RHINOLOGY Corrected Proof ORIGINAL CONTRIBUTION

Three-dimensional anatomy of the junction between the posterior ethmoidal region and the sphenoid sinus

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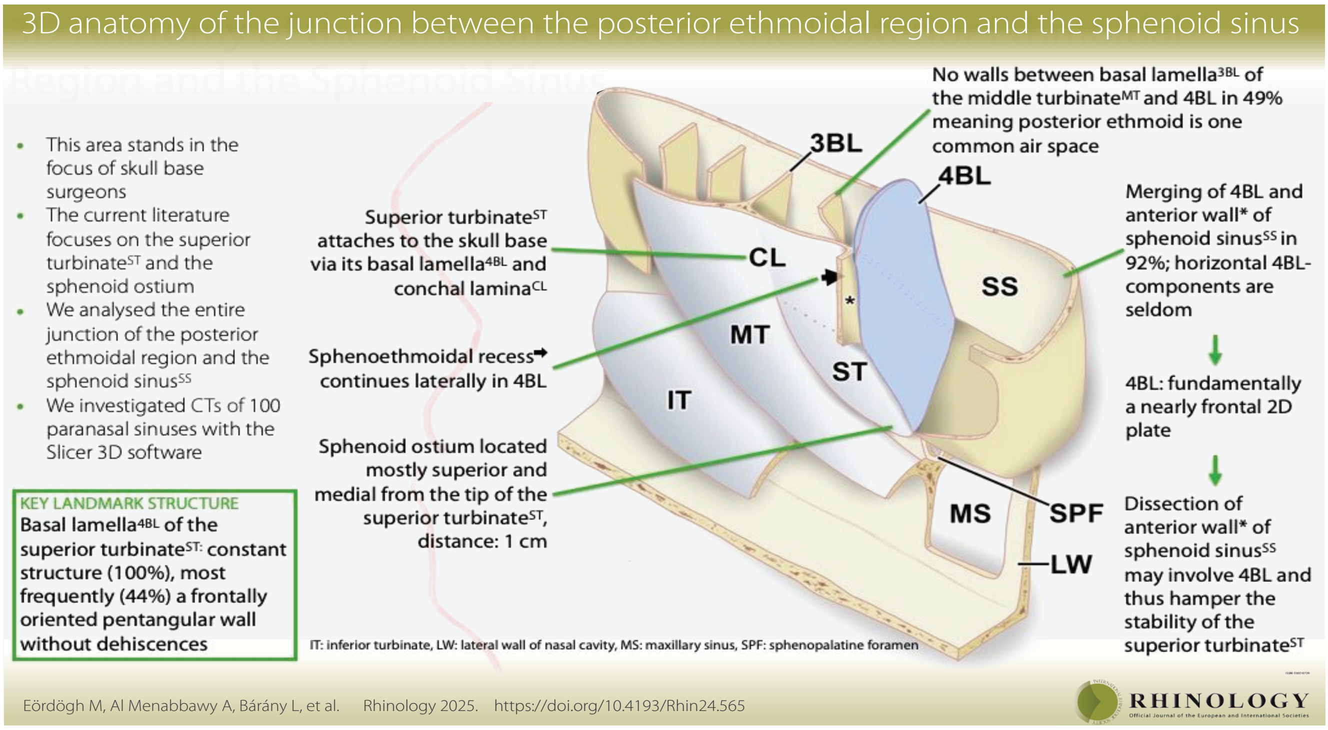


Abstract

Background: The anatomy of the sphenoethmoidal recess is of clinical importance, however, the literature focuses on the superior turbinate and the sphenoid ostium. We analyzed the entire junction of the posterior ethmoidal region and the sphenoid sinus (SEJ) to define possible regularities. **Methods**: We analyzed the junction between the posterior ethmoidal region and the sphenoid sinus on CT scans of 100 paranasal sinuses from 50 individuals using the 3D Slicer software. **Results**: The SEJ had two components: medially the sphenoethmoidal recess, laterally the wall between these aeriated regions, the latter built by the basal lamella of the superior turbinate (4BL) in 92.0%. The 4BL was a constant structure (100.0%), its most frequent phenotype was a frontally oriented pentangular wall without dehiscences (44.0%). There were no bony walls between the 3BL and the anterior wall of the sphenoid sinus in 49.0% and there was one wall in 42.0%. The 4BL had three complicating factors: firstly, it shifted to anterior, if the supreme turbinate was present (43.0%). Secondly, the pneumatization of the 4BL and the superior turbinate (25.0%) was related to an incomplete-dehiscent anterior 4BL wall. Thirdly, sphenoethmoidal cells (36.0%) led to a bony contact of the optic canal and the 4BL (33.0%). **Conclusions**: The 4BL is an important landmark for endoscopic sinus and skull base surgery with highly constant morphology and a typical phenotype. Surgeons should be aware that after dissection of the 3BL the next wall is likely the 4BL which mostly merges to the ASW. This study can help surgeons to detect anatomical variations and improve their intraoperative orientation.

Key words: endoscopic minimally invasive surgery of the skull base, endoscopic skull base surgery, sinus anatomy, skull base

Introduction

The posterior ethmoidal region is highly variable and stands in the focus of rhinosurgeons and neurosurgeons performing endonasal or transnasal surgical procedures. This tiny area is of particular importance in the context of landmark-based surgery, especially around the superior turbinate (ST) and the sphenoethmoidal recess (SER) [1–3]. For a better understanding of the anatomy as the basis of a tailored minimal invasive surgery, there have been CT-analyses of the anterior ethmoidal region [4]. There are numerous references to local morphological individualities, however, anatomical overviews are much fewer [5]. Earlier we investigated the middle turbinate and its basal lamella (3BL) which divides the anterior and posterior ethmoidal region [6]. The goal of the present study was to analyze the junction of the posterior ethmoidal region and the sphenoid sinus (SEJ) to define possible regularities and compare them with the structures described in the literature.

Materials and methods

CT scans of 50 individuals (100 sides) were analyzed with the 3D Slicer software [7] (www.slicer.org) to describe the ST and its neighboring structures and the anatomical particularities around the SEJ. The workup algorithm is shown on Figure 1A. We defined parameters of the 4BL and ST (dehiscence, pneumatization patterns) and studied the neighboring anatomical structures with their topographical relation to the SER, the optic canal and the ethmoidal cells. We used a segmentation method published earlier [6] to accurately describe the geometrical shape of the 4BL (Table 1, Figure 1B). All investigations were carried out anonymized and in accordance with relevant guidelines (Supplementary Material). For this type of study, a formal consent is not required.

Table 1. Segment types of the basal lamella of the superior turbinate.

Segment	Description
Frontal plate	Plain plate in the frontal plane
Frontal wave	Bent plate in the frontal plane with anterior and posterior protrusions, appears on axial images as a waveform
Sigma plate	Bent plate with sigmoid or "S"-like angulation
Horizontal plate	Plain plate nearly in the horizontal plane
Concave plate	Plate bent due to ethmoidal cell bulging, appears concave from an anterior point of view
Convex plate	Plate bent due to ethmoidal cell bulging, appears convex from an anterior point of view

Results

Topography of the posterior ethmoidal region

The posterior ethmoidal region was bordered anteriorly by the 3BL, posteriorly by the anterior wall of the sphenoid sinus (ASW) and/or a sphenoethmoidal cell (Figure 2). The medial wall of the posterior ethmoidal region was composed of the CL and the ST as well as the the supreme turbinate (SpT; present on 43 sides, 43.0%). The SER is located between the medial and posterior wall. The ST was pneumatized on 25 (25.0%), the SpT on 4 sides (9.3% of cases with SpT).

The posterior ethmoidal cells are usually larger but less numerous than the anterior ones. We reviewed the current literature to summarize the described variant anatomical structures (Table 2). The 4BL was identified in all cases (100.0%), the 5BL on 43 sides (43.0%). The pneumatization of both the ST and 4BL was completely linked. The basal lamella of the supreme turbinate (5BL) was always fused to the ASW and only identifiable if the SpT was present. Figure 2 depicts the most frequent phenotype (44 sides) where the non-pneumatized 4BL merged to the ASW and there was no SpT.

In general, the SEJ had two components: laterally the common wall between these ethmoidal and sphenoidal aeriated regions, medially the SER.

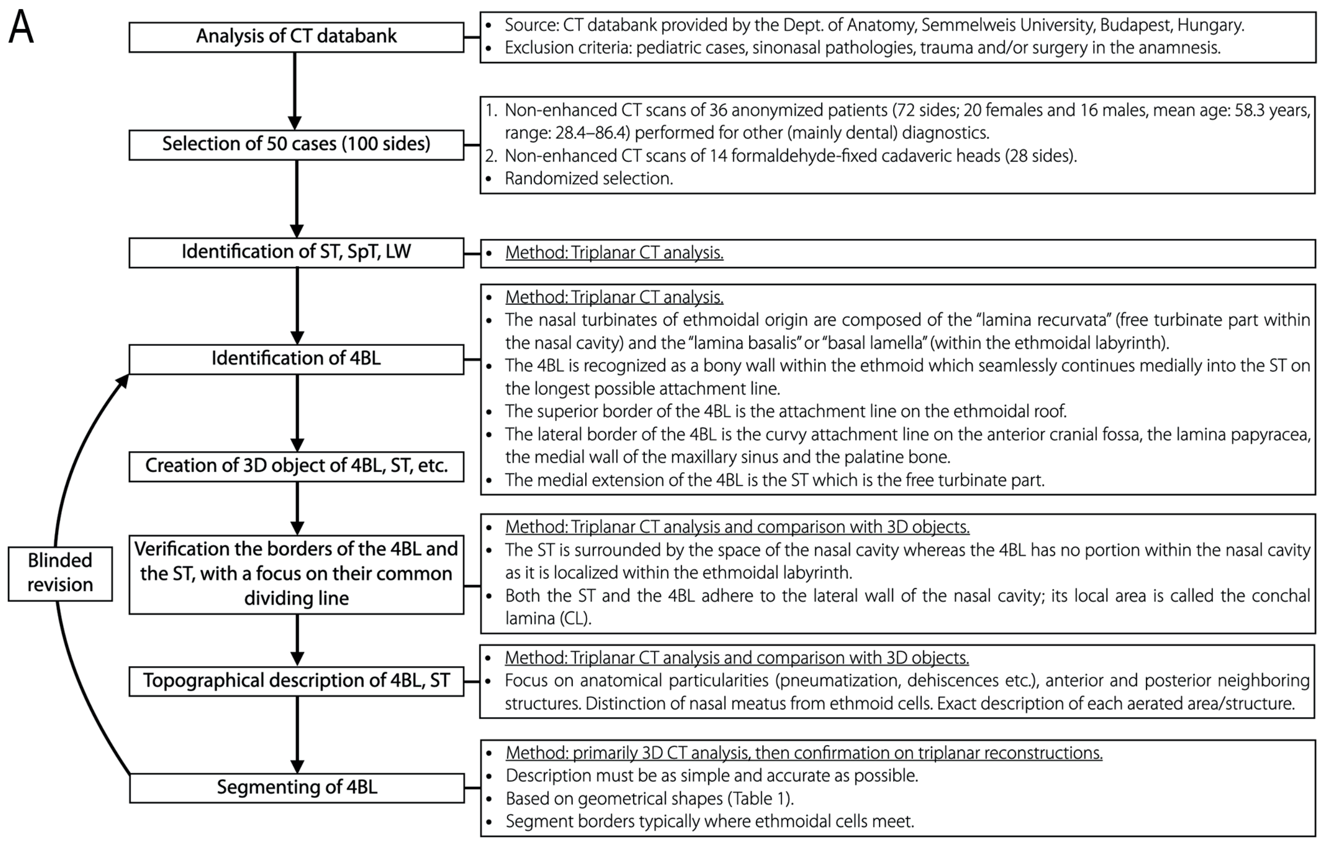
Medial junction of the posterior ethmoidal region and the sphenoid sinus: the sphenoethmoidal recess

In the axial plane, the orientation of the SER´s posterior wall (i.e. the ASW) was anteromedial-posterolateral (73 sides, 73.0%) or frontal (27 sides, 27.0%). If the SpT was present (43.0%), the 4BL was displaced from the SER as the SpT dislocated the 4BL to anterior. In those cases, we found supreme ethmoidal cells between the 4BL and the ASW (Figure 3). The 5BL was then adherent to the ASW.

The posteroinferior insertion of the ST is a surgical landmark to find the opening of the sphenoid sinus. In our material the sphenoid ostium was placed mostly superior and medial from the ST´s tip with an average direct distance of 1 cm (Table 3). Correspondingly, in the majority the opening was at the horizontal level of the CL and not the ST.

Lateral junction of the posterior ethmoid and the sphenoid sinus: the role of the 4BL

In theory, within the posterior ethmoidal region, separate frontal walls follow each other from anterior to posterior: 3BL, 4BL, 5BL, ASW. We regularly observed merging of the 4BL with different walls (3BL: 16 sides, 16.0%, 5BL: 41 sides, 41.0%, ASW: 92 sides, 92.0%; no merge: 4 sides, 4.0%). Multiple merging was common but most frequently the 4BL fused only to the ASW (47 sides, 47.0%). Consequently, the SEJ can only be understood together with the 4BL. From the 43 sides where SpT was present, in 31 (72.1%) the 4BL merged with the ASW and the 5BL. At the horizontal level of the sphenoid ostium, there were no bony walls between the 3BL and the ASW on 49 sides (49.0%), there was one wall on 42 sides (42.0%) and 2 walls on 9 sides (9.0%). Consequently, the posterior ethmoidal region can be understood in



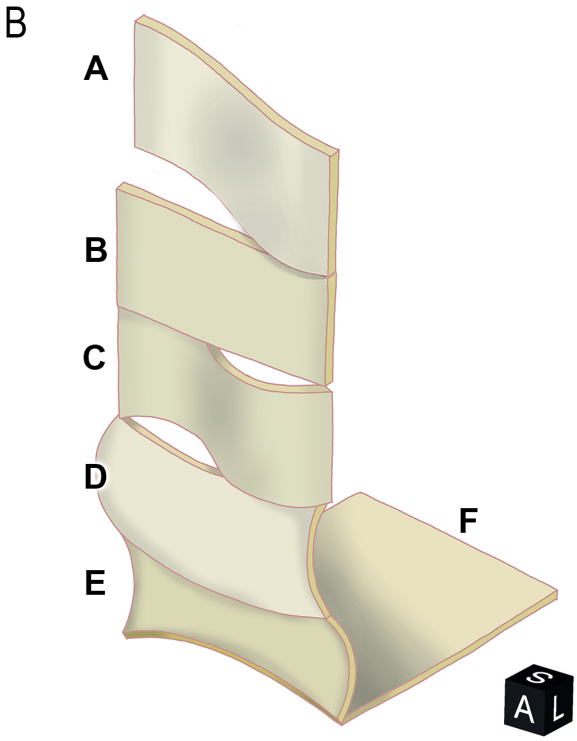


Figure 1. Applied methods. A) Workflow diagram demonstrating the case acquisition and evaluation. B) Schematic three-dimensional drawing of the segment types as viewed from anterior-superior-medial. Sigma plate (A), frontal plate (B), frontal wave (C), convex plate (D), concave plate (E), horizontal plate (F). Black box (from Slicer 3D software) shows orientation (A: anterior, L: left, S: superior). Based on the illustration from Eördögh et al. [6].

most of the cases as one compartment between the 3BL and the fused 4BL/ASW (Figure 4).

Sphenoethmoidal cells (36.0%, N=36) further complicate this situation as they invade the sphenoid bone and are in contact with the optic canal (In the manuscript, the Ónodi cell is understood as the sphenoethmoidal cell). The 4BL was regularly fused to their anterior (22.2%, N=8) or posterior wall (66.7%, N=24). On one side both walls merged with the 4BL (2.8%). Accordingly, the 4BL adhered to the bony optic canal on 33 sides (33.0%).

The posterior ethmoid is highly variable, however, the 4BL was a constant structure. This is due to its very frequent merging with the ASW which was mostly a frontally oriented wall (Figure 5).

The surface of the 4BL was 219.7 ± 91.0 mm^2 (range: 28.0–458.8) on the left and 221.3 ± 99.6 mm^2 (range: 74.6–522.6) on the right side. In most cases the 4BL looked like a more or less frontally oriented pentagonal wall.

The 4BL was a solo non-pneumatized layer on 75 sides (75.0%) and pneumatized in 25 cases (25.0%). Pneumatization of the 4BL and the ST (N=25, 25.0%) was linked as they built a common air space (Figure 6). Pneumatization of the 4BL led to two partly fused leaflets where the bigger posterior leaflet was like to the non-pneumatized 4BLs. In these cases, the 4BL could be defined, however, the exact border between the ST and the CL was not

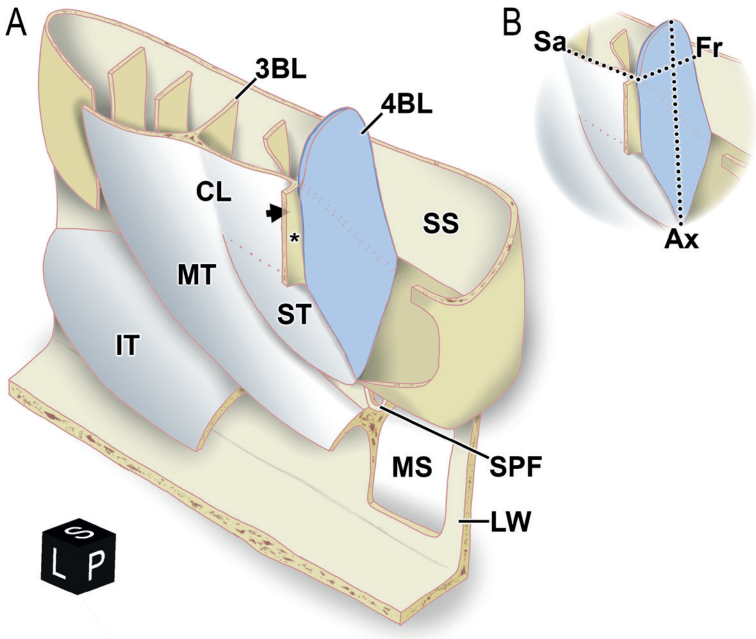


Figure 2. Anatomy of the junction between the posterior ethmoidal region and the sphenoid sinus, right side. A) Posterior-superior-medial aspect of the nasal cavity with fenestrated structures and removed ethmoidal roof. The most frequent phenotype of 4BL is shown. 3BL: basal lamella of the middle turbinate (MT). 4BL: basal lamella of the superior turbinate (ST). CL: conchal lamina. IT: inferior turbinate. LW: lateral wall of the nasal cavity. MS: maxillary sinus. SPF: sphenopalatine foramen. SS: sphenoid sinus. *: anterior wall of the SS. Arrowhead: sphenoethmoidal recess. Black box shows orientation (L: left, P: posterior, S: superior). B) Detail of A. The 4BL anchors the ST to the skull base in the axial (Ax) and frontal (Fr) planes, the CL anchors it in the sagittal (Sa) plane.

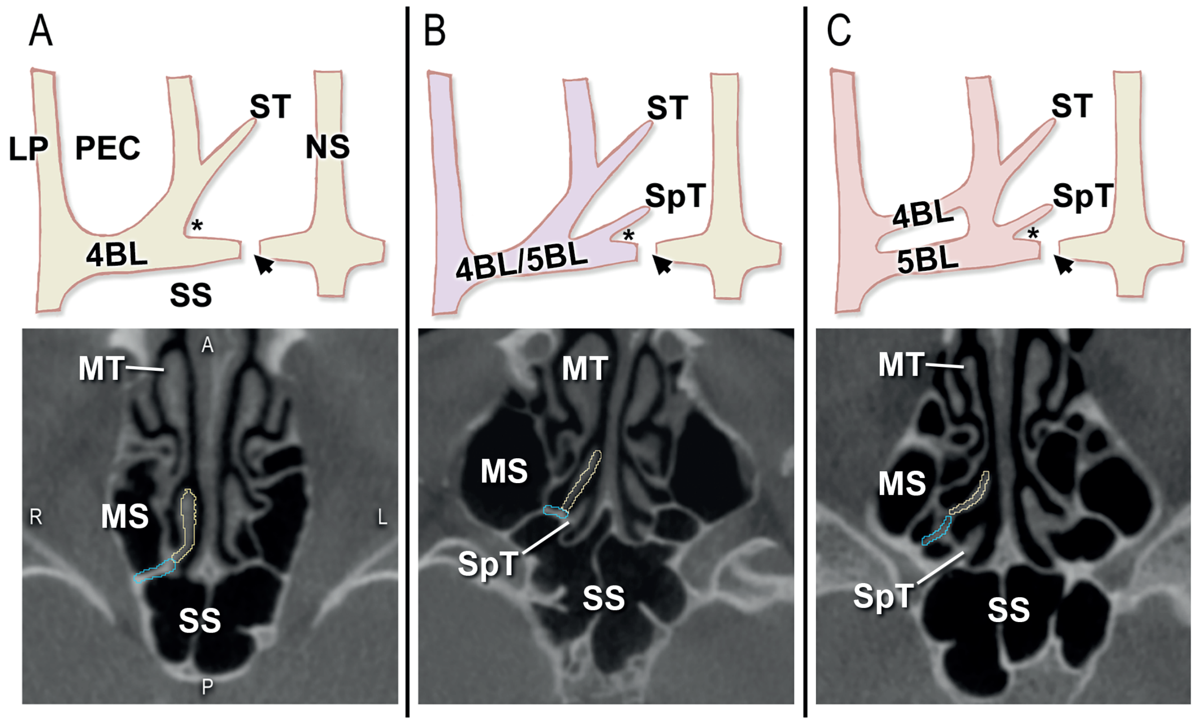


Figure 3. Axial schematic drawing (above) with corresponding CT image (below) of the sphenoethmoidal recess without (A) and with present supreme turbinate (B-C), right side. A) The basal lamella of the superior turbinate (4BL) is adherent to the anterior wall of the sphenoid sinus (ASW). B) Both the 4BL and the basal lamella of the supreme turbinate (5BL) fuse with the ASW. C) The 5BL fuse with the ASW, the 4BL shifted to anterior. LP: lamina papyracea, MS: maxillary sinus, MT: middle turbinate, NS: nasal septum, PEC: posterior ethmoidal cell, SS: sphenoid sinus, SpT: supreme turbinate, ST: superior turbinate, arrowhead: opening of the sphenoid sinus, *: sphenoethmoidal recess. The 4BL is marked blue on the CT, the ST is yellow. A: anterior, L: left, P: posterior, R: right.

Table 2. Variant anatomical structures.

Structure or anatomical condition	Incidence [literature], comments	Incidence (present study) N=100 if not otherwise mentioned
Basal lamella of the middle turbinate (3BL)	100% [Kim 2001 [4], Eördögh 2021 [6]]	100.0%
Pneumatized superior turbinate	7.1% [394 sides, CT, Kajiwara [15]], 10.4% [2000 sides, CT, İla 2018 [17]], 23.7% [410 sides, CT, Cobzeanu 2014 [30]], 34.6% [104 sides, CT, Ariyürek 1996 (18)], Ariyürek, İla and Cobzeanu gave another data (putting both sides together as single occurence)	25.0%
Basal lamella of the superior turbinate (4BL)	100.0% [100 sides, cadaver, Kim 2001 [4]]	100.0%
Dehiscent 4BL		43.0%
Pneumatized 4BL	32.2% of the frontal part, 22.8% of the horizontal part [394 sides, CT, Kajiwara 2019 [15]]	25.0%
4BL merged with 3BL	31.0% [100 sides, cadaver, Kim 2001 [4]]	16.0%
4BL merged with ASW		92.0%
Supreme turbinate	8–50% [Gotlib 2018 [25]], 50.0% [100 sides, cadaver, Kim 2001 [4]], 60% [40 sides, cadaver, Orhan 2010 [2]]	43.0%
Basal lamella of the supreme turbinate (5BL)	30.0% [100 sides, cadaver, Kim 2001 [4]]	43.0%
Ethmomaxillary sinus	0.6% [2900 sides, CT, Şirikçi 2004 [31]], Şirikçi gave another data (putting both sides together as single occurence)	3.0%
Ethmomaxillary sinus adherent to 4BL		100.0% (N=3)
Ónodi (superolateral sphenoethmoidal) cell	3–51% [DeLano 1996 [23], Weinberger 1996 [28]], original description [19]	36.0%
4BL comprised the anterior wall of Ónodi cell		22.2% (N=36)
4BL comprised the posterior wall of Ónodi cell		66.7% (N=36)
4BL comprised anterior and posterior wall of Ónodi cell		2.8% (N=36)
4BL inserted to optic canal´s wall		33.0%
Inferolateral sphenoethmoidal (Jinfeng) cell	0.5% [556 sides, CT, Liu 2019 [32]], compare with Jinfeng 2017 [33]	1.0%
Sphenoethmoidal sinus	11.1% [72 sides, CT, Rusu 2020 [34]], Rusu gave another data (putting both sides together as single occurence)	1.0%
Central Ónodi cell	From a case report [Cherla 2013 [14]], compare with "H"-cell (Al-Zaidi 2022 [13]]	1.0%
Supraseptal ethmoidal sinus cell	From a case report [Gore 2019 [35]]	3.0%
"H"-cell	From a case report [Al-Zaidi 2022 [13]], compare with central Ónodi cell [Cherla 2013 [14]].	0%
Retroantral ethmoidal cell	16% [116 sides, CT, Chapurin 2016 [12]], no subject of the present study, compare with retromaxillary pneumatization [Herzallah 2016 [11]]	2.0%
Retromaxillary pneumatization	79.4% [524 sides, CT, Herzallah 2016 [11]], no subject of the present study, compare with retroantral ethmoidal cell [Chapurin 2016 [12]]	Not analyzed

Table 3. Position of the opening of the sphenoid sinus in relation to the posteroinferior insertion of the superior turbinate.

Measurement	Total (N=100)*	Left (N=50)	Right (N=50)
Direct distance (mm)	10.0 ± 2.4 (4.7–15.5)	9.4 ± 2.1 (4.7–14.3)	10.6 ± 2.5 (5.3–15.5)
Vertical distance (mm)	8.7 ± 2.5 (2.7–14.7)	8.1 ± 2.2 (3.6–13.0)	9.2 ± 2.6 (2.7–14.7)
Vertical position (N)	superior (98), unclear (2)	superior (49), unclear (1)	superior (49), unclear (1)
Mediolateral distance (mm)	4.2 ± 1.9 (0.0–8.7)	3.8 ± 1.8 (0.3–7.1)	4.6± 1.9 (0.0–8.7)
Mediolateral position (N)	medial (97), unclear (2), identical (1)	medial (49), unclear (1)	medial (48), unclear (1), identical (1)
Sagittal distance (mm)	1.7 ± 1.5 (0.0–7.5)	1.8 ± 1.4 (0.0–5.2)	1.7 ± 1.5 (0.0–7.5)
Sagittal position (N)	anterior (51), posterior (43), identical (4), unclear (2)	anterior (22), posterior (24), identical (3), unclear (1)	anterior (29), posterior (19), identical (1), unclear (1)

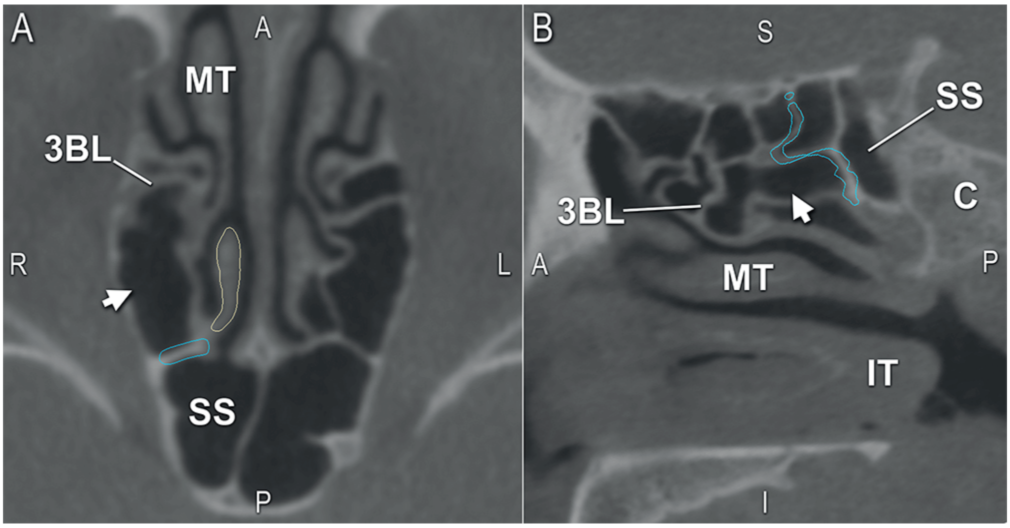


Figure 4. Fusion of walls within the posterior ethmoid. A) Axial CT image. B) Sagittal CT reconstruction. Yellow: superior turbinate, blue: basal lamella of the superior turbinate (4BL). The posterior ethmoidal region can be understood in most of the cases as one compartment (arrowhead) between the 3BL and the fused 4BL/ASW. IT: inferior turbinate, MT: middle turbinate, SS: sphenoid sinus. A: anterior, I: inferior, L: left, P: posterior, R: right, S: superior.

entirely clear. The anterior leaflet was smaller and dehiscent where the opening of the pneumatized cell was found. Dehiscences were like a small hole or a larger gap meaning that the wall does not reach entirely the side borders of the ethmoid. Overall, a solo dehiscence was observed on 42 sides (42.0%), on another side (1.0%) there was a double dehiscence of the 4BL. Therefore, we considered the main posterior leaflet for further analysis.

We applied a segmenting algorithm to describe the 4BL´s shape (Figure 1). On both sides the 4BL (in case of pneumatization: the posterior leaflet) was built of 1.2 ± 0.4 segments (median: 1; range: 1–2, Figure 5). The 4BL was built by a solo segment in 42 cases (84.0%) on the left and 39 cases (78.0%) on the right side. We identified a 2nd segment in 8 cases (16.0%) on the left and in 11 cases (22.0%) on the right side. The cranial (1st) segment was much larger than the caudal (2nd) one. The 1st segment was a frontal plate in 76.0% (76 sides), sigma plate in 9.0% (9 sides), convex plate in 9.0% (9 sides), concave plate in 5.0% (5 sides), frontal wave in 1.0% (1 side). The 2nd segment (N=19) was a horizontal plate in 57.9% (N=11), convex plate in 31.6% (N=6), frontal plate in 10.5% (N=2). The most common phenotype of the 4BL (44.0%) was monosegmental (frontal plate), non-pneumatized and not dehiscent (Figure 2A and 5A). The second most frequent form had a frontal plate cranially and a horizontal plate caudally (10.0%). This corresponds to the commonly accepted "L"-shaped 4BL appearance with an anterior frontal and a posterior horizontal portion in a lateral view. Any other shapes were seen in less than 10.0%. We observed a lower variability of the 4BL´s shape compared to the 3BL.

The 4BL is bordered superiorly by the ethmoidal roof; superomedially by the conchal lamina (CL), which is part of the lateral nasal wall (LW); inferomedially by the superior turbinate (ST); inferolaterally by the palatine bone and/or the medial wall of the maxillary sinus; and superolaterally by the lamina papyracea (LP). These correspond to the five sides of the pentagonal structure (Figures 2A and 5C). The pentagonal pattern observed from an anterior point of view was described on 98 sides (98.0%), independently from the segments. The components in the sagittal plane were marginal as in most cases there was only one, nearly frontally oriented segment. A caudal segment was present in 19.0% (19 sides) and it was only in 11.0% (11 sides) horizontally oriented which would have the largest sagittal dimension. Its surface was also significantly smaller than of the cranial segment. Consequently, the 4BL anchored the ST in the remainder 89.0% (89 sides) only in two of the tree main anatomical planes: frontal and axial. As the sagittal components of the 4BL were usually minor or lacking, the 4BL alone cannot stabilize the ST in the three main planes (Figure 2B). Apart from the 4BL, the CL also contributed to the ST´s skull base fixation. The CL was a sagittally oriented structure which caudally overwent into the ST, contributing to the third axis.

Discussion

Anatomical knowledge of the SEJ is mandatory for rhinologists and neurosurgeons. Variant anatomical structures can lead to disorientation and thus skull base penetration with cerebrospinal fluid leak, meningitis or neurological deficits. Extensive dissection may have rhinological sequelae such as anosmia.

In the surgical literature, the initial focus was set on the sphenoid ostium´s exact location. Even the ST was mentioned mostly from this perspective [8,9]. Lund et al. [5] emphasize that the ostium was located medial to the ST´s posterior end in 83%

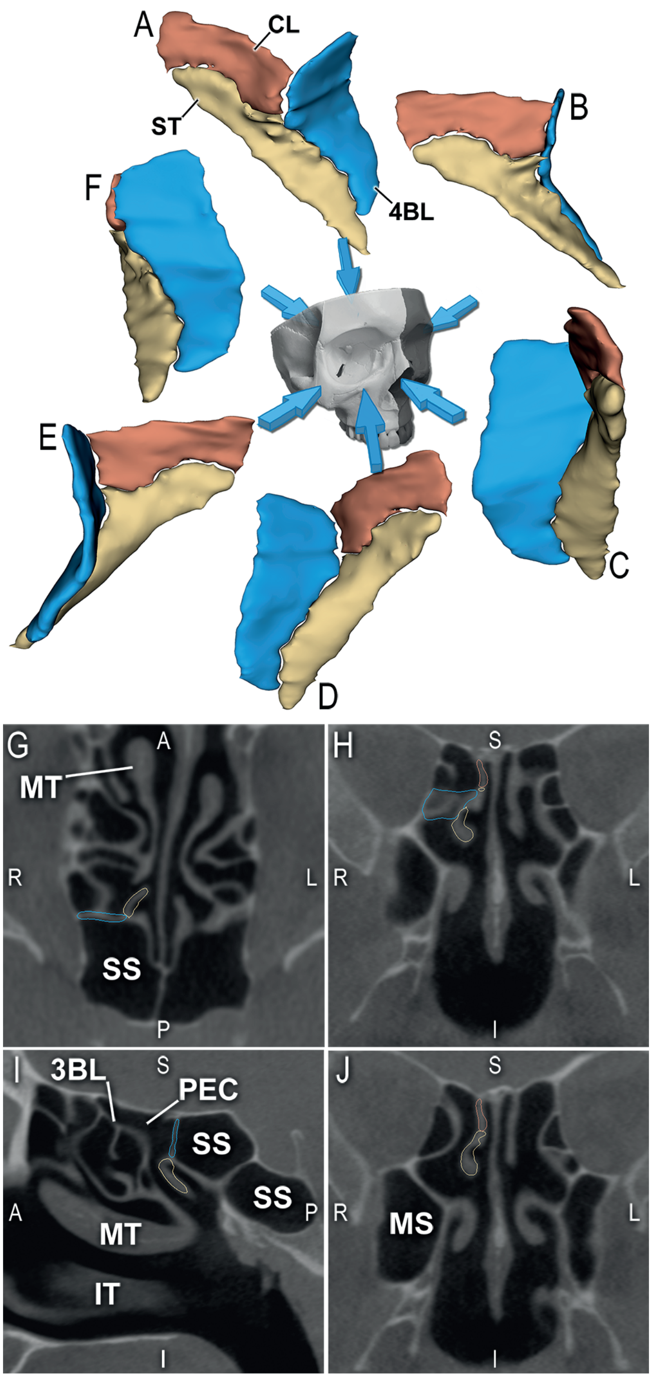


Figure 5. The basal lamella of the superior turbinate, right side. View from superior-posterior-medial (A), medial (B), anterior (C), inferior-anterior-lateral (D), lateral (E), posterior (F). (G) axial CT image of the same individual with frontal (H, J) and sagittal (I) reconstructions. Yellow: superior turbinate, brown: conchal lamina (depicted only in the neighboring area), blue: basal lamella of the superior turbinate (4BL). In most cases the frontal component of the 4BL was pentangular (C, I). 3BL: basal lamella of the middle turbinate (MT), IT: inferior turbinate, MS: maxillary sinus, PEC: posterior ethmoidal cell, SS: sphenoid sinus. A: anterior, L: left, I: inferior, P: posterior, R: right, S: superior. Adapted from Eördögh et al. [6].

(thus easy to identify) or lateral in 17% (therefor difficult to find, depending on the lateral extent of the SER). In our material the opening of the sphenoid sinus was mostly 10 mm superior and medial from the ST´s posteroinferior insertion.

The posterior ethmoid is a tiny area with an average of 3 ethmoidal cells [10]. Table 2 enlists the local variant anatomical structures which are highly variable and occasionally based on new classifications/subtypes, potentially confusing surgeons. Furthermore, surgical video studies, CT-analyses and cadaveric dissections can all come to varying conclusions. Subtle differences of definitions may cause an overlap of entities. For example, the difference between [9] the retroantral ethmoidal cell and the retromaxillary pneumatization seems to be marginal and it can be difficult to distinguish a "H"-cell from a central sphenoethmoidal cell [11–14]. The unclear/changing definition of well-known structures (e.g. Ónodi cell) also results in discrepancies. Involving symptomatic patients might also influence the incidence rates as some variant structures are associated with sinonasal pathologies.

In this study we reviewed the literature and aimed to describe regularities at the SEJ to help surgical orientation. Here the 4BL appeared to be a constant entity. It is a commonly accepted structure, however, not extensively analyzed yet [4,15]. From a lateral view, it is thought to be an L-shaped bony plate, like other basal lamellas. Workgroups of Kim [4] and Kajiwara [15] distinguish an anterior vertical and a posterior horizontal part together building an "L"-like structure, as observed from a medial direction. Contrarily, Eweiss et al. [16] identified the vertical part of the 4BL only in 60.2% and the horizontal in 88.2%. In their landmark paper, Kim et al. [4] provide cadaveric dissections observed from a medial perspective with parasagittal CTs to support their findings. Kajiwara et al. [15] analyzed biplanar CT images. We believe that the algorithm of the present study is more accurate as it is based on the anatomical structures´ real 3D shape, focusing on the relationships with their neighboring areas and it reproducibly compares the spatial data with standard triplanar (2D) CT reconstructions.

In the following, we discuss the most frequent anatomical variant structures around the SEJ.

Pneumatization of the ST can be anticipated on CTs, thus it should not carry a risk for the surgeon. However, the description of the exact pattern is more complicated, that is why the incidence ranges from 7.1% to 34.6% [15,17,18]. Kajiwara et al. [15] distinguished the vertical (32.2%) and horizontal (22.8%) 4BL pneumatization from the pneumatized ST (7.1%). They used a biplanar CT analysis to detect the pneumatized ST, based on the frontal image showing the superior nasal meatus and confirmed it on the axial scan. In our opinion the superior nasal meatus cannot be safely identified comparing two reconstructions as it might resemble ethmoidal cells. Contrarily, we created a 3D object of the ST and carefully analyzed its exact borders, pos-

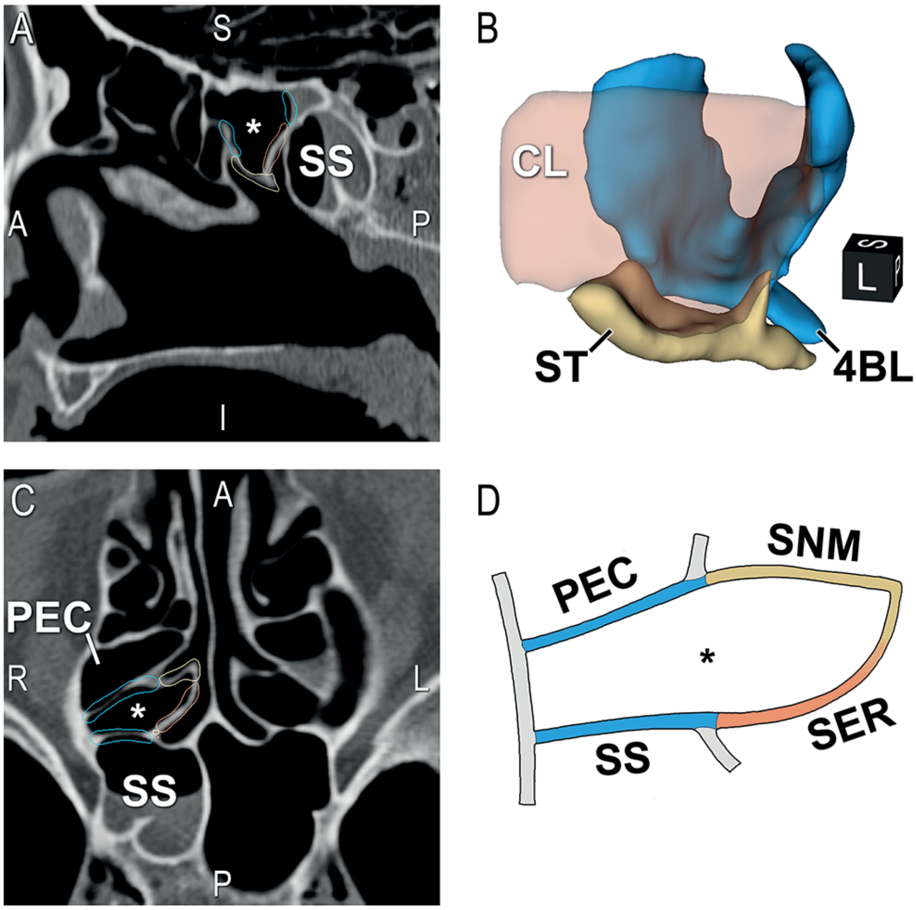


Figure 6. Pneumatized superior turbinate and its basal lamella, right side. A) Sagittal CT reconstruction of the nasal cavity with a pneumatized ST and two 4BL-leaflets. The posterior leaflet is larger; the anterior leaflet is smaller and incomplete. Yellow: superior turbinate, brown: conchal lamina, blue: basal lamella of the superior turbinate (4BL). B) 3D view of the structures viewed from medial and slightly superior (similar to "A"). C) Axial CT image of the same case. D) Schematized anatomy of the common aerated space (*) of the 4BL and ST in the axial plane, similar to "C". The pneumatized cell is bordered by posterior ethmoidal cells (PEC), the superior nasal meatus (SNM), the sphenoethmoidal recess (SER) and the sphenoid sinus (SS). Black box shows orientation (A: anterior, I: inferior, L: left, P: posterior, R: right, S: superior).

sible ostia and the relationship with the neighboring areas. We identified pneumatized ST and 4BL both in 25.0% with a linkage, which is a different finding and should be further investigated. The sphenoethmoidal cell's role in optic nerve injuries is well-known, as – citing Ónodi – it *"comes into view as it would create the upper part of the sphenoid sinus"* which *"is far away from the area of the optic groove* [...] *and the optic canal; with only the latter being closely related to the rearmost ethmoidal cell."* [19]. Ónodi defined this cell solely by *contact* with the optic canal, however, its incidence varies from 3% to 51% due to methodical and definition differences [19–22]. An earlier analysis of coronal CTs detected it in 3% [23]. Currently, the analysis of all three radiological planes is advised [22,24]. In accordance with most authors, we observed them in 36.0% (36 sides). The present study revealed contact between the sphenoethmoidal cell and the 4BL in 91.7% (33 sides), alerting surgeons that the 4BL possibly adheres to the optic canal. We believe that this is a novelty.

Gotlib et al. [25] found the prevalence of the SpT between 8–50%, in our material: 43.0%. This structure is also well-recognizable during surgery and on the CTs. Other variant structures enlisted in Table 2 were of lower frequency and thus of lesser relevance. Our data suggests that the 4BL is a highly frequent anatomical structure with a close relationship to the ASW. This leads us to the main observations of our study. Our results could not prove the standard presence of an L-shaped 4BL with an anterior vertical and posterior horizontal part. Contrarily, the 4BL was mostly monosegmental (81.0%), frontally oriented (76.0%), non-pneumatized (75.0%) and non-dehiscent (57.0%). All these four parameters were simultaneously present in 44.0%, characterizing the most frequent phenotype. We described the strong relationship between the 4BL and the ASW. They were merged in 92.0% determining the 4BL´s shape as a basically two-dimensional, pentagonal shaped bony plate nearly in the frontal plane. To our knowledge this was not reported earlier. If the 4BL and the ASW are fused, the posterior ethmoidal cells are located anterior-inferior from the 4BL and the ST. This is conform with the embryological development emphasizing that the posterior ethmoidal cells communicate with the superior nasal meatus.

It is thought that basal lamellas play a role in fixating their turbinate on the skull base. The 4BL´s components in the sagittal plane were mostly minor in our material. As a part of the LW, the CL attaches on a mainly sagittally oriented line to the ST [26,27].

Only the 4BL and the CL were constant structures with contact to the ST. Others appeared to be mostly smaller, incomplete and irregularly adherent to the 4BL and/or the CL. Therefore, both the CL and the 4BL are closely linked and may have a role in the triplanar biomechanical stabilization of the ST.

We detected three frequent variant structures around the 4BL which generate the following anatomical situations, being nearly identical among involved individuals: firstly, in cases with a SpT (43.0%), we observed a shifting of the 4BL to anterior, creating space between the 4BL and the 5BL (the latter fused with the ASW) for the ethmoidal cells which opened into the supreme nasal meatus. Secondly, the pneumatization of the 4BL and the ST (25.0%) was linked to each other and related to an incomplete, dehiscent anterior layer of the 4BL. Thirdly, the sphenoethmoidal cell should be anticipated due to its fusion with the 4BL to avoid optic nerve injury [14,19,20,28].

The frequent merging with the ASW can cast doubt if the 4BL is truly an existing structure. This should be verified with embryological-developmental studies as this aspect goes beyond our radiological analysis. However, the clinical anatomical and biomechanical findings of this study remain consistent. Accordingly, Mosher [29] stated that "*the attachment of the superior turbinate roughly divides the front face of the sphenoid into thirds. The outer two-thirds are taken up by the common wall* [with the posterior ethmoid]. *The inner third* [...] *is the space between the attachment of the turbinate and the nasal septum.*" The lateral continuation of the SER was mostly the 4BL.

Clinical aspects

The 4BL´s clinical importance is not defined yet. This study revealed a frequent merging of 4BL and ASW (92.0%). There were no bony walls between the 3BL and the ASW in 49.0%. Consequently, the posterior ethmoidal region can be understood in most of the cases as one compartment between the 3BL and the fused 4BL/ASW. During transethmoidal surgical approaches, after dissection of the 3BL the next wall is likely the 4BL which mostly merges to the ASW. This also suggests that an extensive anterior sphenoidotomy and thus the dissection of the 4BL may influence the stability of the ST, possibly leading to pathologic repositioning, scarring and consecutive olfactory issues. The surgeon must know that any dissection within the SER may affect the 4BL´s structural integrity and vice versa. Furthermore, the present study revealed a frequent merging of the 4BL and the sphenoethmoidal cell with a close relation to the optic nerve. This can be of clinical importance and should be verified.

Conclusion

The 4BL is a landmark at the SEJ for skull base surgery with highly constant morphology. Its most common phenotype was non-pneumatized and monosegmental, built by a frontal plate. Surgeons performing transethmoidal approaches should be aware that after dissection of the 3BL the next wall is likely the 4BL, fused with the ASW. The 4BL frequently merges with the sphenoethmoidal cell. Studies using 3D CT reconstructions allow a precise description of the SEJ. This analysis can help surgeons to detect anatomical variations during endoscopic sinus and skull base procedures and improve their intraoperative orientation.

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Abbreviations

2D: two-dimensional; 3D: three-dimensional; 3BL: basal lamella of the middle turbinate (3rd basal lamella); 4BL: basal lamella of the superior turbinate (4th basal lamella); 5BL: basal lamella of the supreme turbinate (5th basal lamella); AEC: anterior ethmoidal cell; ASW: anterior wall of the sphenoid sinus; CBCT: cone beam computed tomography; CL: conchal lamina: IT: inferior turbinate; LP: lamina papyracea (orbital lamina of the ethmoid bone); LW: lateral wall of the nasal cavity; MS: maxillary sinus; MT: middle turbinate; NS: nasal septum; PEC: posterior ethmoidal cell; SEJ: junction between the posterior ethmoidal region and the sphenoid sinus; SER: sphenoethmoidal recess; SNM: superior nasal meatus; SPF: sphenopalatine foramen; SpT: supreme turbinate; SS: sphenoid sinus; ST: superior turbinate.

Authorship contribution

ME: protocol/project development, data collection or management, data analysis, manuscript writing/editing, data analysis and interpretation, 3D imaging; LB: data analysis, manuscript writing/editing; MK: protocol/project development, 3D imaging, data collection or management, data analysis; RR, HWSS, WH: protocol/project development, data analysis, manuscript writing/editing; AAM, GB, HRB: protocol/project development, data collection or management, data analysis, manuscript writing/editing.

Conflict of interest

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References

1. Kim H, Kim S, Kang SS, Chung IH, Lee J, Yoon J. Surgical anatomy of the natural ostium of the sphenoid sinus. Laryngoscope. 2001;111(9):1599–602.
2. Orhan M, Govsa F, Saylam C. A surgical view of the superior nasal turbinate: anatomical study. Eur Arch Otorhinolaryngol. 2010;267(6):909–16.
3. Bodino C, Jankowski R, Grignon B, Jimenez-Chobillon A, Braun M. Surgical anatomy of the turbinal wall of the ethmoidal labyrinth. Rhinology. 2004;42(2):73–80.
4. Kim SS, Lee JG, Kim KS, Kim HU, Chung IH, Yoon JH. Computed tomographic and anatomical analysis of the basal lamellas in the ethmoid sinus. Laryngoscope. 2001;111(3):424–9.
5. Lund VJ, Stammberger H, Fokkens WJ, Beale T, Bernal-Sprekelsen M, Eloy P, et al. European position paper on the anatomical terminology of the internal nose and paranasal sinuses. Rhinol Suppl. 2014;24:1–34.
6. Eördögh M, Baksa G, Grimm A, Bárány L, Petneházy Ö, Reisch R, et al. Three-dimensional structure of the basal lamella of the middle turbinate. Sci Rep. 2021;11(1):17960.
7. Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin JC, Pujol S, et al. 3D Slicer as an image computing platform for the quantitative imaging network. Magn Reson Imaging. 2012;30(9):1323–41.
8. Orlandi RR, Lanza DC, Bolger WE, Clerico DM, Kennedy DW. The forgotten turbinate: the role of the superior turbinate in endoscopic sinus surgery. Am J Rhinol Allergy. 1999;13(4):251–60.
9. Bolger WE, Keyes AS, Lanza DC. Use of the superior meatus and superior turbinate in the endoscopic approach to the sphenoid sinus. Otolaryngol Head Neck Surg. 1999;120(3):308–13.
10. Lang J. Klinische Anatomie der Nase, Nasenhöhle und Nebenhöhlen. Thieme. 1988.
11. Herzallah IR, Saati FA, Marglani OA, Simsim RF. Retromaxillary pneumatization of posterior ethmoid air cells. Otolaryngol Head Neck Surg. 2016;155(2):340–6.
12. Chapurin N, Honeybrook A, Johnson S, Wang C, Jang DW. Radiographic characterization of the retroantral ethmoid cell. Int Forum Allergy Rhinol. 2016;6(12):1315–8.
13. AL-Zaidi HMH, Badr HM. Unusual large central sphenoethmoidal cell separating the two sphenoid sinuses - A case report. Transl Res Anat. 2022;28:100212.
14. Cherla DV, Tomovic S, Liu JK, Eloy JA. The central Onodi cell: a previously unreported anatomic variation. Allergy Rhinol. 2013;4(1):ar.2013.4.0047.
15. Kajiwara R, Omura K, Takeda T, Ohira S, Matsuura K, Furuya H, et al. Anatomical variation of the pneumatized superior turbinate and its impact on endoscopic sinus surgery in chronic rhinosinusitis. Surg Radiol Anat. 2020;42(1):81–6.
16. Eweiss AZ, Ibrahim AA, Khalil HS. The safe gate to the posterior paranasal sinuses: reassessing the role of the superior turbinate. Eur Arch Otorhinolaryngol. 2012;269(5):1451–6.
17. İla K, Yilmaz N, Öner S, Başaran E, Öner Z. Evaluation of superior concha bullosa by computed tomography. Surg Radiol Anat. 2018;40(7):841–6.
18. Ariyürek OM, Balkanci F, Aydingöz Ü, Önerci M. Pneumatised superior turbinate: a common anatomic variation? Surg Radiol Anat. 1996;18(2):137–9.
19. Ónodi A. Az íköböl és a leghátsóbb rostasejt viszonya a látóideghez. Az Orvosi Hetilap Tudományos Közleményei; 1903.
20. Christmas DA, Mirante JP, Yanagisawa E. A possible case of two Onodi cells in a single patient. Ear Nose Throat J. 2004;83(5):307–8.
21. Tomovic S, Esmaeili A, Chan NJ, Choudhry OJ, Shukla PA, Liu JK, et al. High-resolution computed tomography analysis of the prevalence of Onodi cells. Laryngoscope. 2012;122(7):1470–3.
22. Chmielik LP, Chmielik A. The prevalence of the Onodi cell – most suitable method of CT evaluation in its detection. Int J Pediatr Otorhinolaryngol. 2017;97:202–5.
23. DeLano M, Fun F, Zinreich S. Relationship of the optic nerve to the posterior paranasal sinuses: a CT anatomic study. Am J Ophthalmol. 1996;122(2):293–4.
24. Driben JS, Bolger WE, Robles HA, Cable B, Zinreich SJ. The reliability of computerized tomographic detection of the Onodi (sphenoethmoid) Cell. Am J Rhinol. 1998;12(2):105–11.
25. Gotlib T, Kuźmińska M, Sokołowski J, Dziedzic T, Niemczyk K. The supreme turbinate and the drainage of the posterior ethmoids: a computed tomographic study. Folia Morphol. 2017;77(1):110–5.
26. Mouret J. Le schéma des masses latérales de l'ethmoïde. Rev Laryng Bordeaux. 1922;43:8–22.
27. Bodino C, Jankowski R, Grignon B, Jimenez-Chobillon A, Braun M. Surgical anatomy of the turbinal wall of the ethmoidal labyrinth. Rhinology. 2004 Jun;42(2):73–80.
28. Weinberger DG, Anand VK, Al-Rawi M, Cheng HJ, Messina AV. Surgical Anatomy and Variations of the Onodi Cell. Am J Rhinol Allergy. 1996;10(6):365–72.
29. Mosher HP. LXXII. Symposium on the ethmoid. Ann Otology Rhinol Laryngol. 1929 Dec;38(4):869–901.
30. Cobzeanu MD, Bâldea V, Bâldea MC, Vonica PS, Cobzeanu BM. The anatomo-radiological study of unusual extrasinusal pneumatizations: superior and supreme turbinate, crista galli process, uncinate process. Rom J Morphol Embryol. 2014;55(3 Suppl):1099–104.
31. Şirikçi A, Bayazıt YA, Bayram M, Kanlıkama M. Ethmomaxillary sinus: a particular anatomic variation of the paranasal sinuses. Eur Radiol 2004;14(2):281–5.
32. Liu J, Liu Q, Wang N. Posterior ethmoid cell expansion towards the inferolateral region of the sphenoid sinus: a computed tomography study. Surg Radiol Anat. 2019 Jun 27;1–8.
33. Jinfeng L, Jinsheng D, Xiaohui W, Yanjun W, Ningyu W. The pneumatization and adjacent structure of the posterior superior maxillary sinus and its effect on nasal cavity morphology. Méd Sci Monit: Int Méd J Exp Clin Res. 2017;23:4166–74.
34. Rusu MC, Hostiuc S, Motoc AGM, Mogoantă CA, Sava JC, Săndulescu M. The sphenoethmoidal sinus and the modified anatomy of the related structures. Rom J Morphol Embryo. 2020;61(1):143–8.
35. Gore MR. The supraseptal ethmoid sinus cell: a previously unreported ethmoid sinus variant. Clin Case Rep. 2019;7(7):1306–8.

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Corrected Proof

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SUPPLEMENTARY MATERIAL

Ethics

All methods and investigations were carried out in accordance with relevant guidelines and regulations. Regulations on the tissue handling of the Department of Anatomy, Semmelweis University were accepted by the Senate of the university ("Rector act. 1. R/1/2017 VII.24"). A permission to use the samples was obtained from the institutional responsible of body donation. The CTs were anonymized and performed for other diagnostics. These belong to the database of the Department of Anatomy, Semmelweis University. A permission to use the anonymized images was obtained from the institutional responsible. This study is in accordance with the ethical standards of the institutional and/or national research committee, the regulating law ("1997. year CLIV. law 16. § 2nd paragraph") and the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Based on these standards and regulations, for this retrospective study an ethical approval is not necessary. For this type of study, formal consent is not required.