

The extremely rare concha of Zuckerkandl reviewed and reported

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Abstract

Background: Usual descriptions indicate three or maximum four nasal turbinates (conchae) attached to the lateral nasal wall. The middle, superior and, occasionally, supreme ones belong to the ethmoid bone. Few authors include in descriptions the concha that Zuckerkandl described as the fourth or supreme ethmoidal turbinate. Despite some inconsistencies in Zuckerkandl's description, the concha bearing his name lies above Santorini's supreme concha, which, in turn, is above Morgagni's superior concha. Few other authors preferred to name Santorini's concha as the first supreme one and Zuckerkandl's concha as the second supreme one. **Methods:** We retrospectively documented, with various purposes, the archived cone-beam computed tomography files of 350 patients. **Results:** We found in just one case a unilateral sequence of five nasal turbinates. On the opposite side, only four turbinates were detected. Three-dimensional renderizations confirmed that when two supreme turbinates are found, they are joined in a common posterior tail, which, in turn, joins the tail of the superior turbinate. **Conclusions:** Co-existence of two supreme conchae could either indicate their origin from different ethmoturbinals, or from the split of a commonly unique supreme one. Zuckerkandl's concha deserves therefore to be considered when anatomical descriptions, or studies, are delivered.

Keywords: nasal fossa, cone-beam computed tomography, nasal turbinates, concha of Santorini, concha of Morgagni.

Introduction

The nasal turbinates or nasal conchae belong to the lateral nasal walls [1]. The inferior nasal turbinate is an independent bone [1]. The middle, superior and the inconstant supreme (Santorini's concha) turbinates belong to the ethmoid bone [1].

Emil Zuckerkandl (1849–1910), an Austrian anatomist and pathologist [2], described in 1882 the fourth nasal ethmoidal turbinate [3] that will be further known as the concha of Zuckerkandl. However, most publications dealing with the anatomy of nasal turbinates overlooked Zuckerkandl's concha. In "Bergman's Comprehensive Encyclopedia of Human Anatomic Variation" Zuckerkandl's concha was ignored, stating that the nasal turbinates *are usually three but can sometimes be four in number* [4]. Zuckerkandl's concha is also ignored in "Gray's Anatomy": *Occasionally, a fourth concha, the highest or supreme nasal concha, appears on the lateral wall of the sphenoethmoidal recess* [5]. In the second volume of "Scott-Brown's Otorhinolaryngology, Head and Neck Surgery" is explicitly indicated that *three ethmoidal turbinates develop: the persisting middle, superior and – if developed – supreme nasal turbinate* [6], the fourth ethmoidal turbinate described by Zuckerkandl being undocumented.

Therefore, the distinction of two different supreme nasal conchae is uncommon. Usually, the authors do not distinguish between the Santorini's and Zuckerkandl's

concha. Thus, the variable prevalence of a supreme turbinate (8% to 50%) [7] appears to be relative, since Zuckerkandl's concha was neither taken into account, nor excluded.

As we serendipitously found in cone-beam computed tomography (CBCT) a rare evidence of Zuckerkandl's concha, we aimed at documenting here the available descriptions of Zuckerkandl's concha, and to report our evidence.

Inconsistencies of Zuckerkandl's descriptions

Zuckerkandl described in 1882 the fourth (supreme) ethmoidal turbinate or concha (*quatrième [suprême] cornet ethmoïdal*) [3]. In his descriptions he used the terms of ethmoidal turbinates, inferior, middle, and superior [3], which correspond, respectively, to the middle, superior and supreme nasal turbinates in the modern anatomical terminology. Although Zuckerkandl classified its fourth ethmoidal concha as *supreme*, he indicated that in 6.7% of cases it could be observed in infants and embryos a fourth ethmoidal turbinate intercalated between the middle and superior ethmoidal turbinates (*Dans 6,7% des cas, on observe encore, chez les enfants et les embryons, un quatrième cornet ethmoïdal qui se glisse entre les cornets ethmoïdaux moyen et supérieur*) [3]. Along his description, Zuckerkandl further reinforced the highest placement of

the fourth ethmoidal turbinate by indicating how should be considered the ethmoidal turbinates and furrows in the variant with four ethmoidal turbinates. He explicitly indicated the sequence: inferior ethmoidal turbinate, middle ethmoidal turbinate, superior ethmoidal turbinate and, above this later, the fourth ethmoidal turbinate [3]. But he further maintained the inconsistency of his descriptions by indicating a schema of location and displacement of the ethmoidal turbinates (we updated it with modern terminology in Table 1) in which, again, the fourth ethmoidal turbinate was switched beneath the superior one: the elements of the series (columns) were stated being homologous (*Les éléments de deux séries groupés les uns au dessus des autres sont homologues*). It can be observed that the position of the superior ethmoidal turbinate is fixed above all other turbinates, no matter the number of these.

Table 1 – Possibilities of variation of the ethmoidal turbinates, according to Zuckerkandl (1882). The terminology used by Zuckerkandl is correlated with the modern one

No. of nasal turbinates	Inferior ethmoidal turbinate (middle nasal turbinate)	Middle ethmoidal turbinate (SNT)	Fourth ethmoidal turbinate (cZ)	Superior ethmoidal turbinate (sNT)
3	+			+
4	+	+		+
5	+	+	+	+

SNT: Superior nasal turbinate; sNT: Supreme nasal turbinate; cZ: Concha of Zuckerkandl. The concha of Zuckerkandl is placed between those of Morgagni (SNT) and of Santorini (sNT).

According to Zuckerkandl, the fourth ethmoidal turbinate, thus the fifth of all nasal turbinates, has, if well developed, the shape of the middle ethmoidal turbinate or, commonly, it appears as a narrow ridge, which is separated by a furrow from that turbinate which has the highest position in the series [3]. Zuckerkandl further augmented the confusion on the accurate identification on morphological bases of the ethmoidal turbinates (*Si l'on y voit le rudiment d'un cornet ethmoïdal moyen, on a affaire à un sujet qui présente quatre cornets ethmoïdaux; si non, on peut admettre avec quelque vraisemblance qu'il s'agit des cornets ethmoïdaux inférieur, moyen et suprême [quatrième]. Le diagnostic n'est pas absolument sûr, car le cornet ethmoïdal moyen peut avoir subi une régression telle qu'il devient impossible de le reconnaître, et les caractères typiques permettant de distinguer chaque cornet, n'existent plus que pour le dernier.*)

The only available graphic representation provided by Zuckerkandl [3] is reproduced here (Figure 1) and was originally described in a concise manner: *Fosse nasale droite, quatre cornets ethmoïdaux et trois fentes ethmoïdales*. One should observe that those ethmoidal turbinates are not explicitly indicated in that drawing.

It should also be remarked that Zuckerkandl used the term “supreme” only for his fourth ethmoidal concha. He indicated that if only two ethmoidal turbinates are found, the superior one (the superior nasal turbinate in the modern terminology) is Morgagni’s turbinate, but if three ethmoidal turbinates are found, the superior one (the supreme nasal turbinate the modern terminology) is Santorini’s turbinate [3].



Figure 1 – The schema used by Zuckerkandl (1882) to describe the right lateral nasal wall with four ethmoidal turbinates and three ethmoidal furrows.

Two supreme conchae, Santorini’s and Zuckerkandl’s

It was briefly described by Nieto (2015) in the “Tratado de Otorrinolaringología y Cirugía de Cabeza y Cuello” that the concha of Santorini, termed “first supreme”, could be found in 95% of cases, while the concha of Zuckerkandl, termed “second supreme”, occurs in 6.7% of cases [8]. In the “Anatomy of the Nasal Accessory Sinuses in Infancy and Childhood” of Davis (1918), the nasal turbinates (conchae) in a specimen from an infant were identified (Figure 2) from inferior to superior, as follows: concha inferior, concha media, concha superior, concha suprema I, concha suprema II and concha sphenoidalis (ossiculum Bertini) [9].

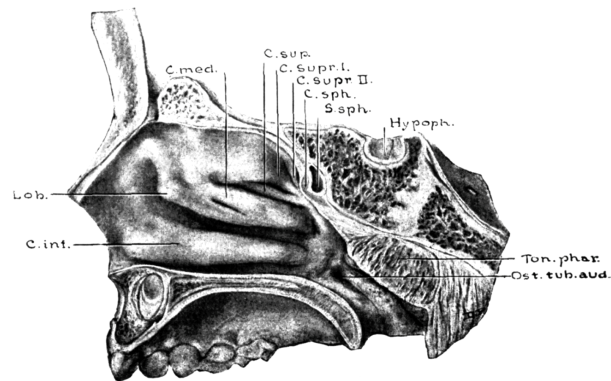


Fig. 6.—Specimen From a Child One Year, Ten Months, and Thirteen Days Old. Sagittal Section Showing Lateral Wall of the Nasal Cavity and the Sinus Sphenoidalis. (Series D, No. 20.)

Note the overlapping of the concha superior by the anterior portion of the concha suprema I; also note the accessory furrow on the medial surface of the concha media. In a plane more lateral than that shown in the illustration, the sinus sphenoidalis is more extensively developed in the posterolateral direction, its inferolateral wall being only 1 mm. from the fossa pterygopalatina and 2 mm. from the foramen rotundum. C.med., Concha media; C.sup., concha superior; C.supr. I., concha suprema I; C. sup. II, concha suprema II; C.sph., concha sphenoidalis (ossiculum Bertini); S.sph., sinus sphenoidalis; Hypoph., hypophysis; Ton.phar., tonsilla pharyngea; Ost.tub.aud., ostium pharyngeum tubae auditivae; C.inf., concha inferior; Lob., lobulus.

Figure 2 – Original drawing and legend of Davis (1918), in which two distinctive supreme turbinates (conchae) are presented in the lateral nasal wall of an infant.

It should be noted that the supreme turbinates, primary and secondary, depicted by Davis (1918), join posteriorly

to form a common posterior tail, which further joins the posterior tail of the superior turbinate. It could be important to note that Davis (1918) studied 160 lateral nasal walls and all the plates he presented depict the concha suprema I, all except one sampling pediatric nasal walls.

Both these descriptions place the concha of Zuckerkandl above Santorini's concha. One should note that while Nieto (2015) used some references different of the original study of Zuckerkandl to support his description, the paper of Davis (1918) has no references. Beyond their inadequate documentation, these publications place the concha of Zuckerkandl above that of Santorini.

☞ Zuckerkandl's concha in CBCT

A retrospective CBCT study of archived files of 350 patients was performed with different purposes [10–18]. The scanning protocol was then detailed. Briefly, it was used a CBCT machine – iCat (Imaging Sciences International [Hatfield, PA, USA]), with the resolution of 0.25 and field of view (FOV) 130. Files were analyzed with the iCatVision software and the Planmeca Romexis Viewer 3.5.0.R software. We evaluated two-dimensional multiplanar reconstructions (2D-MPRs), as well as three-dimensional (3D) volume renderizations of specified areas. The patients have given written informed consent for CBCT scans to be used for research purposes, but anonymized. Of these patients only one (female, 48-year-old) was recorded with the unilateral evidence of a fifth nasal turbinate, being detailed further here.

The nasal fossae in the case we documented for the presence of Zuckerkandl's concha were observed on coronal MPRs (Figure 3). The left nasal fossa was moderately larger than the right one and the nasal septum had a right deviation. The inferior nasal turbinates were anatomically normal. On the right side, the middle nasal turbinate had an upper lamellar pneumatization (lamellar concha bullosa media), while inferiorly it had a sagittal groove on its medial surface which led to the paradoxical curvature of its middle third. The left middle nasal turbinate had a bullous type of concha bullosa at the junction of its anterior and middle thirds, and in its middle third a

sagittal groove of its medial surface determined its paradoxical curvature. Prominent ethmoidal bullae were found bilaterally. The medially bent uncinat processes appeared as accessory middle turbinates. Above the posterior third of the right middle nasal turbinate (concha) were found three ridges which were identified as superior, first supreme and second supreme turbinates (*i.e.*, Morgagni's, Santorini's and, respectively, Zuckerkandl's conchae) (Figure 4). Above the posterior third of the opposite middle turbinate were only superior and supreme nasal turbinates (*i.e.*, Morgagni's and, respectively, Santorini's conchae) (Figure 5). The last three ethmoidal turbinates on the right side were observed on 3D renderizations: the first supreme and the second supreme ones were joined posteriorly in a common tail, which was subsequently joining the posterior tail of the superior turbinate. On the left side (Figure 5), the superior and supreme turbinates posterior tails were also joined.

☞ The ethmoturbinals

A series of six folds (ridges, turbinals) can be identified in the lateral wall of the cartilaginous nasal capsule during 9th and 10th week of gestation (63rd–70th day), where they are separated from each other by corresponding grooves (furrows) [19–21]. Of these folds, the lowest is the maxilloturbinal, which will form the inferior turbinate [6]. The following folds are the series of five ethmoturbinals [6]. The primitive turbinals are further fused into fewer (3–4) crests in the following weeks [19, 20]. Therefore, from the first two or three of the five ethmoturbinals, two to three ethmoidal turbinates are known to result: the persisting middle, superior and, if developed, supreme nasal turbinate [4, 6, 22]. The supreme nasal turbinate remains approximately at 5 mm length from 14th to 36th week and is present in fetuses in only 65% [20]. These descriptions ensure a developmental background for the first supreme (Santorini's) turbinate. Unfortunately, it was not documented whether the fourth, or the fifth ethmoturbinal could persist as the second supreme (Zuckerkandl's) turbinate.

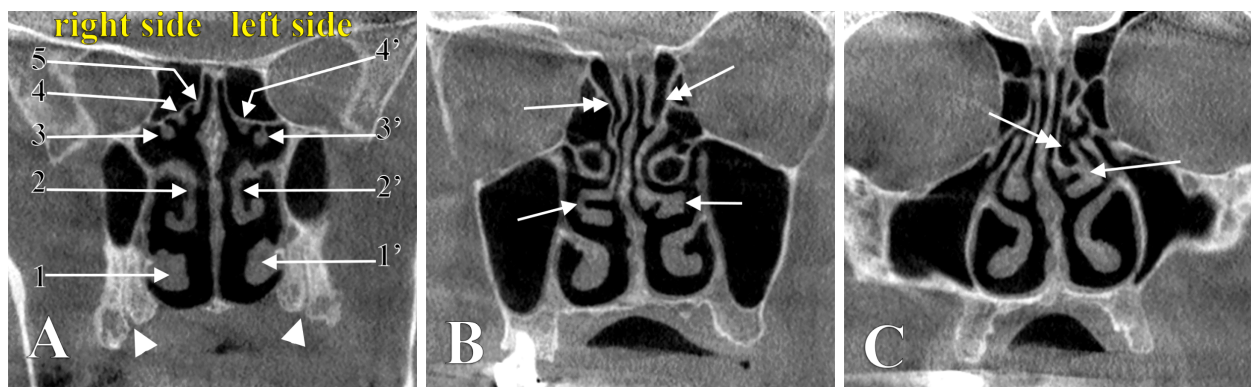


Figure 3 – Coronal multiplanar reconstructions through the posterior (A), middle (B) and anterior (C) thirds of the middle turbinates. (A) On the right side, five turbinates are identified: inferior (1), middle (2), superior (3), first supreme (4) and second supreme (5). On the left side, there are four turbinates: inferior (1'), middle (2'), superior (3') and supreme (4'). The lesser palatine canals are indicated bilaterally (arrowheads). (B) Bilateral evidence of lamellar middle concha bullosa (double-headed arrows) and paradoxical curvatures of middle turbinates (arrows). (C) The paradoxical curvature of the left middle turbinate (arrow) extends anteriorly inferior and is concomitant with a bullous type of concha bullosa media.

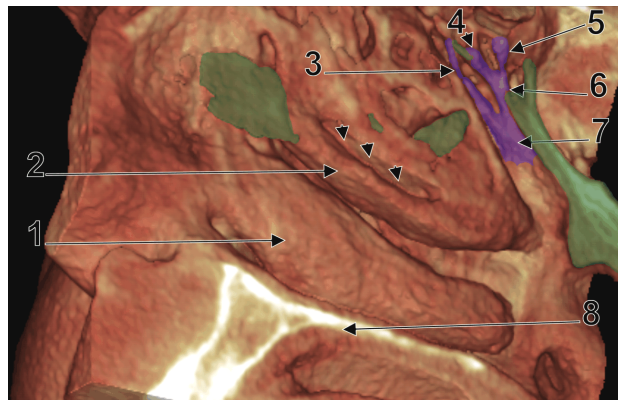


Figure 4 – Three-dimensional volume renderization of the right lateral nasal wall, antero-infero-medial view. Pieces of the nasal septum are distinguished (digitally supracolored in green), as also are the superior and supreme turbinates (digitally supracolored in purple). 1: Inferior turbinate; 2: Middle turbinate with a sagittal groove (arrowheads) determining its paradoxical curvature; 3: Superior turbinate; 4: First supreme turbinate; 5: Second supreme turbinate; 6: Common posterior tail of the supreme turbinates; 7: Joined posterior tails of the superior and supreme turbinates; 8: Hard palate.

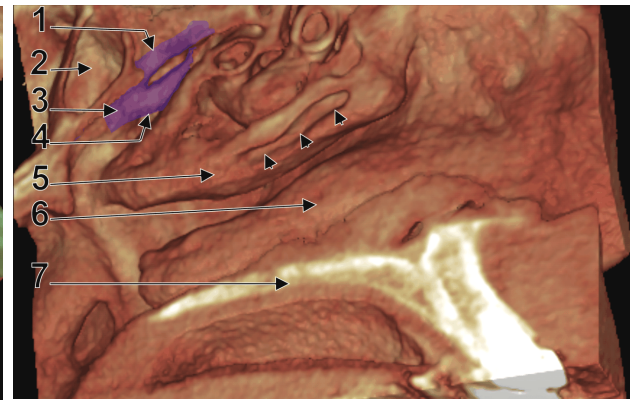


Figure 5 – Three-dimensional volume renderization of the left lateral nasal wall, antero-infero-medial view. The supreme and superior turbinates are digitally supracolored in purple. 1: Supreme turbinate; 2: Sphenoidal sinus; 3: Posterior common tail of the superior and supreme turbinates; 4: Superior turbinate; 5: Middle turbinate; 6: Inferior turbinate; 7: Hard palate.

☐ The concha of Santorini, inconsistencies, and the concha of Morgagni

Giovanni Domenico Santorini (1681–1737) was born in Venice, in 1681 [23, 24]. Numerous anatomical structures bear his name, including the supreme nasal concha or Santorini's concha [1, 3, 16, 25]. Although his work has been carefully documented, an error occurred when it was indicated that the “superior” nasal concha is Santorini's concha [23]. The superior nasal concha bears the name of Giovanni Battista Morgagni (1682–1771) (Morgagni's concha) [3, 26, 27].

☐ Conclusions

When five nasal turbinates are found, the highest is Zuckerkandl's concha or the second supreme turbinate. Co-existence of two supreme conchae joined by a common posterior tail could either indicate their origin from different ethmoturbinals, or could suggest they result from splitting a commonly unique supreme one. Zuckerkandl's concha deserves therefore to be considered when anatomical descriptions, or studies, are delivered.

☐ Conflict of interests

All authors declare that there is no conflict of interests.

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