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ABSTRACT

Ph. D. Thesis

Anatomo-imaging and exploratory research of the ethmoid

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Motivation of the research theme

Sinonasal inflammatory disorders represent the commonest human pathology and an imaging study requires an assessment of the extension of the lesion and the identification of several factors, including anatomical ones, which complicate the clinical picture and the therapeutic approach; by fine-tuning the quality of the images, computed tomography can assess both the bone substratum and the soft adjacent parts (1). Paranasal sinuses are among the least described anatomical sites of the human body (2). Among the paranasal sinuses, the ethmoid sinus is considered to be the cornerstone of the sinus system because the drainage of the other paranasal sinuses is carried out through the ethmoid labyrinth or adjacent to its lateral wall (2).

The importance and the currency of the theme

Despite continuous research, the ethmoid still remains an unclear subject (3). The anatomical boundaries of the ethmoid are represented by: laterally – the medial wall of the orbit, through the papyraceous or orbital lamella, superiorly – the base of the cranium (the ethmoid fovea), medially – the lateral surface of the middle nasal concha, posteriorly – the sphenoid, anteroinferiorly – the nasal fossa. (4). The ethmoid cavity acts as a drainage portal for the aerial paranasal sinuses (4).

Scientific objectives of the doctoral research

The research is based on the hypothesis that there are individual anatomical variations which alter the standard vesalian anatomical information (5) and particularize it from individual to individual. We assumed that the variational anatomical potential of the ethmoid is important, having a practical effect on surgical procedures both in eye and in nose surgery. The following main objectives have been defined in the present Ph. D. thesis: (1) gathering extensive information from the existing literature about the pre- and postnatal ethmoid morphological particularities; (2) conducting original research of the ethmoid components, such as the cribriform plate (the roof of the nasal cavity), the ethmoid pneumatization (the joint wall of the orbit and the nasal fossa) and the ethmoid nasal conchae.

Contents of the Ph. D. thesis

The general part of the doctoral thesis entitled „Anatomo-imaging and exploratory research of the ethmoid" contains results from specific reference sources. The three chapters of the general part offer embryology and anatomy information, as follows: Chapter 1 – the morphogenesis of the ethmoid, Chapter 2 – elements of nasal anatomy, and Chapter 3 – elements of ethmoid anatomy. The personal part contains the author's original research. The anatomical-imaging study of ethmoid structures was carried out on a group of 171 cases assessed with cone beam computed tomography, identifying: (1) pneumatization models of the posterior nasal (ethmoid) wall, (2) anatomical variations of the ethmoid uncinate process, (3) ethmoid pneumatization (anatomical variations in the agger nasi cells and the sphenoethmoid sinuses), (4) anatomical possibilities of the ethmoid nasal conchae (variations of their nasal insertions, conchal pneumatizations, paradoxical curvature of the middle turbinate, combinations of conchal anatomical variants, conchal bifidus, conchal agenesis and hypogenesis). In the end we presented studies of the ethmoid sinoliths.

ABREVIERI

3DVR – 3-dimensional volume rendering EB – ethmoid bulla UB – uncinate bulla ANC – agger nasi cell LC – lacrimal cell LNC – lacrimonasal canal INC – inferior nasal concha BINC – bifid inferior nasal concha	SMNC – secondary middle nasal concha SNC – superior nasal concha sNC – supreme nasal concha CT – computer tomography CBCT – Cone Beam CT PPF – pterygopalatine fossa PPG – pterygopalatine ganglion (Meckel's sphenopalatine)	SNM – superior nasal meatus BMR – bidimensional multiplane reconstruction UP – uncinate process FR – frontal recess SER – sphenoethmoid recess FS – frontal sinus MS – maxillary sinus SS – sphenoid sinus

MNC – middle nasal concha AMNC – accessory middle nasal concha	IE – ethmoid infundibulum INM – inferior nasal meatus MNM – middle nasal meatus	SES – sphenoethmoid sinus

GENERAL PART OF THE DOCTORAL THESIS

1 ELEMENTS OF ETHMOID MORPHOGENESIS

From an embryological point of view, the ethmoid differs from the other sinuses. The ethmoid bone originates in the cartilaginous nasal capsule or paleo sinus (enchondral bone), while the other paranasal sinuses are extensions of the ethmoid (extracapsular) in membranous bones (neosinuses) initially achieved by epithelial diverticula. Sinuses develop as a consequence of the primary and secondary pneumatization; primary pneumatization is correlated with the differentiated growth of the cartilaginous nasal capsule, with initial formation of diverticular sacs which extend between the boundaries of the capsule forming elaborate intracapsular air spaces. Ethmoid sinus architecture can be understood by studying the primitive oncogeny of the region; during prenatal development, the insertions of ethmoid bone structures of the lateral nasal bone, such as UP, MNC and SNC are formed by the basal lamellae. Their lateral extremities end abruptly, but medially they project beyond the ethmoid labyrinth into the nasal fossa. The anterior lamella is the lateral extension of the uncinate process, the second lamella being the EB lamella, as it medially extends forming the EB, the third lamella being the one which attaches the frontal part of the middle nasal concha (MNC has the following parts: parasagittal, frontal and transversal, and the first and the last do not play any role in separating the anterior ethmoid from the posterior ethmoid).

2 ANATOMICAL ELEMENTS OF THE NASAL FOSSAE

The nasal cavity (the internal nose) belongs to the viscerocranium and consists of the two nasal fossae divided by a bony nasal septum. Each nasal fossa has four walls: lateral, medial (the nasal septum), inferior (floor), superior (roof). The nasal roof has three segments. The nasal septum consists of the perpendicular lamella of the ethmoid bone and the vomer. The nasal septum may have exostoses, spurs or deviations, usually located in the anterior part of the septum. The lateral nasal wall contains the nasal conchae. The inferior nasal concha is an independent bone, while the other three, the middle concha, the superior concha and Santorini's supreme concha, are ethmoid conchae. The lateral nasal wall has two floors, superior or orbital and inferior or maxillary, and consists of three bony plates. The external plane is represented by the maxilla and the medial pterygoid plate. The intermediate plate consists of the lacrimal bone and the perpendicular plate of the palatine bone. The internal plate corresponds to the ethmoid labyrinth and the inferior nasal concha. The nasopharyngeal communication forms the choana, which is delimited superiorly by the body of the sphenoid bone and the wing of vomer, and inferiorly by the horizontal plates of the palatine bone which articulate with each other and form the posterior nasal spine; laterally the sphenoid joins the palatine bone through the lateral pterygoid plate. The choanae are oval, with a vertical longitudinal axis.

3 ELEMENTS OF ETHMOID ANATOMY

The ethmoid bone belongs to the neurocranium. It is a lightweight cubical bone located, through its various components, between the anterior cranial fossa and the nasal fossae, with components in the walls which separate the nasal fossae from the orbits and, respectively, form the bony nasal septum. It is an unpaired bone located in the ethmoid foramen of the frontal bone. It consists of the cribriform plate which lies horizontally, in medial plane, between the nasal fossae and the anterior cranial fossa; it has foramina for the threads of the olfactory nerves. Medially, above the cribriform plate, rises the apophysis of the crista galli to which the falx cerebri (fold of the dura mater) is attached. Crista galli is connected anteriorly to the frontal crest through the wings of the crista galli. Inferiorly and medially, the perpendicular plate of the ethmoid descends, being a part of the bony nasal septum. A group of pneumatic ethmoid cells, collectively called the ethmoid labyrinth, are located between the orbit and the nasal fossa. The medial face of the ethmoid labyrinth contains the ethmoid nasal conchae, middle, superior, and sometimes Santorini's supreme nasal concha. At the same time, inferior to the middle nasal concha, at the level of the ethmoid labyrinth, there is the ethmoid bulla, the uncinate process and the ethmoid infundibulum. The thin bony plate which covers the ethmoid labyrinth laterally, towards the orbit, is the lamina papyracea or orbital lamina.

THE PERSONAL PART OF THE DOCTORAL THESIS

4 ANATOMO-IMAGING STUDY OF THE ETHMOID MORPHOLOGY

4.1 Pneumatization models of the posterior nasal roof

4.1.1 Introduction

Anatomically, the roof of the nasal fossae has the following components: anterior nasofrontal, intermediate, ethmoid, and posterior sphenoid. The ethmoid component is represented by the cribriform plate of the ethmoid bone. Above the cribriform plate lie the olfactory bulb and tract, while inferior to the cribriform plate lies the olfactory mucosa with the olfactory receptors, which facilitate the damaging of the olfactory tract, either posttraumatic, or in chronic sinusitis, or post-rhinosinusitis surgery.

4.1.1.1 Hypothesis

The hypothesis of the study was that the pneumatizations adjoining the cribriform plate of the ethmoid can send extensions into the posterior segment of the roof of the nasal fossa.

4.1.1.2 Aim

The aim of the study was to document the pneumatization models of the ethmoid segment of the nasal roof using methods of imaging anatomy.

4.1.2 Material and methods

The study was conducted on a group (#1) of 35 patients subjected to Cone Beam CT (CBCT) in order to assess the existing anatomical substratum for various dental treatments. We documented the variable ethmoid or sphenoid pneumatizations of the posterior segment of the cribriform plate: MPEP: median posterior ethmoid recess; BPPEP: bilateral paramedian posterior ethmoid process; OR: Onodi cell recess in the nasal roof; SR: anterior recess of the sphenoid sinus in the nasal roof; SSR: sphenoseptal recess. „1" the recess exceeds superiorly the ethmoid cribriform plate (intracranial location); „2" the recess does not exceed superiorly the ethmoid cribriform plate (intranasal location). We identified the bilateral and double pneumatizations. Prevalence was analyzed with Microsoft Excel 2013. The images were processed using Adobe Photoshop CC.

4.1.3 Results

In 34% of the cases, no pneumatization was found in the posterior segment of the ethmoid cribriform plate. In 23% of the cases, pneumatization at that level was caused by median recesses of the posterior ethmoid cells; in 29% of the cases, by anterior recesses of the sphenoid sinuses; in 11% of the cases, by bilateral paramedian posterior ethmoid process, and in 3% of the cases, pneumatization was caused by an Onodi sphenoethmoidal cell. In eight cases we found median ethmoid recesses which pneumatized in the nasal roof; in two of these cases the recess was located at the level of the cribriform plate, and in the other six cases it was located above the cribriform plate. One of the six cases had a bifidus recess. Of the cases with sphenoid recess in the nasal roof, 60% had an intranasal location and 40% and intracranial location. In 18 of the 35 cases, we found a sphenoseptal recess, although not in the nasal roof.

4.1.4 Discussion

The anatomical pneumatization models identified in the ethmoid segment of the nasal roof are: type I: lack of pneumatization; type II: intracranial ethmoid pneumatization, above the ethmoid cribriform plate; type III: intranasal ethmoid pneumatization, in the depth of the ethmoid cribriform plate; type IV: intracranial sphenoid pneumatization; type V: intranasal sphenoid pneumatization; type VI: pneumatization of the nasal floor coming from an sphenoethmoid Onodi cell. It is important to underline that the morphological possibilities of median pneumatization associated with the ethmoid cribriform plate are not mentioned in literature, representing an even higher risk element as they are not documented in reference sources. This supports the fact that although functional endoscopic surgery is considered safe, it may have complications due to the vicinity of paranasal sinuses with important structures such as the orbit and the base of the anterior cranial fossa. In mainstream descriptions, the frontal lobe and the ethmoid cribriform plate form the base of the anterior cranial fossa, a structure which has not been described as possibly pneumatized. Existing descriptions indicate only variable models where the frontal bone are covered by the ethmoid labyrinth and do not indicate the variables determined by the pneumatization of the posterior segment of the ethmoid cribriform plate. It has been debated that the lack of cover of the ethmoid labyrinth induces surgical risk in ethmoidectomies, but only lateral to the MNC insertion. Based on the presented results, we consider that this risk also extends to the median sphenoethmoid junction. If we consider the location of Onodi cells in relation to the sphenoid sinus, it has been identified as superior, lateral or superolateral to the sinus. The possibility of an anterosuperior location to the sphenoid sinus, which in one of our cases resulted in the situation of the Onodi cell in the roof of the sphenoethmoid recess, was not discussed.

4.2 The anatomical variability of the uncinate process

4.2.1 Introduction

The uncinate process (UP) is a lamella originating from the posteromedial border of the lacrimonasal canal (LNC). It has a great practical importance in the endoscopic functional sinus surgery.

4.2.1.1 Hypothesis, aim

We started from the hypothesis that the superior insertion of the UP is variable, aiming at identifying its morphological possibilities in imaging anatomy, on coronal sections of CBCT.

4.2.2 Material and methods

The study was conducted on a group (#2) of 26 patients, subjected to Cone Beam CT (CBCT) for the assessment of the existing bony substratum for various dental treatments. Out of the 26 patients, 12 (46%) were men and 14 (54%) women, aged between 38 and 52 years.

4.2.3 Results

We identified 9 anatomical types of superior insertion of the uncinate process: type 1: insertion to the ethmoid lamina papyracea (10%); type 2: insertion to the wall of the agger nasi cell (4%); type 3: insertion to the lamina papyracea and to the junction between the ethmoid cribriform plate and the MNC (24%); type 4: insertion to the junction between the ethmoid cribriform plate and the MNC (6%); type 5: insertion to the ethmoid roof, outside the lateral lamina (6%); type 6: insertion to the lamellar segment of the MNC (4%); type 7: insertion to the lamina papyracea and the ethmoid roof (22%); type 8. insertion to the lamina papyracea and the MNC (4%); type 9: insertion through multiple digitations (20%).

4.2.4 Discussion

The uncinate process of the ethmoid has a well-defined functional role in the physiology of sinonasal ventilation, as it offers a barrier-like protection to anterior sinuses from allergens and microbes and facilitates sinus ventilation. Endoscopic sinus surgery aims at preserving the mucosa, differing from transmaxillary procedures which completely remove the pathological mucosa. Although endoscopic surgery offers a more detailed observation, the field of vision is narrower. The uncinate process is the most important landmark in the lateral nasal wall during endonasal endoscopic surgery. In middle meatal antrostomy the UP is the first one removed in order to enlarge the ostium of the maxillary sinus. The abnormal size and the pneumatization of the UP make sinus drainage more difficult. The anatomical variations of the ethmoid uncinate process were systematized in types I - IV: (I) the superior insertion of the uncinated process may belong to three main types: type I – the UP tilts laterally in its superior segment and is inserted in the lamina papyracea (79,8%); II – the UP climbs to the ethmoid roof (16,67%), and lies at the base of the cranium; III – the superior end of the UP tilts medially and is attached to the middle concha; seldom, the superior attachment can be a multiple one, through multiple digitations, to the middle concha, at the base of the cranium and the lateral nasal walls; (II) UP curved medially; (III) UP curved laterally; (IV) pneumatized UP or uncinate bulla. This systematization identifies only three possibilities of the superior insertion of the UP, adding the multiple insertions, which are not as detailed as in our study.

4.3 Anatomo-imaging study of ethmoid cells

4.3.1 Introduction

The development of endoscopic surgery heightens the diagnostic and preoperative role of CT anatomy in sinonasal anatomy; although anatomical variants do not represent pathological situations, they can alter the normal anatomical drainage and access ways. The sinuses and the ethmoid cells can be considered the cornerstone of the sinus system because they come into contact with any of the sinus drainage ways and may have a heterogeneous morphological variation.

Agger nasi cells (ANC) are usually considered anterior ethmoid cells and, although they are considered to be present in all cases, the term seems to be used for various structures such as lacrimal cells (LC), frontal sinus cells and the terminal recess. An ANC is located in the agger nasi site, a ridge situated anterior to the MNC insertion at the level of the frontal process of the maxilla (2). A LC corresponds laterally to the lacrimal bone and is situated posterior to the NAC.

4.3.1.1 Work hypothesis

We started from the hypothesis that the assessment of NAC prevalence is altered by the anatomical confusion between a NAC and a LC.

4.3.1.2 The aim of the research

We tried to identify the anatomical possibilities of pneumatization in the anatomical site of agger nasi, in order to determine the proper prevalence of NAC.

4.3.2 *Material and methods*

The study was conducted on a group (#3) of 36 patients, subjected to Cone Beam CT (CBCT) to assess the existing anatomical substratum for various dental treatments. Of the 36 patients, 15 (42%) were men and 21 (58%) women, aged between 37 – 61 years.

4.3.3 *Results*

In the group of 36 patients examined bilaterally, we identified the following unilateral anatomical models in the conventional site of agger nasi cells (ANC): (I) 20 cases with simple lacrimal cells (LC); (II) 6 cases with associated LC (+); (III) 4 cases with extended LC (>) with uncinate bulla (UB); (IV) 1 case with LC>UB associating (+) and a NA cell; (V) 19 cases with NAC > LC; (VI) 8 cases with NAC > CL > UB. In the situations with simple LC, in 6 patients these were present unilaterally, and in 14 patients the anatomical model was bilateral. This led to a total of 34 such pneumatizations, of a total of 72 lateral nasal walls. Of the 6 cases with unilateral simple LC, 5 associated contralaterally LC coalescent with NAC and in one case contralaterally we found a LC coalescent with UB. In 2 of the 34 cases LC drained in the FR, while in the remaining 32 cases drainage took place in the EI. Of the 6 cases with simple LC but associated to other pneumatizations, 17% drained into the ethmoid infundibulum, 33% drained into the middle nasal meatum, and 50% drained into the frontal recess. In the 4 cases in which we identified LC coalescing with UB, these were unilateral and drained into the EI. In 7 cases we presented agger nasi cells coalescent with LC, unilaterally, and in 6 patients we found 14 such models bilaterally. In the cases with unilateral location of this anatomical model, on the opposite site we found simple LC in 5 cases, NAC coalescent with LC in one case, and coalescence of NAC, LC and UB in one case. Of the 19 cases in which NAC coalesced with LC, 4 drained into the FR and the rest into the EI. In 1 patient the coalescence was bilaterally triple (NAC, LC, UB) and in 6 patients this anatomical model was present unilaterally. In the case of distinct or simple ANC, located in the frontal process of the maxillary, these were associated in 6 cases unilaterally with LC, and in one case also unilaterally with LC > UB. Simple NAC drained either into the frontal recess (50%), or in the middle nasal meatus (33%), or in the ethmoid infundibulum (17%). We assessed anatomically simple LC which had the following relations: (a) laterally with the orbit, in immediate contact with the lacrimal sac; (b) anteriorly with the frontal process of the maxillary; (c) superiorly with the FR; (d) posterosuperiorly with an anterior ethmoid cell (with such anterior ethmoid cells, LC can coalesce); (e) posteroinferiorly with the UP root; (f) medially with MNM; (g) posteriorly with the ethmoid infundibulum; (h) inferolaterally with the NLC. In one case with bilateral asymmetry, we found, on the right side, NAC draining in the frontal recess, the latter being located superior to the same side LC. NAC and LC were not coalescent. On the opposite side, there was no NAC, only a simple LC; however, there was a narrow anterolateral recess of the MNM projecting from the anterior part of the respective LC. This meatal recess (can be called the agger nasi recess of the MNM because it contacts the frontal process of the maxillary at the level of agger nasi) thus projects up to the medial orbital wall, under the fossa of the lacrimal sac, being easily mistaken for a small NAC on sagittal and coronal RPM. In 4/36 cases, we identified unilaterally coalescent lacrimal cells with uncinate bullae; all of these drained into the ethmoid infundibulum. The triple coalescence, NAC, LC and UB, allows the three spaces separated by incomplete septa to communicate jointly with the ethmoid infundibulum. Using the two lacrimal ridges as landmarks, the anterior one from the frontal process of the maxillary and the posterior one from the lacrimal bone, we considered the NAC as being the pneumatization anteriorly exceeding the anterior lacrimal ridge. The NAC and LC coalescence could anatomo-clinically give the aspect of a large NAC.

4.3.3.1 *The sphenoethmoidal sinuses*

The sphenoethmoidal sinus (SS) varies widely both intra- and inter-individually. Peele (1957) observed that normal SSs are rare and sinus extensions are common and should be considered a characteristic of the SS. We haven’t found in our reference works any morphological possibility of a giant sphenoethmoidal sinus associated with a sagittally shorter lateral nasal wall.

The sphenoethmoidal sinus (case #1). In this case, the SS bilaterally reached anteriorly above the posterior third of the MNC and INC. We called it sphenoethmoidal sinus (SES). On each side, these pneumatic models corresponded to the post-sellar model, completely filling the body of the sphenoid. In plaus, each of the SES presented a pterygoalar recess in the root of the pterygoid process and in the larger sphenoid wing. On each side, the maxillary nerve canal was located at the superoexternal limit of the pterygoalar recess base. The vidian nerve canal was located in the free margin of a septum of the pterygoid recess plate. These SES were relatively equal in size, being divided by a median intersinus septum. Each had two chambers, an anterior ethmoid one and a posterior sphenoidal one, divided by an incomplete frontal septum inserted on the sphenopalatine foramen, above the PPF. The anterior, ethmoidal chamber opens through the sinus ostium into its anterior wall, ostium located medially to the NCs on the same part. The ethmoidal chambers of the SES have thus pushed anteriorly the sphenoethmoidal recess on each side, reaching the roof of the nasal fossae. The posterior wall of each MS was oriented towards the PPF and the pterygoid process. The posterior walls of the MS had two recesses: an inferior one, towards the pterygoid process, which attached the MNC (we called it the pterygoid recess of the MS), and a superior one directed posterosuperiorly towards the ethmoidal chamber of the SES on the respective side (we called it the sphenoethmoidal recess of the MS). The pterygoid recess of the MS on the right side was located immediately inferiorly to the PPG fossa, and the sphenoethmoidal recess was located above.

The sphenoethmoidal sinus (case #2). In the second case we also found bilateral SESs, with a slight left deviation of the intersinus septum, post-sellar pneumatization and pterygoalar recesses. The vidian canal on the right side had a pediculate insertion to the sinus plate, and the one on the opposite side crossed to the sinus plate. The two pterygoid canals (vidian) ended anteriorly in the PPG fossa, on the respective side. The wall between the left SES and the PPF was dehiscent, which brought the PPG into direct contact with the sinus mucosa. Although the two SESs were extended anteriorly in the anatomical space of the ethmoid, they were not divided into chambers.

4.3.4 Discussion

4.3.4.1 The study of the coalescent pneumatizations in the agger nasi site

The incidence of the agger nasi cells was reported between 3 – 100%, its presence being definitely associated with frontal sinusitis. During prenatal development, the lateral nasal wall grows ethmoturbinal ridges which have an ascending anterior part and a descending posteroinferior part. The descending part of the first ethmoturbinal becomes the UP and the ascending part becomes the agger nasi (nasoturbinals).

Marquez et al (2008) made a clear distinction between a real NAC and a LC, the lateral NAC wall being formed by the frontal process of the maxillary and the lateral wall of the LC being formed by the lacrimal bone. Coronal sections show that the margins of the middle nasal concha are not adjacent to a NAC, but it becomes visible when the section passes through a LC. We used these landmarks and we identified the lack of NAC in 52.77%, and its replacement by a LC in various combinations (types I and III). We consider that when the anatomical identification is done based on CT slices, we cannot assume simplistically that the most anterior ethmoidal cell in the lateral nasal wall would be a NAC and the middle nasal concha, the frontal process of the maxillary and the lacrimal bone must be identified to indicate if the adjacent pneumatization is a NAC or a LC. A pneumatic cell placed above the middle nasal concha is not a NAC, as indicated by certain authors, but a LC. Endoscopy is used both in rhinosinus surgery and in dacryocystorhinostomy (DCR). In DCR, UP and/or NAC usually obstruct access to the lacrimal sac fossa. Our study demonstrates that even a LC and/or UB could prevent access during a DCR. The failures of DCR were accounted for by intranasal problems which prevent the formation of a resilient connection between the lacrimal sac and the nasal fossa. NACs close to the lacrimal sac should be removed during DCR. The uncinate process of the ethmoid belongs to the lateral nasal wall at the level of the middle meatus. Its pneumatization, UB, is a rare anatomical possibility, described as „the extension of some air cells" into the uncinate process.

4.3.4.2 Sphenoethmoidal sinuses, conchal perforation, maxillary insertion of the superior nasal concha

Some possible formation mechanisms of SES can be reasonably speculated. The first one: an adult SES can occur following a morphogenetic event where initial ethmoid pneumatrization is maintained and binds to the secondary sphenoidal one. This theory matches the opening of the SES ostium into the sphenoethmoidal recess. The second possible mechanism takes into account the fact that ethmoidal cells are formed at birth, while SS is formed later; that is why it's possible that the concha sphenoidalis, which forms the anterior wall of a normal SS and separates it from the ethmoid, is resorbed leading to the unification of the ethmoid with the sphenoid. Although this hypothesis is supported by the existence of an incomplete septum between the two chambers of the SES, but only in the first case, SES should open via a posterior ethmoidal cell, either into the SNM or into the sphenoethmoidal recess, which contradicts the evidence. The third possibility considers the fact that SS develops as an extension of the posterosuperior part of the sphenoethmoidal recess which excavates the concha sphenoidalis. That is why the SES can be connected to an abnormal length of the sphenoidal body which, thus, crosses through the nasal roof into the lateral nasal wall, causing sagittal hypoplasia to an otherwise normal ethmoid.

In order to test the third hypothesis, we measured the sagittal nasion-concha sphenoidalis distance (N-SC) in both patients, and it was below 40 mm. Afterwards, we extended the study group investigated for this distance with 32 more cases, similarly explored via CBCT (group #5). In 28/32 cases, who didn't have sphenoethmoidal pneumatization (non-SES cases), the N-SC distances were greater than 40 mm. It is interesting that in 4/32 patients we identified unilaterally N-SC distances below 40 mm – we reexamined these cases and we identified unilateral sphenoethmoidal pneumatizations in these cases (the ethmoidal anterior chambers were located anterior to the respective sphenopalatine pillars). The sphenopalatine pillars were located in the coronal plane of the MNC tail, which is normal as long as we know that the tail of the MNC is the landmark for the sphenopalatine foramen.

4.4 The nasal conchae – study of anatomical variations

4.4.1 Introduction

The development of modern imaging methods revealed a wide range of variations of the nasal conchae, which is important for the nasal endoscopic techniques. The secondary middle nasal concha (SMNC) is a rare anatomical variation, which was reported in 0.8 – 6.8 % of the cases, and represents a structure arising from the lateral wall of the middle nasal meatus. The accessory middle nasal concha (AMNC) represents a medially bent uncinate process and has a different formation mechanism from the SMNC. A paradoxical concha is defined as an inferomedially curved concha (concave), in such a way that its concave surface is oriented towards the nasal septum. The bifidus inferior nasal concha (BINC) is a rare anatomical variant, easily seen on CT but often missed during endoscopy. At first, only a few cases were reported, two with unilateral BINC and five with bilateral BINC. The agenesis and hypogenesis of the nasal conchae are extremely rare and were reported only for MNC and INC (10, 55, 123, 124). There were no agenesis or hypogenesis cases reported for SNC.

4.4.2 Material and methods

We carried out research of conchal (turbinal) variational anatomy on a group (#4) of 40 patients subjected to Cone Beam CT (CBCT) in order to assess the initial anatomical substratum for various dental treatments.

4.4.3 Results

4.4.3.1 The variability of nasal concha insertion

The nasal conchae of the patients in our study group (N=40) presented three balanced possibilities (32%, 33%, 35%) of insertion to the nasal wall, sphenoidal, ethmoidal and sphenoethmoidal/combined. The superior nasal conchae showed various possibilities of bilateral symmetry and insertion to the lateral nasal wall. We identified symmetrical bilateral ethmoidal insertion in 29/40 cases (72%), sphenoidal insertion in 2/40 cases (5%) and sphenoethmoidal insertion, at the level of the ethmoidal labyrinth and the sphenoidal sinus wall in 5/40 cases (12%). We also found a bilateral asymmetry of the nasal parietal insertion of the SNC with the following associations: unilateral ethmoidal and contralateral sphenoethmoidal insertion in 1/40 cases (3%), unilateral ethmoidomaxillary and contralateral sphenoethmoidal insertion in 1/40 cases (3%).

4.4.3.2 Anatomical study of nasal concha pneumatization

4.4.3.2.1 Panconcha bullosa, with communicating inferior lamellar concha bullosa

In one of the retrospective cases (52-year-old patient), Cone Beam CT showed pneumatization of all the nasal conchae, i.e., panconcha bullosa. We found a type-5 Mladina deformation of the nasal septum, without septal deviation. In the posterior part of the nasal septum we found a septal or anterior recess of the right sphenoidal sinus.

4.4.3.2.2 Concha bullosa suprema

We present the prevalence of the cases with bilaterally absent, bilaterally present and unilaterally absent/present supreme nasal concha. of the 14/40 cases (35%) with bilaterally present supreme nasal concha, three had bilateral pneumatization (concha bullosa suprema) and out of the 6/40 cases (15%) with supreme nasal concha, five has supreme concha bullosa.

4.4.3.2.3 Concha bullosa superior

In 14/40 cases (35%) we did not find concha bullosa superior; this was present unilaterally in 9/40 cases (23%) and bilaterally in 17/40 cases (42%).

4.4.3.2.4 Giant concha bullosa superior

In a 58-year patient (retrospective case), we found a type-4 Mladina deformation of the nasal septum. We found supreme and superior nasal conchae bilaterally. Only the left SNC was pneumatized, 17.43/5.34 mm in coronal section. It descended between the middle nasal concha and the nasal septum, supported by the paradoxical twist of the respective middle concha. An incomplete septum divided the left superior concha bullosa cavity into two communicating chambers, anterior and posterior.

4.4.3.2.5 Concha bullosa media

We did not find the subtype bulbar concha bullosa media in any of the patients included in the study group (N=40). In 5/40 cases (13%) we couldn't identify the presence of MNC pneumatization, in 20/40 cases (50%) we found bilateral lamellar pneumatization, in 7/40 cases (17%) the lamellar pneumatization of the MNC was unilateral, and the extended pneumatization, combining the lamellar and the bulbar subtypes was bilateral in 2/40 cases (5%) and unilateral in one case (2%). We revealed various pneumatization combinations, i.e., bilateral asymmetry, in 5/40 cases (13%), when on one side of the median plane we found extensive pneumatization of the MNC and on the other side we found only the lamellar subtype.

4.4.3.2.6 Concha bullosa inferior

We found no concha bullosa inferior in 28/40 cases of our study group (70%). The discrete/subtle type of pneumatization was bilaterally present in 8/40 (20%) cases, the rest of the cases having either unilateral pneumatization or a combination of bilateral subtle + moderate or moderate + moderate subtype.

4.4.3.3 Middle nasal concha bifidus, sagittal turbinate

In the group investigated for conchal morphology, we found MNC bi- and trifidus in various anatomical models.

4.4.3.4 Agenesis and hypogenesis of the superior nasal concha

Two of the cases investigated for nasal concha variation (N=40) had agenesis, respectively hypogenesis of the superior nasal concha.

4.4.4 Discussion

4.4.4.1 Concha bullosa

The commonest anatomical variation of nasal conchae is the concha bullosa. Some authors define this only the pneumatization of the MNC body, while others indicate the pneumatization both of the lamellar part and of the turbinal body (the bulbar part). Thus, the reported prevalence of concha bullosa, between 4% and 80% comes from the differences in the definition, from the groups of investigated patients, the ethnical variations, the types and methods of study (dissection, imaging). Conchal pneumatization results in a resistance to nasal respiration and can determine patients to breathe through their mouths.

4.4.4.2 Middle nasal concha bifidus

There are only two studies that reveal a middle concha bifidus, and the variation is not mentioned in Bergman's Encyclopedia of Anatomical Variations either.

We reported a number of cases in which we identified the presence of MNC bi- or trifidus. These were associated with conchal paradoxical curvatures. The respective morphologies were induced by the specific location of the conchal sagittal groove. The variants were either unilateral or bilateral. A medial conchal sagittal groove determines a paradoxical curvature, with the convexity of the concha oriented laterally, but such a groove located inferiorly results in concha bifidus.

4.4.4.3 Agenesis and hypogenesis of the superior nasal concha

We could speculate that in the case of SNC agenesis or hypogenesis the cause may lie in an anomaly in the development of the third ethmoturbinal. As we've only introduced the first proof in this sense, the morphogenetic substratum cannot be detailed.

5 ETHMOIDAL SINOLITHS

We present here the sinoliths located bilaterally in the ethmoidal sinuses, identified in one of the study cases, through Cone Beam CT (CBCT). At the same time, in another patient, we identified bilateral sphenoidal sinoliths which associated a unilateral ethmoidal sinolith.

CONCLUSIONS OF THE PH. D. THESIS

1. For a correct and thorough diagnosis, CT studies assessing lateral nasal wall pneumatizations should use RPM in all the anatomical planes, as well as tridimensional models. The agger nasi cells hould be carefully diagnosed so as not to distort prevalence results.
2. We identified pneumatization possibilities in the posterior segment of the ethmoidal cribriform plate. These possibilities make certain structures, considered so far as constant (the nasal roof and the floor of the anterior cranial fossa), become variable. Consequently, we can conclude that patients should undergo a thorough preoperative examination, in order to avoid missing certain anatomical sites considered so fas as invariable. The pneumatization of the nasal roof and of the floor of the anterior cranial fossa correlate ethmoidal sinusitis with dysomia, and recommend prudence in the ethmoidal endoscopic surgery.
3. The ethmoidal uncinate process is an essential structure of the lateral nasal wall, with various variational possibilities. This fact requires an individual preoperative morphological assessment by CT or CBCT, especially in functional endoscopic surgery.
4. The combination of variants at the level of the middle nasal concha, pneumatization with paradoxical curvature, is rarely found. A thorough knowledge of the anatomical variations of the lateral nasal wall is relevant in ENT surgery. The possibilities of vertical or sagittal variational combinations reveal the fact that vesalian anatomy has become obsolete in the practice of variational anatomy, and the established anatomical possibilities can combine to generate new variants.
5. Taking into account the combination of variants considered as independent in an ethmoidal structure, the middle nasal concha, we consider that anatomo-imaging diagnosis should also take into consideration the possibility of multiple anatomical variations, by association. Preliminary knowledge of the middle nasal concha morphology should not be based exclusively on coronal sections, and also consider combined morphological types .
6. it is possible that the paradoxical curvature and the middle nasal concha bifidus, the latter being documented for the first time in the present thesis, to be only the remains in the adult of a primitive morphology of the middle concha. Bifidity and the paradoxical curvature of the middle concha can be considered persistent pediatric morphological types.
7. Sphenoethmoidal sinuses invade the ethmoidal anatomical sites and alter the sagittal length of the lateral nasal wall. That is why the sagittal pneumatization of the sphenoid sinus should not be classified only in relation to the sella turcica, but also in relation to the sphenopalatine pillar.
8. Agenesis and hypogenesis of the superior nasal concha are extremely rare anatomical variations which should, however, be anticipated and identified in order to establish an individualized treatment scheme. Apparently any of the nasal conchae may be absent, such an anatomical situation requiring an individualized endoscopic approach.

9. Although superior nasal conchae are known as components of the ethmoid bone, their insertions into the lateral nasal wall can be extended to adjacent non-ethmoidal structures resulting after secondary pneumatization, the maxillary and sphenoid sinuses.
10. In the agenesis and hypogenesis of the superior nasal concha, the cause may lie in an anomaly in the development of the third ethmoturbinal. Such a case has never been described before.
11. The pneumatization of all nasal conchae is a rare anatomical variation which sums up the individual possibilities of turbinal pneumatization. Concha bullosa can be properly assed via CT and CBCT, in all the three planes and through tridimensional reconstruction/rendering.