle that comprises hypophysial fossa is located on top of the sphenoid body.

The inferior wall of the sphenoid sinuses neighbors to the nasal cavity (the sphenoid body together with the sphenoid conchae form the superior nasal wall). Moreover, the inferior wall of the sphenoid sinus is located next to the pterygopalatine fossa, that contains the following anatomical structures:

- Pterygopalatine ganglion
- Maxillary nerve (that divides into zygomatic, infraorbital and pterygopalatine nerves)
- Maxillary artery
- Part of pterygoid venous plexus

Sphenoidal rostrum that is located on the bottom part of the sphenoid joins the wings of the vomer by schindylesis. Aeration of the pterygoid processes may result in a direct neighborhood of the structures that are associated with them. The base of the pterygoid process is pierced sagittally by the pterygoid canal, traversed by the nerve and vessels of the pterygoid canal (of Vidius). Medial and lateral pterygoid laminae join along their anterior margins forming pterygopalatine sulcus (traversed by the maxillary artery and the pterygoid venous plexus). The laminae embrace pterygoid fossa posteriorly.

The anterior wall is located next to the posterior ethmoidal cells and the spheno-ethmoidal recesses (orifices of the sphenoidal sinuses), and through the recesses also indirectly with the superior nasal meatuses and the nasal cavity.

In sum, the walls of the sphenoid sinuses, depending on the level of pneumatization can be located next the following structures:

1. Lateral wall of the sphenoid sinuses:
    1. Optic nerve
    2. Ophthalmic artery
    3. Cavernous sinus (internal carotid artery; cavernous plexus; abducens nerve; oculomotor nerve; trochlear nerve; ophthalmic nerve; maxillary nerve)
    4. Superior ophthalmic vein
    5. Superior branch of the inferior ophthalmic vein
    6. Mandibular nerve
    7. Venous plexus of oval foramen

8. Nervus spinosus
9. Middle meningeal vessels

2. Superior wall of the sphenoid sinuses:
   10. Pituitary gland
   11. Optic chiasm
3. Inferior wall of the sphenoid sinuses:
   12. Pterygopalatine ganglion
   13. Maxillary nerve
   14. Maxillary artery
   15. Pterygoid venous plexus
   16. Vomer
   17. Nerve of the pterygoid canal
   18. Vessels of the pterygoid canal
4. Anterior wall of the sphenoid sinuses:
   19. Posterior ethmoidal cells
   20. Optic chiasm
5. Posterior wall of the sphenoid sinuses:
   21. Cavernous sinus (together with structures included) [11, 16–19]

Functional Endoscopic Sinus Surgery (FESS)

During last decade one can easily observe dynamic development of FESS [17, 29]. Application of minimally invasive endoscopic procedures decreases the number of classical extensive operations on sinuses. The most frequent indications for intranasal transsphenoidal approaches include:

- Suspicion of the tumor of the sphenoidal sinus
- Diagnostics and treatment of the fistula
- Tumors of the sellar region
- Inflammation of the sphenoid sinuses; drainage of the sphenoidal apertures
- Compression of the optic nerve

Endoscopic access enables also:

- Treatment of the rhinorrhea
- Treatment of the meningoencephalocele
- Ligation of the arteries in course of epistaxis
- Approach to the orbital apex, sphenoid bone and the pituitary gland
- Treatment of the nasal and sphenoidal tumors
- Treatment of the complications of the sphenoid sinus inflammation (i.e. subperiosteal or orbital abscess, meningitis, brain abscess)
- Treatment of muco- and pyocele
- Treatment of invasive or allergic mycotic inflammation of the sinuses [29, 30].

Functional endoscopic sinus surgerywas introduced in USA in 1985 by David Kennedy, and next in Europe by Messenklinger and Stammberger [31]. From the beginning of 90s this method is widely considered as a method of choice in the operative treatment of the chronic inflammation of paranasal sinuses. Endoscopic techniques enable good viewing of poorly accessible regions, smaller trauma and shorter recovery period of patients comparing to classical procedures [32, 33].

Complication of FESS

Potential complication of FESS are similar to these that may result after traditional surgical approach, although their frequency is lower [29]. These complication (depending on the cause of the procedure) may include:

- Bleeding
- Blood transfusion (risk of infection incl.)
- Rhinorrhea
- Anosmia
- Ocular complications (optic nerve trauma, injury to extraocular muscles, lesion to medial orbital wall, orbital emphysema, orbital haemorrhage, anisocoria, diplopia, ischaemic neuropathy of the optic nerve, blindness)
- Lesion to cavernous sinus/ internal carotid artery (including: fistula, aneurysm, rupture of the internal carotid artery; compression of the internal carotid artery with subsequent brain stroke, thrombosis, embolism)
- Lesion of the cribriform plate and frontal lobes
- Lesion of the anterior cerebral artery
- Lesion of the nasolacrimal duct
- Anesthesiology risk (including death)
- Risk of the nasal septal repair
- Hipopituitarism
- Diabetes insipidus
- Others (i.e. lacrimation, numbness or discomfort of upper teeth, pain of numbness of the lips and periocular regions [29, 34–69].

Conflict of interest

None declared.

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