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Evaluation of some important anatomical variations and dangerous areas of the paranasal sinuses by CT for safer endonasal surgery*

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SUMMARY *The purpose of this study is to determine some important variations and dangerous areas carrying risks for major complications, in the routine CT examination. We also made specific measurements to evaluate the individual differences. This prospective study consisted of 111 patients (222 sides). Eighty patients underwent coronal, and the rest coronal and axial CT. The depth of lamina cribrosa, its distance to the inferior turbinate, and the distance of anterior ethmoidal artery (AEA) either to the orbital roof or inferior turbinate were measured. Variations of the upper attachment of uncinate process were encountered in 23%. AEA coursed freely within ethmoidal cells in 43%. Anterior clinoid aeration was seen in 14%, optic canal bulging into the sphenoid sinus in 13% and an extreme medial course of the carotid canal in 12% of the patients. The mean depth of lamina cribrosa was 5.9 mm, and its mean distance to the inferior turbinate was 25.7 mm. The mean distance of AEA to the orbital roof was 13.7 mm, and to the inferior turbinate 30.05 mm. Anterior clinoid aeration correlated well with the variations of carotid and optic canals, statistically ($p < 0.01$).*
A detailed CT study will provide important information on the areas carrying risks of complications and the size of the area to be worked on.

Keywords: Paranasal sinus, CT, endonasal surgery, complication, anatomical variations

INTRODUCTION

The paranasal sinuses are neighbours of the very important anatomical structures such as orbita and its contents, optic nerves, the anterior skull base and the carotid artery, which are under considerable risk during functional endoscopic sinus surgery (FESS) (Buus et al., 1990; Maniglia, 1989). Orbito-ocular complications can occur during FESS for many reasons. The damage of *lamina papyracea* or laceration of anterior ethmoidal artery (AEA) can lead to serious complications, such as herniation of the orbital contents or bleeding from AEA. The optic nerves and veins can be injured by direct or indirect trauma (Buus et al., 1990; Maniglia, 1989; Rauchfuss, 1990; Rudert et al., 1997; Stankiewycz, 1987). Direct penetrating trauma to dura, intradural meningeal veins, anterior cerebral artery and AEA via *fossa olfactoria* may result into serious intracerebral complications (Kainz et al., 1988; Maniglia, 1989, Rauchfuss, 1990; Rudert et al., 1997), while operating sphenoid sinus, fatal bleeding from the carotid artery may occur or the optic nerve may be damaged (Buus et al., 1990; Rauchfuss, 1990).

Complete knowledge of anatomy in the region of interest and appropriate surgical technique may keep the surgeon away from these complications during FESS. The surgeon should be aware of the variations which enable the complications to occur easily, as well as crucial dangerous points while operating. The anatomical variations and the dangerous points in the paranasal sinuses have been well documented by cadaver studies (Kainz et al, 1988; Krmpotic-Nemanic et al., 1993; Lang, 1988; Messerklinger, 1982, 1987; Rontal and Rontal, 1991). The studies concerning the anatomical variations, dangerous points, and special landmarks by means of computed tomography (CT) are rare (Bansberg et al., 1987; Simmen and Schuknecht, 1997). The aim of this study is to include some important variations, guiding anatomical structures and dangerous areas in the routine evaluation of the preoperative CT examination and to find some evidence that can help the surgeon to avoid the major complications of FESS. By using specific measurements we also intended to evaluate the individual differences.

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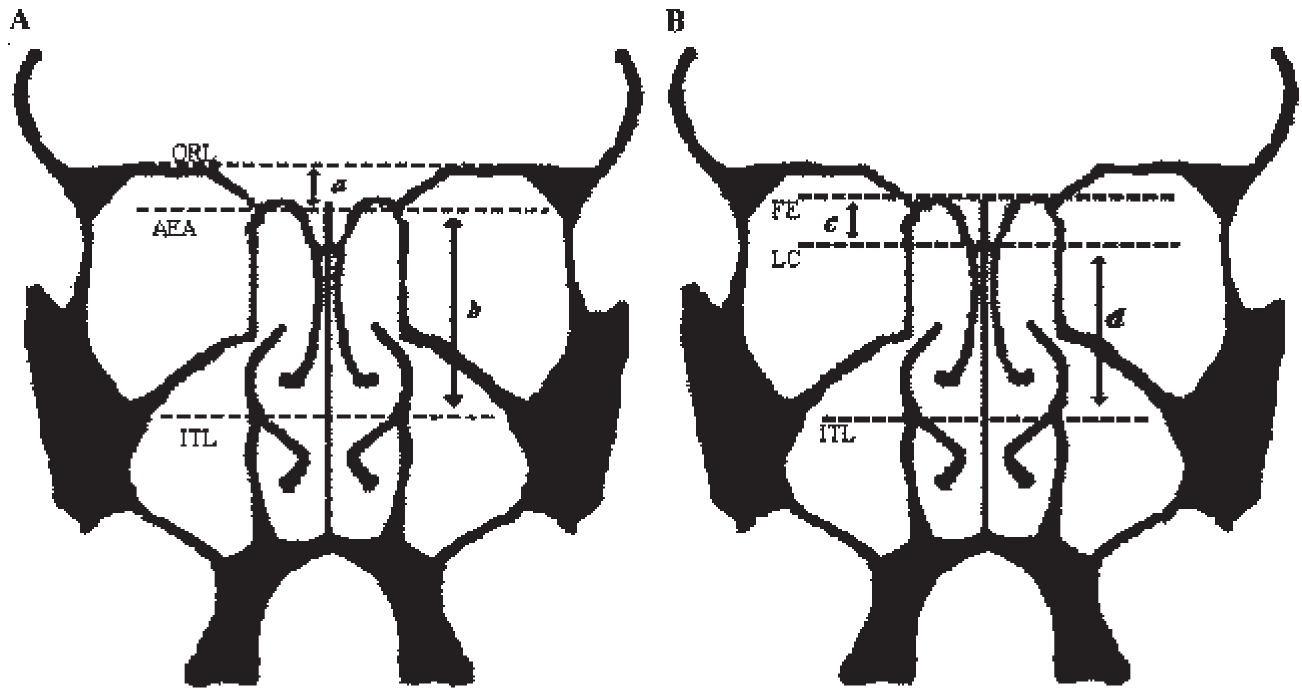

Figure 1A: Specific measurements for anterior ethmoidal artery (AEA); the distance of the artery to the orbital roof (ORL=orbital roof line; shown as "a"), and to the attachment point of the inferior turbinate (ITL=inferior turbinate line; shown as "b") was measured.
Figure 1B: Specific measurements for *lamina cribrosa* (LC); the depth of *lamina cribrosa* was measured as the length of lateral lamella (FE=*fovea ethmoidalis;* shown as "c"). The distance of *lamina cribrosa* to the attachment point of the inferior turbinate, shown as "d", was also measured.

MATERIAL AND METHOD

One hundred and eleven patients (67 men, 44 women; age range: 15-85 years; mean age: 41 years) were included in this study who were examined by CT, prospectively. CT examinations with high resolution parameters were performed in the coronal plane only, in 80 patients, and in both coronal and axial planes in 31 subjects. The coronal sections were taken perpendicular to the orbito-meatal line, while axial sections were parallel to the same line. In the coronal study the slice thickness was 5 mm with table index of 4 mm, but thinner slices (slice thickness: 3 mm, table index: 3 mm) were obtained in the ostio-meatal region. In the axial study, 3 mm thick slices were taken in every 3 mm, from the bottom of the maxillary sinus up to the roof of the frontal sinus. In all studies no intravenous contrast material was used.

The variations of upper attachment of *processus uncinatus* (PU), the course of anterior ethmoidal artery, the depth of *lamina cribrosa*, Onodi cell, the extreme medial course of the carotid canal and bulging of the optic canal into the sphenoid sinus, the presence of dangerous sphenoid septum, the degree of pneumatisation of the sphenoid sinus and aeration of the anterior clinoids were noted during the assessment of the CT images.

Dangerous sphenoid septum was evaluated in all 111 patients (right and left, 222 sides in total), but Onodi cell was examined in 31 patients only, in both axial and coronal planes (62 sides).

The qualitative parameters were grouped as "present", "absent" or "undetermined". The CT examinations were classified as "undetermined" when presence or absence of the variation was unclear, as a result of previous surgery or widespread poliposis. The sphenoid sinus was classified as "overpneumatised" in the case of sphenoid sinus aeration extending to the greater wing of the sphenoid bone, and "hypoaerated" when the aerated sinus occupied 20% less than the expected, or otherwise "normal". In the existence *lamina papyracea* of variation of PU, the discrepancies were classified separately according to their attachment to, or skull base (*fovea ethmoidalis* or lateral lamella), or lateral surface of the middle turbinate.

The height of the lateral lamella was measured to assess the depth of *lamina cribrosa*. The distance of AEA at the point leaving the orbit to the upper border of the orbital roof was also calculated. Finally, the distance of *lamina cribrosa* and AEA to the attachment point of the osseous lamella of the inferior turbinate to the medial wall of the maxillary sinus were recorded (Figure lA, B).

The correlation between the variations of the carotid or optic canals and anterior clinoid or sphenoid sinus aeration was analysed statistically. Also, correlation between Onodi cell and degree of the sphenoid sinus aeration was assessed statistically. Pearson's correlation coefficient test was used for statistical analysis, where p value was accepted as 0.001.

RESULTS

The upper attachment of PU was identified in 179 sides (81%), the remainder 43 sides (19%) were in the "undetermined" group (Table 1). Variation of PU was detected in 59 sides (27%). Most of them were attached to *lamina papyracea* (54%), 20 to the lateral surface of middle turbinate (34%), and in 7 to the skull base (7%) (Figure 2). The course of AEA was identified in 82% of all sides. Abnormal course of the optic canal was encounter-

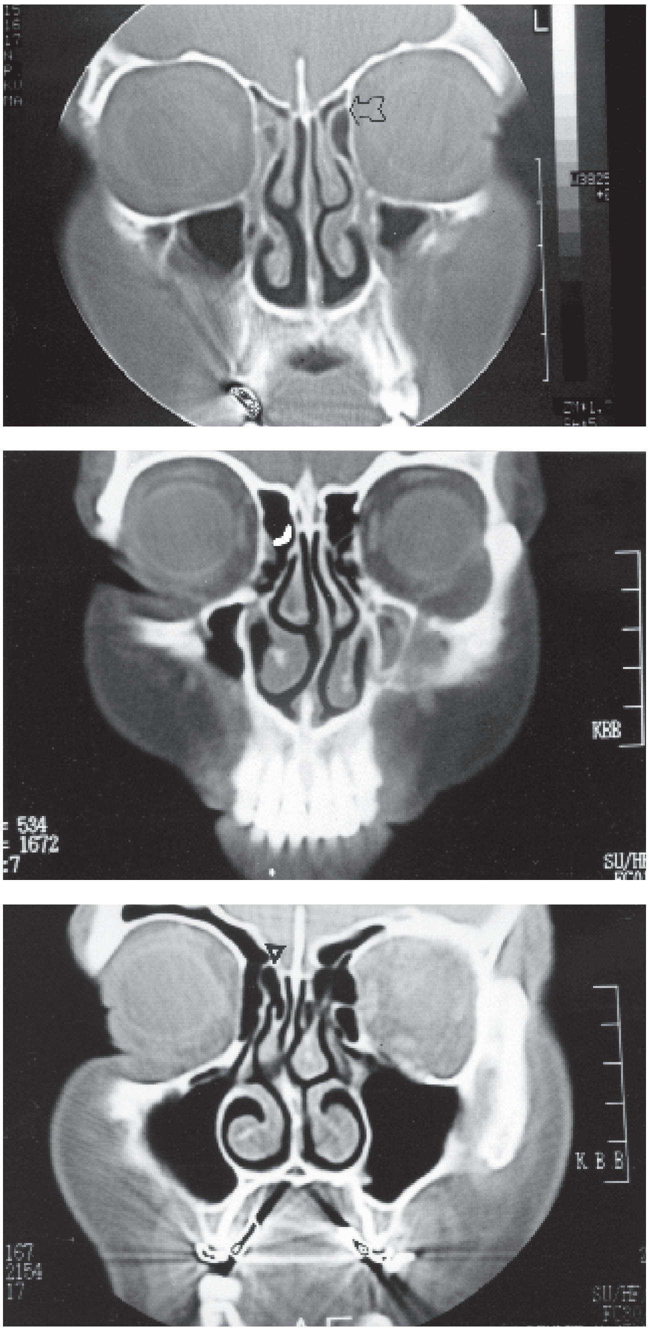

Figure 2: The upper tip PU is attached to (a) *lamina papyracea* (black arrow), (b) lateral surface of middle turbinate (white arrowhead), and (c) anterior skull base (black arrowhead).

ed in 13% (Fig. 3 and 4), abnormal course of carotid artery in 12% of all sides (Figure 5). The percentage of anterior clinoid pneumatisation was 14% Dangerous sphenoid septum was encountered in 3% of the 111 patients (Figure 5). Onodi cell was seen in 43% of the 62 sides (Table 1).

The mean depth of *lamina cribrosa* was 59 millimetres The mean distance between *lamina cribrosa* and inferior turbinate was 25.7 mm (Table 2). Table 3 is summarising the number and percentages of the depth of *lamina cribrosa* according to Keros classification.

Free course of AEA was seen in 78 (43%) sides and course in the anterior skull base in 104 (57%) sides Figure 6). The mean

Table 1: Important variations, guiding anatomical structures and dangerous areas evaluated by CT.

	Present		Absent		Undetermined	
	Number	%	Number	%	Number	%
Variation of the upper tip of PU	59/222	27	120/222	54	43/222	19
The course of AEA*	162/222	82	33/222	15	7/222	3
Bulging of the optic canal	28/222	13	194/222	87		
Extreme medial course of the carotid canal	26/222	12	196/222	88		
Anterior clinoid pneumatisation	31/222	14	191/222	86		
Dangerous sphenoid septum	9/222	8	102/111	2		
Onodi cell**	27/62	43	35/62	57		

*AEA: anterior ethmoidal artery
**Onodi cell was evaluated only in axial scans.

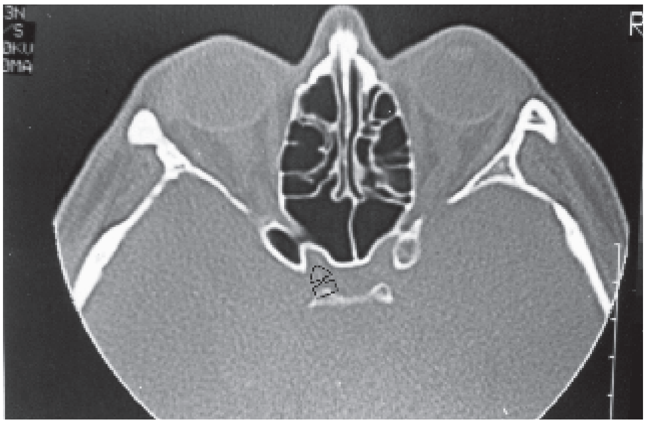

Figure 3: The axial CT image clearly delineated the bulging of the optic canal into the sphenoid sinus (arrow), and anterior clinoid aeratrion on the left side.

Figure 4: Coronal CT section revealed: anterior clinoid pneumatisation and the free course of optic canal in sphenoid sinus (black arrowhead) bilaterally.

distance of AEA to the orbital roof was 13.7 mm, and to the inferior turbinate 30.05 mm (Table 4). There was no correlation between the degree of sphenoid sinus aeration and the extreme medial course of the carotid artery and, the bulging of the optic

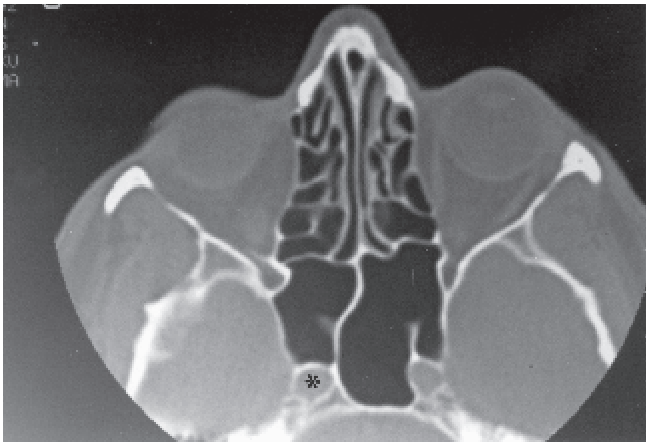

Figure 5: In axial CT image, the right and left carotid artery protrude into the sphenoid sinus (asterix). Note the sphenoid septum is dangerously attached to carotid canal on the left side.

Table 2: The specific measurements of *lamina cribrosa.*

	Minimum (mm)	Maximum (mm)	Mean (mm±SD)
Height of lateral lamella	1	11	5.995±2.310
Lamina cibrosa-inferior turbinate distance	18	34	25.768±3.283

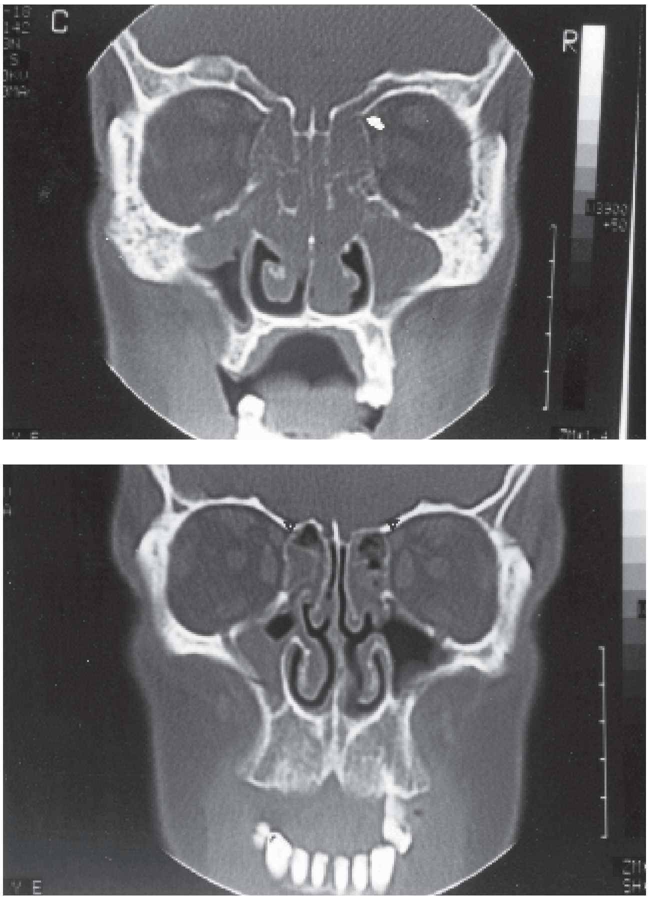

Figure 6: AEA is coursing (a) freely between the infected ethmoidal cells (white arrowhead), and (b) in the anterior skull base(black arrowhead).

Table 3: The distribution of measurements of the depth of *lamina cibrosa* according to Keros classification.

	Number	%
Type I (1-3 mm)	31/222	14
Type II (4-7 mm)	129/222	58
Type III (8-16 mm)	62/222	28

Table 4: The specific measurements for anterior ethmoidal artery (AEA).

	Minimum (mm)	Maximum (mm)	Mean (mm±SD)
AEA to orbital roof	7	29	13.705±2.274
AEA to inferior turbinate	22	40	30.055±3.608

canal or Onodi cell. However, there was significant correlation between the abnormal course of the carotid canal and pneumatisation of the anterior clinoids, statistically at $R = 0.7899$, $p = 0.001$) Abnormally coursing optic canal showed significant correlation with aerated anterior clinoids $R = 0.5913$, $p = 0.001$).

DISCUSSION

Paranasal sinus CT is the best method to evaluate the existence and extension of the sinus pathologies. The anatomical variations and their role in the aetiology of sinusitis have been considered many times, just as those examined by CT (Appil et al, 1993; Bolger et al., 1991; Brunner et al., 1996; Havas et al., 1988, Güney et al., 1995; Lloyd et al., 1991; Lusk et al., 1996; Schatz and Becker, 1984; Som, 1985; Tonai and Shunkychy, 1996; Weber et al., 1991, Zinreich et al., 1987). Other than assessing the anatomical variations and the spread of the disease, paying attention to understand and re-evaluate some guiding points and dangerous areas may be profitable in preventing complications. To our knowledge, there are few studies concerning the preoperative CT where this issue is taken into serious consideration in the literature (Bansberg et al., 1987; Simmen and Schuknecht, 1997).

The upper tip of the PU normally ends by meeting the lateral nasal wall around the base of *agger nasi* (Riche and Schaefer, 1993; Stammberger, 1991). The PU variations have mostly been examined in the context of medialisation, lateralisation, or pneumatisation (Bolger et al., 1991; Lloyed et al., 1991; Lusk et al., 1996; Messerklinger, 1987; Zinreich et al., 1987). However, attachment of PU to *lamina papyracea,* lateral surface of middle turbinate or anterior skull base are the variations leading to serious complications (Mafee, 1993; Ömerci, 1996; Rice and Schaefer, 1993; Simmen and Schuknecht, 1997). The coarse manipulation of PU may cause fracture in the attachment areas in either condition (Mafee, 1993; Simmen and Schuknecht, 1997). In this study 27% of the CT examinations revealed one of the those variations mentioned above. In the presence of such variations, avoiding hard manipulations during unsinectomy, cutting the upper tip of the uncinate instead of plucking may keep away the surgeon from those complications.

The AEA enters the nasal cavity via anterior ethmoidal foramen and courses in *canalis ethmoidalis anterior.* Anterior ethmoidal artery may course adjacent to anterior skull base or freely between the ethmoid cells. Posterior to *crista galli* and lateral to *lamina cribrosa*, AEA enters the skull and after a short distance it branches back through the nasal cavity (Kainz and Stammberger, 1988; Rontal and Rontal, 1991; Simmen and Schuknecht, 1997). The anterior ethmoidal artery can be localised by CT, and its course can be estimated. A "V" shaped notch can be seen in the area where AEA comes out through the *lamina papyracea* which suits the fronto-ethmoidal sulcus .The exit of AEA is about the anterior ethmoids, and usually above *bulla ethmoidalis.* Maxillary sinus ostium is situated just inferior to the artery (Bansberg et al., 1987; Simmen and Schuknecht, 1997). We have defined the course of AEA in 82% of the CT's. In 43% of these occurrences the AEA was coursing freely inside the ethmoid cells. The risk of coming face to face with AEA and to damage the artery during FESS is higher in these patients. Cadaver studies have already shown that the artery is about 5 mm away from the skull base (Kainz and Stammberger, 1988). In our study we intended to search individual differences by means of specific measurements. We accepted the roof of the orbita as a rather constant point and measured AEA's distance to the upper most point of it. We have found a difference of 22 mm between the lowest and the highest values. These results are showing the individual variations in the course of the AEA, objectively.

Another dangerous area is *lamina cribrosa* and its lateral lamella at the upper medial region during FESS, where complications usually occur (Kainz and Stammberger, 1988; Stammberger, 1991). The deeper the *lamina cribrosa*, the thinner the lateral lamella (Kainz and Stammberger, 1988). In cases where the lateral lame lla is long and obviously thin, the possibility of intracranial complications is higher. We determined the depth of *lamina cribrosa* by measuring the length of lateral lamella. Taking into consideration the Keros classification 58% of CT's were included in type II and the 28% fell within category III.

The upper lateral border of FESS is determined by AEA and the upper medial border by the *lamina papyracea.* The inferior border is the attachment point of the inferior turbinate to the medial wall of the maxillary sinus (Rontal and Rontal, 1991). The measurements between the attachment point of the inferior turtinate and the AEA and the *lamina cribrosa* can show us the dimensions of the area that is going to be worked on. The distances between the attachment point of the inferior turbinate to the AEA, and to the *lamina cribrosa* varied from 22 to 40 mm and from 18 to 34 mm respectively There are important personal differences between the lowest and the highest values. Keeping in mind that the width of the fully opened straight ethmoid forceps is 10 mm, we think that; before the operation, every surgeon should be aware of the limits of the space to be worked on.

The definition of the Onodi cell was used by Rice and Schaefer (19930 and Lang (1988) for the posterior ethmoid cell which is in contact with the optic nerve medially, superiorly and inferiorly. Lang (1988) has given the percentage of the Onodi cell as 11.7%. Wigand (1989) has used the definition of Onodi cell for all the posterior ethmoid cells that are neighbouring the optic nerve. However, according to Lang (1988) the percentage given for the optic nerve to freely course inside the Onodi cell is 10% (Wigand et al., 1989). Some authors define the contact of the optic nerve and the lateral wall of the posterior ethmoid cell as Onodi cell in the axial CT scans (Bansberg et al., 1987; Mafee, 1993; Simmen and Schuknecht, 1997). Bansberg (1987) has found out that the percentage of Onodi cell was 48 in his CT study, relying on this definition. We think that the differences between the rates noted in the CT studies and the cadaver studies are due to the differences in definitions of the Onodi cell. We have found the Onodi cell to be 43%. As the differentiation of Onodi cell in a coronal plan is impossible, it is necessary to take CT scans both in coronal and axial planes for patients undergoing FESS (Hudings, 1993; Krmpotic-Nemanic et al., 1993; Mafee, 1993; Rudert et al., 1997; Simmen and Schuknecht, 1997). It is thought that, the lesser sphenoid sinus pneumatisation, the larger the posterior ethmoid cell expansion and the Onodi cell is seen more (Bansberg et al., 1987; Buus et al., 1990). However, we could not find any correlation between Onodi cell and the sphenoid sinus pneumatisation degrees.

The relationship of the sphenoid sinus with the optic and the carotid canal is very important in terms of complications. The optic canal in between the two roots of the lesser wing of the sphenoid bone. The length of the canal is 4-12 mm (Bansberg et al., 1987). The carotid artery is close to the posteior lateral wall of the sinus. These structures, which are existent before the sinus development, may protrude into the sinus wall in different degrees as the cavity develops or they may course freely in the sinus (Bansberg et al., 1987; Mafee, 1993: Rudert et al., 1997). The protrusion of the carotid artery and the optic nerve seen in the coronal CT scans, may be defined as a deep *recessus optico-caroticus* at the level of the tuberculum sella (Rudert et al., 1997). It has been noted in cadaver studies that in the well pneumatised cavities, the sphenoid sinus is separated from the adjoined structures by a very thin bony lamella, and in the case of extensive pneumatisation, the protrusion of these structures into the sinus increases (Krmpotic-Nemanic et al., 1993; Lang 1988). However, we could not find any correlation between the extreme medial course of the carotid canal or bulging of the optic canal into the sphenoid sinus and the sphenoid sinus pneumatisation degrees, statistically. Adversely we have found a strong correlation between the anterior clinoid pneumatisation and the abnormal course of the optic canal and the carotid artery. Bansberg et al. (1987) could not find any relationship between the optic canal and the sphenoid sinus pneumatisation, explaining that the larger the degree of pneumatisation, the higher the course of the optic nerve courses. We found out in our study that a similar relationship between the anterior clinoid pneumatisation and extreme medial course of the carotid canal and bulging of the optic canal into the sphenoid sinus, we found out in our study, could be explained by means of an inverse mechanism. In other words, the existence of anterior clinoid pneumatisation may limit the superior course of the optic nerve. The same suggestion may be valid for the carotid artery. The existence of anterior clinoid pneumatisation carries risks for complications, which has to be taken into account. During surgery, manipulation of the intrasphenoidal septum attached to the bony canal of the carotid artery or to the optic nerve may lead to serious complications such blindness or bleeding (Mafee, 1993; Simmen and Schuknecht, 1997). We encountered dangerous sphenoid sinus septum in 8% of the CT scans. We could not make a certain numerical evaluation on the bone dehiscence due to the limitations of CT. While evaluating the *lamina papyracea*, the skull base and the sphenoid sinus, attention to the existence of bone dehiscence will keep the surgeon away from serious complications.

A detailed pre-operative CT study will provide the surgeon with important information on the areas possibly carrying the risk of complications and the size of the area to be worked on. In order to understand the abnormal course of the optic canal and the carotid artery and to recognise the Onodi cell the performance of CT studies on two planes will be very helpful. In conclusion, the course of AEA, optic and carotid canal, as well as the possible existence of anterior clinoid pneumatisation, Onodi cell, dangerous sphenoid septum, bone dehiscence and variations of the upper tip of PU should be taken under consideration in routine, while evaluating CT before FESS.

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