European Annals of Otorhinolaryngology, Head and Neck diseases xxx (2016) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Original article

Structure of the lateral mass of the ethmoid by curved stacking of endoturbinal elements

R. Jankowski , C. Perrot , D.T. Nguyen , C. Rumeau *

CHU de Nancy, Institut Louis Mathieu, Service ORL et Chirurgie Cervico-Faciale, rue du Morvan, 54511 Vandoeuvre-lès-Nancy cedex, France

ARTICLE INFO

Keywords:
Ethmoid
Ethmoturbinal
Evo-devo
CT scan
Sinus

ABSTRACT

Context: According to evo-devo theory, the embryonic development of the nasal organ mimics its phylontogenic formation: the lateral masses of the human ethmoid bone develop by curved "onion" stacking of the endoturbinals (the horizontal bone septa of the mammalian olfactory chamber) under the impact of facial and skull-base remodeling, rather than by pneumatization of cavities communicating via ostia.
Objectives: To assess the frequency of the onion structure on coronal CT.
Material and methods: Three independent examiners performed a retrospective descriptive study of coronal CT scans taken ahead of septorhinoplasty between June 2010 and December 2012 in adult patients without history of sinonasal surgery.
Results: Fifty patients were included. In the anterior right and left and posterior right ethmoid, an onion arrangement of the endoturbinals was systematically found on at least 1 view, and on 60% of views taking all ethmoid compartments together. Two endoturbinals were generally involved, but a rolling-up of 3 endoturbinals was also observed, significantly more frequently in the posterior compartments ($P = 0.004$ on the right side, $P = 0.012$ on the left).
Conclusion: The onion structure of the lateral masses of the ethmoid can be observed on coronal CT scans. This structure confirms evo-devo theory. The ethmoid thus appears fundamentally different from the paranasal sinuses, suggesting that the pathogenesis of nasal polyposis and ethmoidectomy techniques need to be reconsidered.

1. Introduction

According to classical anatomy, the lateral masses of the ethmoid, or ethmoid labyrinths, are formed from ethmoid cells (Onodi and Haller cells, bullae), described as gas-filled bone cavities opening via ostia onto grooves (uncibullar, retrobullar, meatal and infundibullar grooves), running between the cells to drainage crossroads (ostiomeatal complex) [1–4]. In classical physiology, the lateral masses of the ethmoid are a group of small sinus cavities, each ventilated and drained by an ostium in a labyrinth of grooves [5–8]. Classic embryology describes embryonic ethmoid formation [9]; postnatally, ventilated ethmoid cells give rise to the paranasal sinuses by colonization of the maxillary, sphenoid and frontal bones [1].

However, this concept of the ethmoid-sinus complex fails to account for certain anatomic facts. For example, if the ethmoid cells underlie the formation of the paranasal sinuses and one cell in particular gives rise to the sphenoid sinus, why does the sphenoid sinus ostium not open into the lateral mass of the ethmoid [2,3]?

According to evo-devo theory [10], The paranasal sinuses (maxillary, sphenoid and frontal) do not develop from the ethmoid, but rather from a biological mechanism of pneumatization: postnatal degeneration of the sphenoid [11], maxillary and frontal erythropoietic bone marrow into gas cavities that become the maxillary, sphenoid and frontal sinuses [10]. The same mechanism underlies the pneumatization of the human temporal bone, and of many bones in birds [12]. The ethmoid is the anterior skull-base bone, the cartilage precursor of which, known as the cartilaginous olfactory capsule, appears during human embryonic development in the mesenchyma separating the primitive brain from the bottom of the invagination pits of the olfactory placodes in the embryonic frontal bud. The prechordal cartilage, inherited from early vertebrates (jawless fish: agnatha), and its successive developments (including the cartilaginous olfactory capsule and the ethmoid) are, phylontogenically, the structure in which olfactory mucosa resulting from olfactory placode invagination constantly lodges.

According to evo-devo, or phylontogenic, theory, embryonic development reproduces the phylogenic development of the nose.

* Corresponding author. Tel.: +33 6 64 23 54 80; fax: +33 3 83 15 54 10.
E-mail address: cecile.rumeau@gmail.com (C. Rumeau).

http://dx.doi.org/10.1016/j.anorl.2016.07.007
1879-7296/

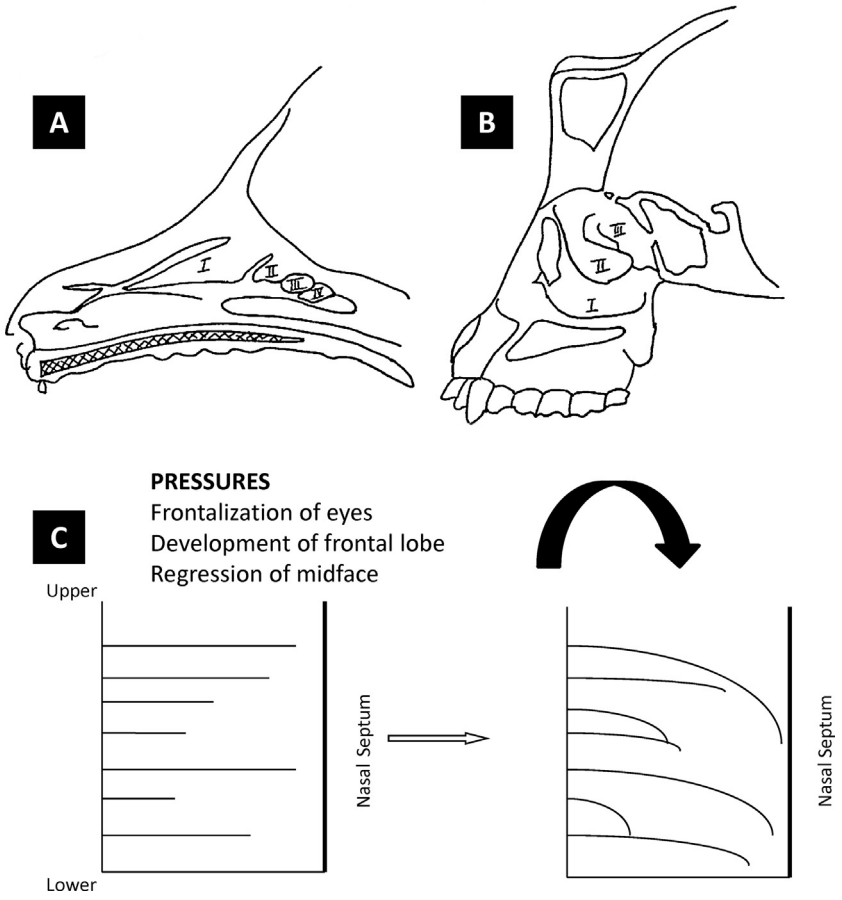

Fig. 1. Evolution of ethmoid labyrinth in primates. A. Sagittal slice, lemur: "olfactory" and "respiratory" nose separated by the transverse lamina, showing 4 ethmoturbinals in each nasal cavity (numbered I, II, III and IV anteroposteriorly). B. Sagittal slice, chimpanzee: the transverse lamina has disappeared; the respiratory corridor remains in the inferior part of the nasal cavity. The ethmoturbinals are smaller, have shifted from an anteroposterior to a vertical arrangement, and are 3 in number (I, II and III inferosuperiorly). C. Diagram of the distribution of endoturbinals (long) and exoturbinals (short) and coronal rearrangement under craniofacial remodeling (from R. Jankowski. The evo-devo origin of the nose, anterior skull base and midface).

Thus, in mammals the ethmoid comprises two olfactory chambers entirely covered in olfactory mucosa. Each contains a stack of thin transverse bone plates (ethmoturbinals), increasing olfactory mucosa surface area in the same way as intestinal villosities or cerebral circumvolutions. The ethmoturbinals are more or less ramified, projecting perpendicularly to the lateral wall in each of the two olfactory chambers in mammals. The "exoturbinals" are shorter, and the "endoturbinals" are longer, reaching the medial septum between the chambers [13].

The formation of the lateral masses of the ethmoid is specifically human and seems to derive from the combined action of bipedalism, frontal eye positioning, regression of the midface, and cerebral lobe enlargement [13,14]. All of these phylogenic morphologic craniofacial transformations involve the ethmoid bone. Thus, the cribriform plate has shifted from an almost vertical orientation in quadruped mammals to a horizontal position in humans under the anterior growth of the frontal lobes; regression of the midface pushed the ethmoid backward, while the frontalization of the eyes pushed the endoturbinals against the perpendicular plate of the ethmoid bone (medial septum between the olfactory chambers) (Fig. 1).

These phylogenic transformations seem to be reiterated during human embryogenesis. By the end of the 8th month, the cartilaginous olfactory capsule shows its characteristic "m" shape [15]. The lateral masses of the ethmoid then develop by folding of the lateral branches of the cartilaginous "m", forming structures resembling ethmoturbinals, which entangle to form the ethmoid labyrinths. All of these changes lead in humans to the disappearance of olfactory mucosa from the ethmoid labyrinths, to be confined within the olfactory grooves.

The present study hypothesis is that, during the evolution of mammals into humans, the endoturbinals, which were initially superimposed like so many shelves, became flattened against the medial septum between the olfactory chambers and rolled up under each other, giving the lateral masses of the ethmoid an onion-like structure. This onion structure has never previously been described in the literature, but can be seen on coronal anatomic cross-sections (Fig. 2A).

The objective of the present study was to determine the frequency of this onion structure in the lateral masses of the ethmoid on coronal CT slices (which are easier to collate than anatomic cross-sections).

It seems important to specify this ethmoid architecture, as it has significant implications for surgery: a technique intended to separate two superimposed bone plates is fundamentally different from one that consists in collapsing ethmoid cell walls.

2. Material and method

A retrospective descriptive study was performed using the data-bank of our radiology department, analyzing all consecutive CT scans taken for preoperative assessment ahead of septo- and/or rhino-plasty between June 2010 and December 2012 in adult patients without history of sinonasal surgery. The sinus CT acquisition protocol specified axial slices in the orbitomeatal

Please cite this article in press as: Jankowski R, et al. Structure of the lateral mass of the ethmoid by curved stacking of endoturbinal elements. European Annals of Otorhinolaryngology, Head and Neck diseases (2016), http://dx.doi.org/10.1016/j.anorl.2016.07.007