Optico-carotid recess and anterior clinoid process pneumatization – proposal for a novel classification and unified terminology: an anatomic and radiologic study*

A. Andrianakis[1], P.V. Tomazic[1], A. Wolf[1], F. Anderhuber[2,†], C. Gerstenberger[1], U. Pilsl[2], H. Stammberger[1,†]

[1] Department of Otorhinolaryngology, Medical University of Graz, Austria

[2] Division of Macroscopic and Clinical Anatomy, Gottfried Schatz Research Center for Cell Signaling, Metabolism and Aging, Medical University Graz, Austria

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Abstract

Background: The aims of this study were to propose a novel and unified classification system of the optico-carotid recess (OCR) and anterior clinoid process (ACP) pneumatization, determine their frequency in a Caucasian population and measure the size of the OCR.

Methodology: A total of 200 specimen (400 sphenoid sinuses) were evaluated in a separate anatomic cadaveric study (n=100) and radiologic study (n=100) by using sphenoidal sinus cast and computed tomography (CT) scan. OCR was divided according to its location to the optic nerve into sub-optical and latero-optical OCR grade I-III.

Results: An OCR was found in 39% of the samples (78/200) and in 19% (38/200) it occurred bilaterally. Both, sub-optical and latero-optical OCR were identified in 14% of the sides (58/400), with a mean length and depth of 6.9 mm; 7.7 mm and 2.3 mm, 7.1 mm, respectively. We determined the pneumatized ACP frequency with 23% (46/200) and defined 3 unified different types of pneumatization.

Conclusions: The OCR is a reliable landmark to identify the optico-carotid region in endoscopic sphenoid sinus surgery, and can even be visualized by CT. Hence, preoperative investigation of the sphenoid region is mandatory. In our opinion, the classification presented in this study can be useful in order to avoid surgical complications.

Key words: optico-carotid recess, anterior clinoid process, pneumatization, classification, endoscopic sinus surgery

Introduction

Since the development of functional endoscopic sinus surgery (FESS) by Messerklinger in the 1970s, the special anatomy around the sellar region became significantly important for endonasal approaches to the sphenoid sinus and anterior skull base. The sphenoid sinus has a close relationship to adjacent neurovascular structures, in particular to the optic nerve, internal carotid artery and cavernous sinus with its contents. Therefore, it was necessary to define, name and identify endoscopic landmarks in order to avoid major surgical complications. One of these landmarks is the so-called optico-carotid recess (OCR), which was first described by Van Alyea et al. in 1941 as the "superior lateral recess of the sphenoid sinus" (1). When present, it is located on the lateral wall of the sphenoid sinus between the protrusions of the optic nerve superiorly and the anterior knee of the intracavernous carotid artery inferiorly. Based on the course of these structures, the OCR usually has a more or less triangular "entrance". The term optico-carotid recess was first mentioned by Fujii et al. in 1979 and established internationally in the past decades (2). In the last years several authors identified a second OCR, which should clearly be separated from the OCR described previously (3-6). According to Labib et al. this so-called medial optico-carotid recess (mOCR) lies on the posterior wall of the sphenoid sinus (7). Depending on the degree of pneumatiza-

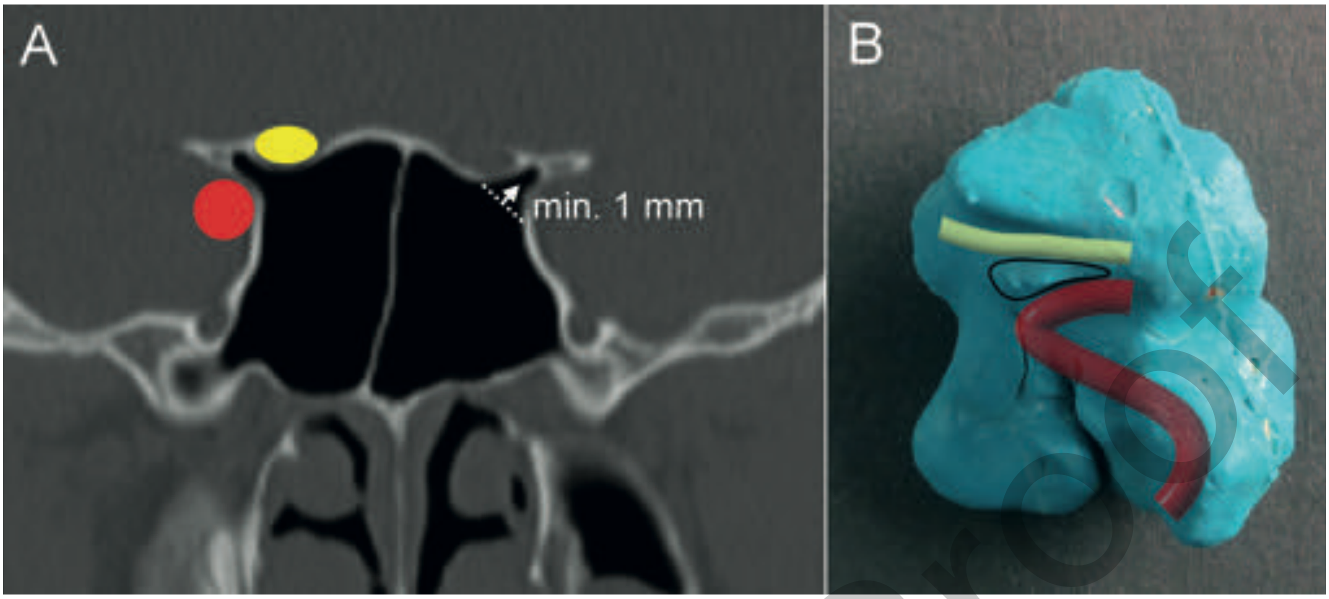

Figure 1. A: Definition of OCR on the coronal plane as a recess between a protrusion caused of optic nerve superiorly (yellow circle) and carotid artery inferiorly (red circle) with a depth of at least 1 mm (white arrow). B: Left sphenoid sinus cast from a posterolateral view with projected optic nerve (yellow line) and carotid artery (red line) course and triangle shaped OCR (black-rimmed triangle).

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tion, the OCR can extend far lateral and pneumatize the anterior clinoid process (ACP). Numerous authors investigated the pneumatization pattern of the ACP, however, there is not yet an exact definition of the varying degrees of ACP pneumatization [8-11]. Furthermore, based on our prior knowledge there is no study that examined the size of present OCRs. A unified definition and classification of the OCR and ACP pneumatization would be helpful, in order to avoid confusion caused by the existing different terminology and nomenclature.

The aim of this study was to 1) propose a novel OCR classification, 2) determine the frequency and scale the size of the OCR in the Caucasian population 3) suggest a unified definition and terminology of ACP pneumatization.

Materials and methods

A total of 200 specimen (400 sphenoidal sinus) were evaluated in a separate anatomical and radiologic study. The radiologic study was conducted according to the guidelines of the Declaration of Helsinki. The anatomic-cadaver study was performed under the approval and strict rules of the Anatomical Donation Program of the Medical University of Graz and according to Austrian law. Exclusion criteria in both studies were: age under 18, sphenoidal sinus disease, intracranial tumors, previous FESS or skull base surgery, craniofacial malformations.

In the radiologic study 100 patients (45 men and 55 women, mean age of 71 ± 9,4 years (range, 23 – 91 years)] who obtained a head computer tomography scan (CT) were retrospectively studied. The patients were presented at the emergency department of our hospital in the year of 2017 and have been randomly chosen. Imaging on these 100 patients was performed on multidetector-row and high-speed CT scanners with non-contrast axial and coronal 1.5-mm cuts and bone window was selected for examination. CT scans were analyzed in a "picture archiving and communication system (PACS). Every CT scan was evaluated by two independent otorhinolaryngologists (H.S. and A.A.), specialized in Rhinology and endoscopic sinus and skull base surgery.

In the anatomical study, sphenoidal sinus casts of 100 unselected Caucasian human cadaver heads [48 men and 52 women, mean age of 83 ± 10,5 years (range, 53 – 100 years)], made of quadrofunctional hydrophilic addition reaction silicone, were performed. All human cadaver have been donated to the Department of Anatomy of the Medical University of Graz, Austria and were embalmed by Thiel's method [12,13]. The cadavers were investigated during two dissection courses in the year 2016/2017 and 2017/2018 for medical students. The cadaver heads were therefore divided in the median-sagittal plane using a circular saw. Based on the sphenoidal sinus casts and the cadaver halve skulls, two sets of measurement were taken by using a mm measuring tape: 1) length of the OCR "entrance": We defined the OCR "entrance" as the plane between the deepest protrusion of the internal carotid artery and optical nerve into the sphenoid sinus. Based on the course of these two structures, this plane is more or less triangular shaped. The posterior apex of the triangle is formed by the junction of the optical nerve and the anterior bend of the internal carotid artery. The base of the triangle points towards the anterior wall of the sphenoid sinus (Figure 1B). The length of the OCR-entrance was measured between the

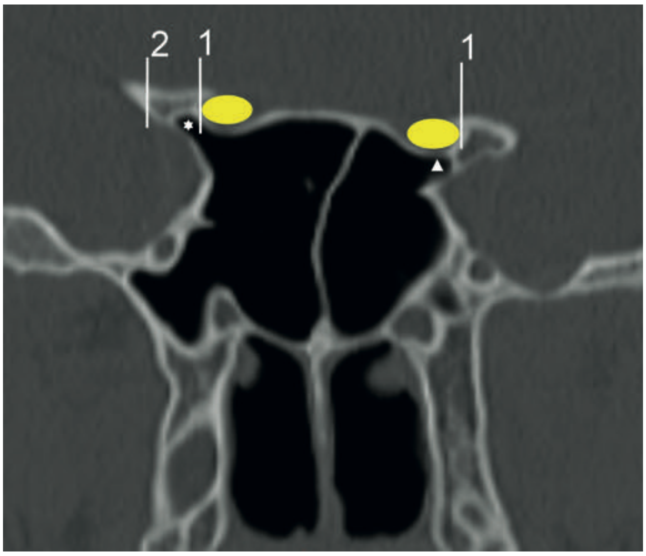

Figure 2. Differentiation between sub-optical and latero-optical OCR. The left sphenoid sinus presents a sub-optical OCR (white triangle) which is solely located inferiorly to the optic nerve (yellow circle). On the right side a latero-optical OCR grade I (white asterisk) is shown. Note the extension of the recess beyond a virtual vertical line of the lateral margin of the optic nerve (1. white line) without reaching the lateral margin of the ACP (2. white line).

midpoint of the base and the posterior apex of the triangle. 2) depth of the OCR: The second measurement was taken between the midpoint of the first measurement and the deepest extension of the OCR. After sphenoidal sinus casting, an anterior transethmoidal sphenoidotomy was performed to determine an OCR or ACP pneumatization with a sphenoethmoidal-cell origin. Each anatomical observation and measurement were performed by both an anatomical specialist (F.A. and U.P.) as well as an otorhinolaryngologist (H.S. and A.A.). The statistical software SPSS version 21.0 was used for the statistical analysis of the data.

We defined the OCR as a recess between a protrusion caused of optic nerve superiorly and carotid artery inferiorly with a depth of at least 1 mm (Figure 1A). In the radiologic study we used the coronal plane for this definition. Depending on the extension of the OCR in relation to the position of the optic nerve, we classified the OCR into two subtypes: sub-optical and the latero-optical OCR. The latero-optical OCR extended beyond the lateral margin on a virtual vertical line of the optic nerve compared to the sub-optical OCR, which was located solely inferior the optic nerve (Figure 2). This classification was used in the anatomical study as well as in the radiographic study. The latero-optical OCR was further classified into three different grades, depending on its extension of pneumatization. This classification was only used in the radiologic study. Grade I did not reach the lateral margin of the ACP / lesser wing (Figure 2). At Grade II the OCR pneumatization extended to the lateral margin of the ACP / lesser wing (Figure 3). Additionally, a latero-optical OCR Grade III pneumatized the whole ACP in an antero-posterior direction (Figure 4).

We defined the lateral margin of the bony optic nerve canal as the key landmark for ACP pneumatization. Hence, latero-optical OCR corresponded to pneumatized ACP (Figure 5A). A recess which extended superiorly to the optic nerve into the ACP we termed supra-optic-recess – SOR (Figure 5B). Simultaneously presence of latero-optical OCR and SOR on the same side, were titled as peri-optical recess – POR (Figure 5C). In such case the optic canal is completely surrounded by air or is attached to a thin bony lamella to the lateral wall of the sphenoid sinus.

Results

Anatomical study

An OCR was found in 38% of the skulls (38/100) with 9% only on the left side (9/100), 10% only on the right side (10/100) and 19% presented bilateral OCRs (19/100). According to our new

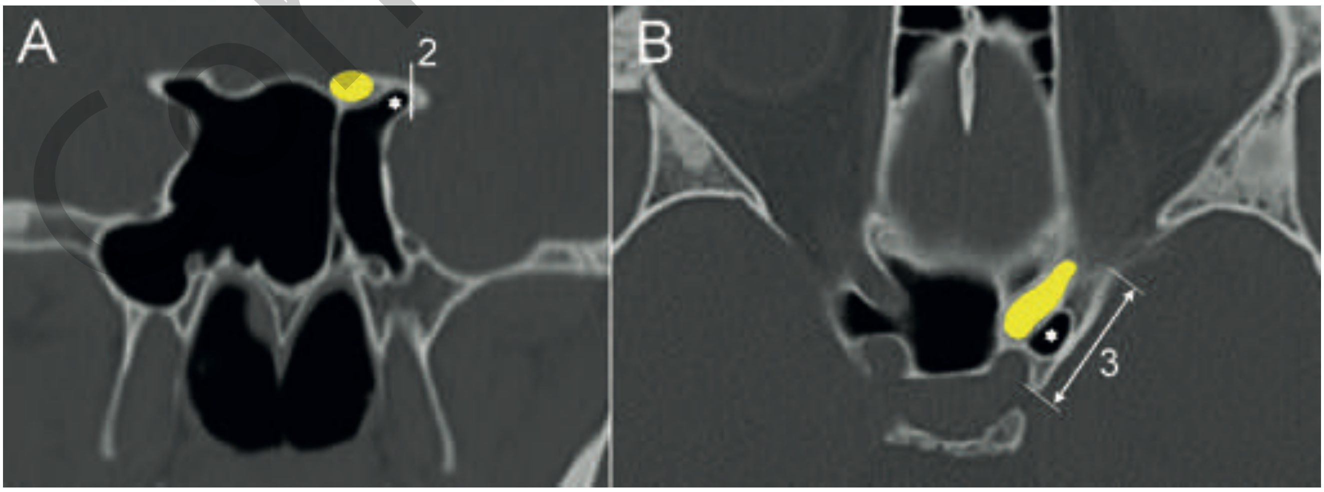

Figure 3. Definition of latero-optical OCR grade II (white asterisk). A: Extension of the recess reaching the lateral margin of the ACP (2. white line). B: ACP is not fully pneumatized in an antero-posterior direction. (3. white line). A – coronal plane, B – axial plane.

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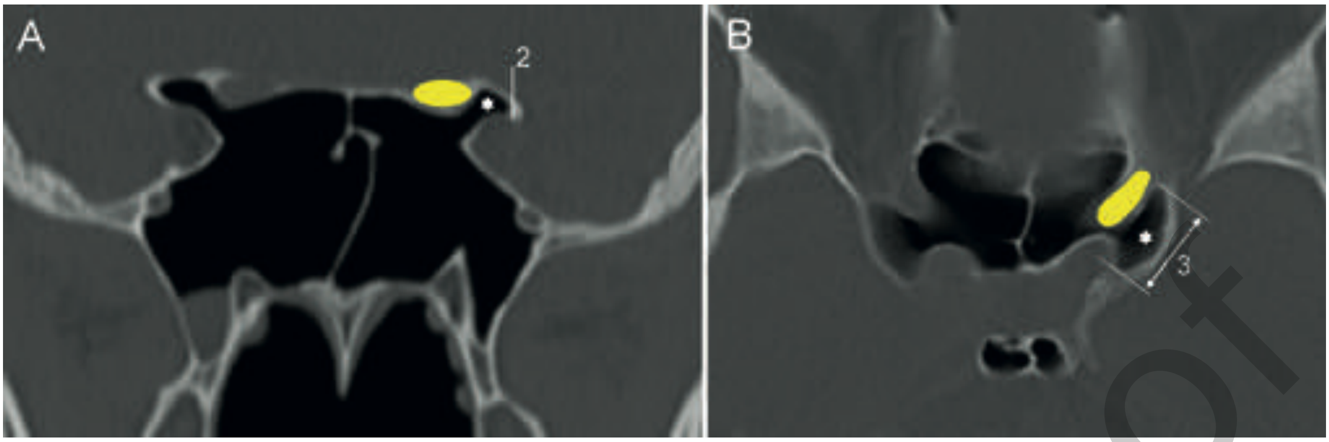

Figure 4. Definition of latero-optical OCR grade III (white asterisk). A: Extension of the recess reaching the lateral margin of the ACP (2. white line). B: Fully pneumatization of ACP in an antero-posterior direction (3. white line). A – coronal plane, B – axial plane.

classification, a sub-optical and a latero-optical OCR was found in 16% and 12.5% of the sides (32/200 and 25/200), respectively. Regarding laterality, sub-optical and latero-optical OCR occurred in 7.5% and 6.5% on the left side (15/200 and 13/200) and in 8.5% and 6% on the right side (17/200 and 12/200), respectively. The mean length of the OCR "entrance" measured 7.3 ± 1.3 mm (range, 5-10 mm). Oriented on the subtypes, the mean length of the sub-optical and latero-optical OCR measured 6.9 ± 1.4 mm and 7.7 ± 0.9 mm (range, 4-10 mm and 6-10 mm), respectively. Sub-optical and latero-optical OCR had a mean depth of 2.3 ± 0.9 mm and 7.1 ± 1,6 mm (range, 1-5 mm and 5-10 mm), respectively. In total the mean depth of OCR measured 4.3 ± 2.6 mm (range, 1-10 mm). We observed no SOR or POR in the anatomical study.

Radiologic study

Amongst the CT-scans, an OCR was visualized in 40% (40/100) with 12% only on the left side (12/100), 9% only on the right side (9/100) and 19% (19/100) showed bilateral OCRs. Dividing into subtypes, a sub-optical and a latero-optical OCR was found in 13% and 16.5% of the sides (26/200 and 33/200), of whom presented in 8.5% and 7.5% on the left side (17/200 and 15/200) and 4.5% and 9% on the right side (9/200 and 18/200), respectively. Grade I, II and III was found in 10.5%, 3.5% and 2.5% of the sides (21/200, 7/200 and 5/200), respectively. In 3% of the sides (6/200) we detected a SOR. A POR could be identified bilaterally in 1 CT-scan (Figure 5C).
The summarized results of our study are shown in Table 1.

Discussion

To avoid severe complications during endonasal approaches to the sphenoid sinus region and anterior skull base area a profound anatomical knowledge of these regions is essential. Numerous key landmarks have been described to minimize the risk of iatrogenic injury of the adjacent neurovascular structures. Recent studies reported the OCR to be the most reliable and safest key landmark in the transsphenoidal-transethmoidal approach to the opticocarotid region [14-16].
Ozcan et al. investigated the opticocarotid region on 29 cadaveric specimen. In all specimen they clearly observed an OCR and identified it as the most reliable landmark for optic nerve canal surgery [14]. Similarly, in the cadaveric study of Li et al., an OCR could be seen in all of their 8 samples bilaterally compared to other bony indicators [15]. In their anatomic study Yilmazlar et al. visualized in 28 of 30 specimen an outstanding OCR. In contrast to other anatomic structures, they considered it as a safer endoscopic landmark in transsphenoidal approach to the optic nerve [16]. In comparison to these reports we found a much lower frequency rate (39%) of OCRs. All these studies are limited to a small a sample size compared to the present investigation (n=200). In addition, they evaluated the OCR rate based on endo- or microscopy and not via CT imaging [14-16]. To the best of our knowledge, there is no other comparable radiographic-based and anatomically-based frequency study of the OCR. In an anatomical investigation of the sphenoid sinus by Van Alyea et al., an OCR was visible in 41 of 100 specimens [1]. These data are similar to our anatomic study. We found comparable OCR frequency rates in the anatomic part as well as in the radiographic part of our study. Our study is the first which investigated the OCR in both, a radiological and anatomic-cadaveric way. To summarize, anatomic and radiological OCR data rates are not equal to endoscopical findings in literature. As a significant limitation of this study, we did not investigate the OCR endoscopically and correlated these data to our anatomic/radiological findings.
Due to the clinical relevance as an endoscopic landmark, we classified the OCR according to its location to the optic nerve into sub-optical and latero-optical OCR. We defined the mean length and depth of the OCR "entrance" with 7.3 mm and 4.3 mm. Dividing to our new subtypes sub-optical and latero-optical OCR, we found an average length and depth of 6.9 mm, 7.7

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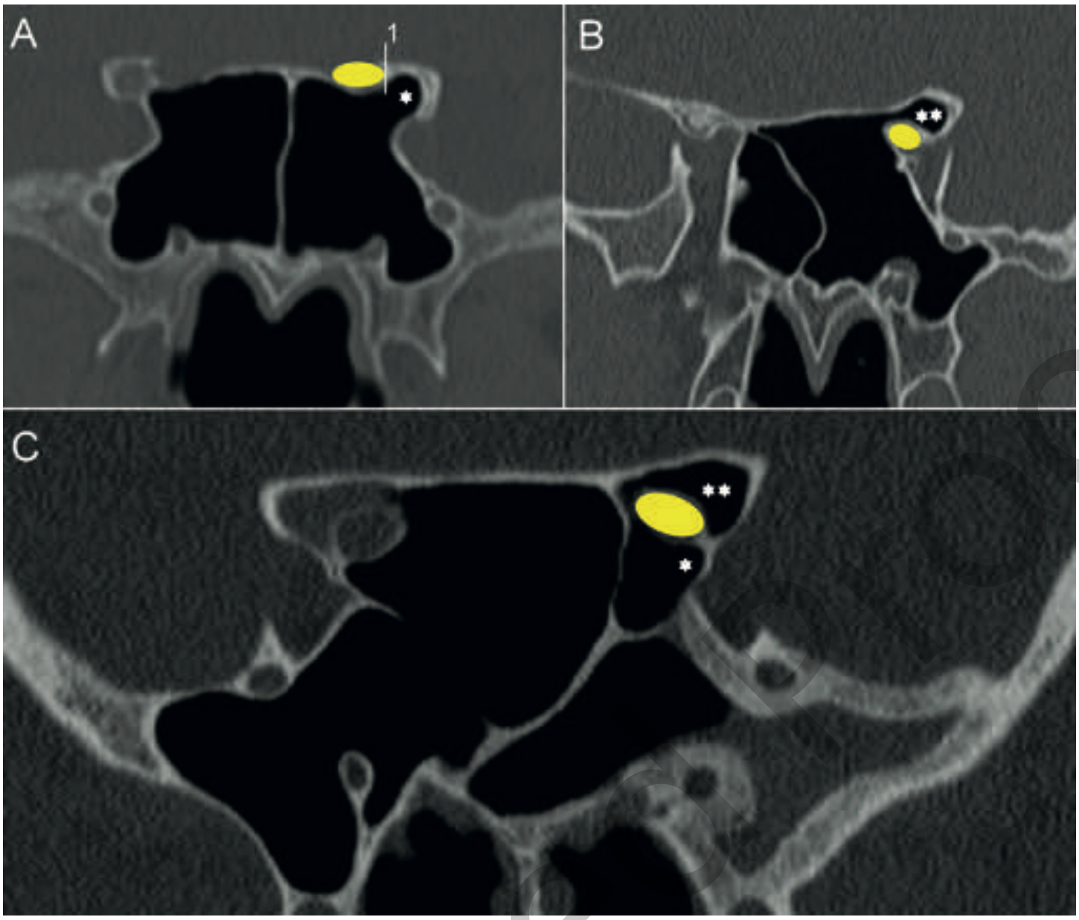

Figure 5. Unified classification of pneumatized anterior clinoid process. A: Pneumatization of anterior clinoid process through a latero-optical OCR (white asterisk). B: Anterior clinoid process is pneumatized by a supra-optic recess (white double asterisk). C: Pneumatized anterior clinoid process via peri-optical recess. Note the simultaneously presence of latero-optical OCR (white asterisk) and supra-optic recess (double asterisk) on the same side and the nearly complete air-surrounded optic nerve canal (yellow circle).

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Table 1. Frequency rates of OCRs and different origins of ACP pneumatization.

	samples (n=200)		sides (n=400)	
	total	unilat./ bilat.	total	left/ right
OCR	78	40 38	116	58 58
sub-optical OCR	38	27 11	58	32 26
latero-optical OCR	31	13 18	58	28 30
simultaneous sub-optical / latero-optical OCR	9	-	-	-
SOR	5	4 1	6	3 3
POR	1	0 1	2	1 1
pneumatized ACP	46	26 20	66	32 34

mm and 2.3 mm, 7.1 mm. Depending on the degree of pneumatization, the recess can reach as far as the anterior clinoid process through the so-called optic strut [17]. This osseous structure connects the sphenoid body with the inferiomedial margin of the ACP and represents the floor of the optic nerve canal. Based on the degree of pneumatization, we divided the latero-optical OCR into 3 grades. The landmarks for this classification are: 1) extension of the OCR beyond the lateral margin of the optic nerve, 2) reaching the lateral margin of the ACP, 3) a fully pneumatized ACP. Grade I and II can be determined in the coronal and axial plane. For identification a grade III, the axial plane is essential. In our study the frequency of the grades decreased with higher grade.

Several authors reported the pneumatization of ACP with a range from 6% to 29% [9-11,18-20]. None of these studies defined exact landmarks for ACP pneumatization. The intracranial opening of the bony optic nerve canal is always located medially to the ACP. Hence, a latero-optical OCR corresponds to pneumatization of ACP. Abuzayed et al. investigated the pneumatization pattern of ACP. They categorized the ACP pneumatization into 3 types. Type I pneumatizes the ACP less than 50%, type II more than 50% and type III pneumatizes the whole ACP. They found a type I, II and III in 6.6%, 3.5% and 2.5%. Type III can be compared to our grade III. For type I and II there are no exact landmarks defined, hence, they are difficult to determine [9]. Besides the ACP pneumatization through a latero-optical OCR, we found a SOR in our radiographic study on 6 sides. The corresponding osseus structure for the SOR is the anterior root of the lesser wing. Mikami et al. analyzed the various directions and origins of ACP pneumatization. They distinguished 3 different types of pneumatization: through the optic strut, the anterior root of lesser wing and a combination of both. These types occurred in their studies in 6.9%, 1.3% and 1%. The third type can be compared to our POR. Furthermore, the origin of pneumatization was differentiated depending on whether it was part of sphenoid sinus, sphenoethmoidal cell or both [10]. Delano et al. characterized four different relationships of the optic nerve to the sphenoid sinus. In type 1, the nerve did not get in any contact with the sphenoid sinus. Type 2 nerves were attached to the lateral wall of sphenoid sinus and caused a protrusion on the wall. In type 3 the nerve ran through the sphenoid sinus. Type 4 nerves came in contact with posterior ethmoidal cells. Type 3 of these relationships are similar to our peri-optical recess [8].

Conclusion

With its typical triangular "entrance", the OCR is – if present – a very reliable endoscopic landmark in sphenoid sinus surgery, and can even be identified preoperatively by CT-based imaging. Therefore a careful preoperative evaluation of sphenoid region in head CT scan is obligatory. We proposed a novel OCR classification and introduced the terms sub-optical and latero-optical OCR grade I-III. To the best of our knowledge, this is the first study that examined the size of present OCRs. We determined the OCR and pneumatized ACP frequency in a Caucasian population with 39% and 23%. Finally, we suggested a unified terminology for ACP pneumatization. It is our firm belief that the here proposed unified terminology and classification can be useful in order to communicate specific anatomical situations better and to help to identify areas of hazard in the future. However, future studies should be done to determine if there is a significant correlation between an endoscopically and CT-based evaluation method of OCR data and to validate the here proposed classification.

Author contribution

AA: collection of data, data interpretation, manuscript writing; AW, PVT: manuscript review/editing and final approval; FA: conception and design, collection of data; UP: collection of data; CG: vizualization; HS: conception and design, collection of data, data interpretation

Conflict of interest

No conflict of interest exists.

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Axel Wolf MD
Department of Otorhinolaryngology
Medical University of Graz
Auenbruggerplatz 26
8036 Graz
Austria

Tel: +43 (316) 385 - 81355
E-mail: a.wolf@medunigraz.at

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