ORIGINAL RESEARCH

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Presence and types of anterior clinoid process pneumatization, evaluated by Multidetector Computerized Tomography

Abstract

Purpose: The types and ratio of anterior clinoid process (ACP) pneumatization in paranasal sinus Multidetector Computerized Tomography (MDCT) were investigated the importance of ACP in neurosurgical approaches discussed.

Methods: Paranasal MDCT images of 499 subjects (259 male, 240 female), between 17 and 65 years of age, were included in the study. Presence and types of pneumatization of the ACP and pneumatization types (I, II or III) were evaluated.

Results: ACP pneumatization was detected in 37.5% of the males and 33.3% of the females. Right, left and bilateral ACP pneumatizations were detected in 12.7%, 9.3% and 15.4% of males and 9.2%, 8.3% and 15.8% of the females, respectively. The most commonly detected types of pneumatization were Type I (49.1%) for right pneumatizations and Type II pneumatization for left (40.9%) and bilateral (37.2%) pneumatizations. In males, Type I (37.1%) and in females, Type II (40.0%) pneumatizations were detected more frequently. Type III pneumatization was detected in 29.9% of the males and 22.5% of the females. ACP pneumatization ratios were higher in younger subjects and lower in older subjects.

Conclusion: Sclerosis process related to aging may be responsible for the lower pneumatization ratios in older subjects. When Type III ACP pneumatization is present, clinoidectomy should not be performed: in this type of ACP pneumatization, cerebrospinal fluid fistula develops in all cases.

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Certain parts of the sphenoid bone are connected by ligaments, including the pterygospinous (between the spine and the upper part of the lateral pterygoid plate), the interclinoid (joining the anterior and posterior clinoid process) and the caroticoclinoid (connecting the anterior and middle clinoid process), and these ligaments occasionally ossify [1].

The anterior clinoid process (ACP) is a posterior and medial continuation of the lesser sphenoid wing [2-5] and is connected to the body of the sphenoid bone (basisphenoid bone) by superior and inferior roots [4,5]. The superior root is flat, forms the roof of the optic canal, and continues as the planum sphenoidale. The inferior root (optic strut) forms the lateral and ventral walls of the optic canal and connects the lesser sphenoid wing with the basisphenoid bone [1].

Pneumatization of the ACP involves extending a paranasal sinus, such as the sphenoid or ethmoid sinus, into the ACP through the optic strut (OS) or anterior root (AR). Tearing these paranasal sinuses can cause pneumocephalus or liquorrhea [6-10]. In this study, we investigated the types and ratio of ACP pneumatization and discussed the importance of it to neurosurgical approaches.

Materials and Methods

This retrospective study was conducted in December 2015 in Kirikkale University Faculty of Medicine according to the principles of the Declaration of Helsinki. Computerized Tomography (CT) images were obtained from the archives of Kirikkale University Faculty of Medicine Radiodiagnostic Department. The study was sanctioned by the the Local Ethics Committee of Kirikkale University Faculty of Medicine (17 November 2015, No: 2015-25-03).

Subjects

Paranasal CT images of 499 subjects (259 male, 240 female), between 17 and 65 years of age, selected from a digital radiology database of all cranial CT in Kirikkale University Faculty of Medicine Radiodiagnostic Department, were included in this study. An effort was made to balance the numbers of male and female subjects and to balance the age profiles of the male and female groups. Age of the males was 35.3 (mean) $\pm$ 13.34 years (ranged from 18.0 to 65.0 years) and age of the females was 34.5 (mean) $\pm$ 12.9 years (ranged from 17.0 to 65.0 years).

Inclusion criteria were as follows: subjects $\geq$ 17 years old and with no chronic diseases. Exclusion criteria were as follows: subjects with cranio-facial fractures; endocrinological

problems; osseous pathologies; previous trauma or surgery history; cranial tumor; pituitary tumor; sinonasal tumor; sinonasal polyposis; CSF leak; or marked facial deformity.

Clinical indications for the CT examinations were headache, sinusitis (except the CTs showing complete obstruction of at least one of the paranasal sinuses) and nasal congestion. This clinical information was present in the original referrals. The subjects were included in the study according to this information. None of the CT examinations was excluded from the study after the study started.

Technical Considerations of Multidetector Computerized Tomography (MDCT)

All of the scans were obtained with routine paranasal CT imaging in the supine position, and no contrast or sedation was used for the procedures. The images were acquired using a 64-slice CT (MSCT; Brilliance 64, Philips Medical System, Best, The Netherlands). All of the scans were obtained using the following parameters: tube voltage = 120 kV; effective mAs = 350; slice thickness = 1.00 mm; field of view = 180 mm; and, image matrix = 768 x 768. The images were transferred to a commercially available workstation, and the raw data was reconstructed using bone algorithms. After scanning, the coronal, axial and sagittal images were reconstructed with a slice thickness of 1.00 mm.

The following image analyses were performed: pneumatization of ACP, evaluated as absent or present (right, left, bilateral); and, type of ACP pneumatization, Type I, Type II or Type III [11]. The definitions of ACP pneumatizations were as follows: Type I, in which less than 50% of the ACP was pneumatized; Type II, in which more than 50% but less than 100% of the ACP was pneumatized; and, Type III, in which the ACP was totally pneumatized [11].

Statistical Analyses

SPSS for Windows 16.0 (SPSS, INC, an IBM Company, Chicago, Illinois) was used for statistical analyses. Chi-square test and Spearman's correlation Rho efficient test were used. ACP pneumatization (absent and present; right, left and bilateral) in males and females, types of the ACP pneumatization (Type I, Type II and Type III) according to the sides (right, left and bilateral), types of the ACP pneumatization (Type I, Type II and Type III) in males and females were analyzed by Chi-square test. The relationship among age, gender (males /females) and the presence of ACP pneumatization (present/absent) was analyzed by Spearman's

correlation Rho efficient test and p value < 0.05 was considered as statistically significant.

Results

Both coronal and axial paranasal sinus CT slides were evaluated (Figure 3A-B). ACP in males and females are presented in Table 1. In males, ACP pneumatization was detected in 37.5% of the subjects and in females it was detected in 33.3% of the subjects. Right, left and bilateral ACP

pneumatization were detected in 12.7%, 9.3% and 15.4% of males and 9.2%, 8.3% and 15.8% of the females, respectively ($p=0.592$ $X^2: 1.907$) (Table 1).

Types of ACP pneumatization, according to the sides, are shown in Table 2. The most commonly detected types of pneumatization were Type I (49.1%) for right pneumatizations and Type II pneumatization for left (40.9%) and bilateral (37.2%) pneumatizations ($P=0.278$ $X^2=5.096$) (Table 2).

TABLE 1. Anterior clinoid process pneumatization in males and females

Anterior clinoid process pneumatization		Males (n=259)		Females (n=240)		P*
		n	%	n	%	
Absent		162	62.5	160	66.7	P=0.592 X2: 1.907
Present	Right	33	12.7	22	9.2	
	Left	24	9.3	20	8.3	
	Bilateral	40	15.4	38	15.8	
Total		259	100.0	240	100.0	

*p value shows the results of Chi-square test

TABLE 2. Types of the anterior clinoid process pneumatization according to the sides

	Type I		Type II		Type III		Total		P*
	n	%	n	%	n	%	n	%	
Right (n=55)	27	49.1	17	30.9	11	20.0	55	100.0	P=0.278 X2=5.096
Left (n=44)	13	29.5	18	40.9	13	29.5	44	100.0	
Bilateral (n=78)	26	33.3	29	37.2	23	29.5	78	100.0	
Total	66	37.3	64	36.2	47	26.6	177	100.0	

*p value shows the results of Chi-square test

TABLE 3. Types of the anterior clinoid process pneumatization in males and females

Anterior clinoid process pneumatization		Males (n=97)		Females (n=80)		P*
		n	%	n	%	
Present	Type I	36	37.1	30	37.5	P=0.472 X2=1.501
	Type II	32	33.0	32	40.0	
	Type III	29	29.9	18	22.5	
Total		97	100.0	80	100.0	

*p value shows the results of Chi-square test

FIGURE 1. ACP pneumatization, Type I (white arrow) on the right and Type III (black arrow) on the left side detected by coronal paranasal MDCT

Types of ACP pneumatization in both males and females are shown on Table 3. In males, Type I (37.1%) and in females, Type II (40.0%) pneumatizations were most commonly detected. Type III pneumatization was detected in 29.9% of the males and 22.5% of the females ($P=0.472$ $X^2=1.501$) (Table 3).

Spearman correlation Rho efficient test results showed that in younger subjects, pneumatization of ACP was higher than older subjects ($p=0.000$, $r=-0.225$). There was no significant correlation between gender and presence of ACP pneumatization ($p=0.338$, $r=-0.043$).

Discussion

In the present study, ACP pneumatization was detected in 37.5% of the males and 33.3% of the females. Right, left and bilateral ACP pneumatizations were detected in 12.7%, 9.3% and 15.4% of males; and 9.2%, 8.3% and 15.8% of the females, respectively. The most commonly detected types of pneumatization were Type I (49.1%) for right pneumatizations and Type II for left (40.9%) and bilateral (37.2%) pneumatizations. In males, Type I (37.1%) and in

FIGURE 2. ACP pneumatization, Type III (white arrow) on the right and Type II (black arrow) on the left side detected by coronal paranasal MDCT

females, Type II (40.0%) pneumatizations were most commonly detected.

In the paper by Mikami *et al.*, pneumatization of the ACP was found in 55 sides (9.2%) of 600 sides in 300 consecutive patients [9]. Pneumatized patterns were divided into three groups according to the route: pneumatization occurred via the optic strut (OS) in 41 sides (74.5%), via the AR in eight sides (14.8%) and via OS and AR in six sides (10.9%). In our study, ACP pneumatization ratios were higher than Mikami's study. We evaluated both coronal and axial paranasal sinus CT slides: ACP pneumatization can more easily be detected in coronal CT sections in comparison with axial sections. The difference in ACP rates between Mikami's study and our study may be related to the genetic differences in subject populations or to environmental exposures to different agents; however, these issues should be investigated in further studies.

In the study by Sirikci *et al.*, pneumatization of the ACP was encountered in 27 (29.3%) patients [12]: on the right side in six (6.5%), on the left in eight (8.7%) and bilateral in 13 (14.1%). Aerated ACP was reported in 6-24% of cases in several imaging studies, occurring bilaterally in over 50% of these cases [9,11,13-15]. In our study, the bilateral ACP pneumatization ratio was found to be lower.

In the present study, pneumatization of ACP was higher in younger subjects and lower in older subjects. Sclerosis

FIGURE 3. A) ACP pneumatization, Type I on the right (white arrow) and Type III (black arrow) on the left side detected by coronal paranasal MDCT; B) axial paranasal MDCT view of the same patient, Type I (white arrow) on the right side and Type III on the left side (black arrow). The pneumatization of the ACP has been shown more clearly on the coronal section compared with the axial section.

process related to the aging may be responsible for the lower pneumatization ratios in older subjects. In future studies, the possible effect of chronic mucosal inflammation and age-related sclerotic changes should be investigated.

Complete or partial removal of the ACP is an important step in the superior approach to the cavernous sinus, management of carotid-ophthalmic, giant internal carotid artery and paraclinoid aneurysms [16-22]. In middle cranial fossa surgery, ACP was drilled and, therefore, better exposure was obtained in the surgical area, especially in supraclinoid and paraclinoid segment aneurysms. Complications of anterior clinoidectomy include opening of paranasal sinuses and the risk of resultant rhinorrhea, impaired vision, oculomotor nerve palsy, damage to optic nerve and/or the internal carotid artery, ophthalmic artery injury, aneurysm rupture and pneumocephalus [11,16,23-26]. Complications following removal of pneumatized ACP include opening of the paranasal sinuses, the concomitant risk of rhinorrhea, and the consequent high risk of sepsis [27]. Performing anterior clinoidectomy causes potential complications owing to its deep location between the ICA and CN II and III. Injuries to CN II

and III can be caused by unexpected motion of the drill or by heat caused by insufficient irrigation [28].

In the present study, Type III pneumatization was detected in 29.9% of the males and 22.5% of the females. When ACP is pneumatized, there is relationship between ACP and sphenoid sinus. In this condition, fistula of the cerebrospinal fluid (CSF) may develop when clinoidectomy was performed. Type III ACP pneumatization is more dangerous in terms of fistula risk. When Type III ACP pneumatization is present, clinoidectomy should not be performed because, in this type of ACP pneumatization, CSF fistula developed in all cases. In these cases, high pterional approach should be used to operate the supraclinoid and paraclinoid aneurysms.

We recommend that paranasal CT slides be evaluated in detail during the preoperative period to detect any ACP pneumatization. Neurosurgeons should avoid performing anterior clinoidectomies in patients with Type III ACP pneumatization, to prevent CSF fistulas.

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