

Evaluation of posterior clinoid process pneumatization by multidetector computed tomography

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Abstract In the present study, we investigated the types and ratio of posterior clinoid process (PCP) pneumatization in paranasal sinus multidetector computed tomography (MDCT). Paranasal MDCT images of 541 subjects (227 males, 314 females), between 15 and 65 years old, were included into the study. Pneumatization of anterior clinoid process and pneumatization types (I, II, or III) were evaluated in the males and females. PCP pneumatization was detected in 20.7 % of the males and 11.5 % of the females. Right, left, and bilateral PCP pneumatizations were detected in 7.9, 5.7, and 7.0 % of the males and 2.9, 3.2, and 4.5 % of the females, respectively. PCP pneumatization of the males is significantly higher than the females. The most detected type of pneumatization was type I (61.2 %) for all groups. In right, left, and bilateral pneumatizations separately, type I pneumatization was the most detected pneumatization type with the ratio of the 70.4, 65.2, and 50.0 %, respectively. In males, type I (61.7 %), and similarly in females, type I (60.6 %) pneumatization were detected more. Type II and type III pneumatizations were

detected in decreasing order in both groups. In younger subjects, pneumatization of posterior clinoid process was found as higher, and in older subjects, PCP pneumatization was found as lower. Sclerosis process related to the aging may be responsible for the lower pneumatization ratios in older subjects. Structure of the surrounding regions of PCP is important for surgical procedures related to cavernous sinus, basilar apex aneurysms, and mass lesions. Preoperative radiological examinations are useful for operative planning. Any anomalies to PCP can cause unnecessary injury to the neurovascular complex structure around the cavernous sinus or postclinoidectomy CSF fistulas. Posterior clinoidectomies should be avoided in patients with type III PCP pneumatization to prevent CSF fistulas.

Keywords Posterior clinoid process (PCP) · Pneumatization · Multidetector computed tomography (MDCT) · Type I · Type II · Type III

Introduction

The anterior, middle, and posterior clinoid processes (PCPs) in the sphenoid bone contribute to the boundary of the sella turcica. The posterior boundary is formed by a square-shaped plate of bone called the dorsum sellae, the superolateral angles of which are raised to form the posterior clinoid processes [1, 2]. Variations in PCPs are important in intracranial neurosurgery. The PCP deepens the sella turcica and gives an attachment to the tentorium cerebelli. Therefore, any anomalies of the PCP may be responsible for the altered attachment of the tentorium cerebelli. Internal carotid artery, superior petrosal sinus, and oculomotor and trochlear nerves are critical structures

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which are located closely to the PCPs. To work in the upper basilar region, the posterior aspect of the pituitary fossa, the cavernous sinus, and the internal carotid artery, the anatomy of the clinoid processes should be known in detail [2].

The sphenoid body has a chondral origin. Ossification centers are the presphenoid (between the lesser wings) and the basisphenoid (between the greater wings) [3–5]. Ossification of the PCPs begins after about 4 years of age. The size of the dorsum sellae increases until puberty [2, 6–8].

In this study, we investigated the types and ratio of PCP pneumatization and discussed the importance of it in neurosurgical approaches. The definition of the PCP pneumatization is performed for the first time in the literature, and we made the classification similar to the classification of anterior clinoid process pneumatization reported by Abuzayed et al. [9].

Materials and methods

This retrospective study was conducted in December 2015 in Kırıkkale University, Faculty of Medicine, according to the principles of the Declaration of Helsinki. Computed tomography images were obtained from archive of the Kırıkkale University, Faculty of Medicine, Radiodiagnostic Department. Approval of the local ethics committee of the Kırıkkale University, Faculty of Medicine, was taken (date: November 17, 2015, no. 25/10)

Subjects

In this study, paranasal computed tomography (CT) images of 541 subjects (227 males, 314 females), between 15 and 65 years old, selected from a digital radiology database of all cranial CT in the Kırıkkale University, Faculty of Medicine, Radiodiagnostic Department, were included. The age of the males was 36.79 (mean) \pm 13.25 years (ranged from 15.0 to 65.0), and age of the females was 33.69 (mean) \pm 13.00 years (ranged from 15.0 to 65.0). Inclusion and exclusion criteria are shown in Table 1.

Technical considerations of multidetector computed tomography (MDCT)

All of the scans were obtained with routine paranasal computed tomography imaging in the supine position, with no contrast or sedation being 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 (FOV) = 180 mm, and image matrix = 768×768 . The images

Table 1 Inclusion and exclusion criteria

Inclusion criteria	The patients between ≥ 15 years old The patients who do not have any chronic diseases
Exclusion criteria	Subjects with craniofacial fractures Subjects with endocrinological problems Subjects with osseous pathologies Subjects with previous trauma or surgery history Cranial tumor Pituitary tumor Sinonasal tumor Sinonasal polyposis CSF leak Marked facial deformity were not included to the study

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:

1. Pneumatization of posterior clinoid process (PCP): It is evaluated as absent or present (right, left, bilateral).
2. Type of posterior clinoid process pneumatization: Type I, type II, or type III (Figs. 1, 2, 3, 4, and 5). The definition of PCP pneumatization is performed for the first time in the literature, and we made the classification similar to the classification of anterior clinoid process pneumatization reported by Abuzayed et al. [9]:

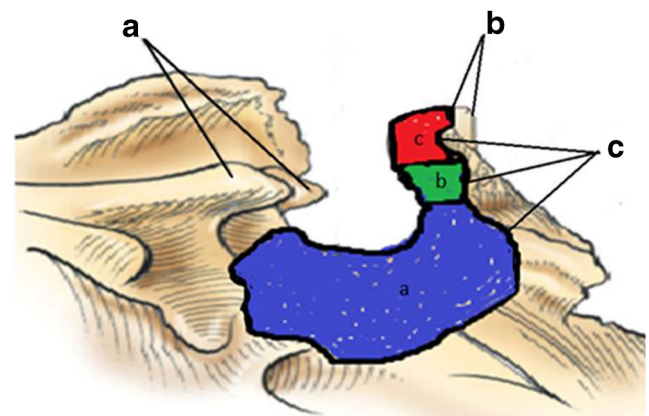


Fig. 1 Schematic view of posterior clinoid process pneumatization types. Anterior clinoid (A), posterior clinoid (B), posterior clinoid (C) pneumatization types: type I, a; type II, a + b; type III, a + b + c

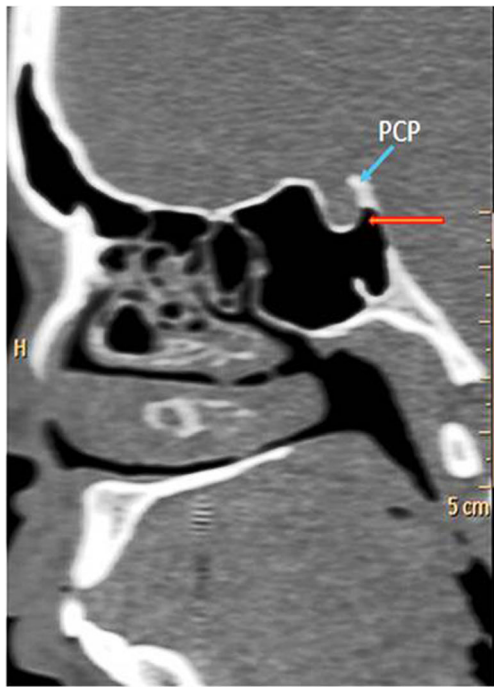


Fig. 2 Type I posterior clinoid process pneumatization (*red arrow*) and posterior clinoid process (PCP, *blue arrow*) are presented in sagittal paranasal computed tomography

- (a) Type I, in which less than 50 % of the PCP is pneumatized.

- (b) Type II, in which more than 50 % but not to totally pneumatized.
- (c) Type III, in which the PCP is totally pneumatized.

Measurements were performed in males and females.

Statistical analysis

SPSS for Windows 16.0 (SPSS Inc., an IBM Company, Chicago, IL). Chi-squared test and Spearman’s correlation rho efficient test were used.

p value <0.05 was considered as statistically significant.

Results

Posterior clinoid pneumatization (PCP) in males and females is presented in Table 1. In males, PCP pneumatization was detected in 20.7 % of the subjects, and in females, it was detected in 11.5 % of the subjects. Right, left, and bilateral ACP pneumatization were detected in 7.9, 5.7, and 7.0 % of males and 2.9, 3.2, and 4.5 % of the females, respectively (*p* < 0.05) (Table 2).

Types of the posterior clinoid process pneumatization according to the sides are shown in Table 2. The most detected type of pneumatization was type I (61.2 %) for all groups. In

Fig. 3 a Sagittal, b 3D sagittal, and c coronal paranasal computed tomography images show left type II posterior clinoid process pneumatization (*red arrow*) and posterior clinoid process (PCP, *blue arrow*)

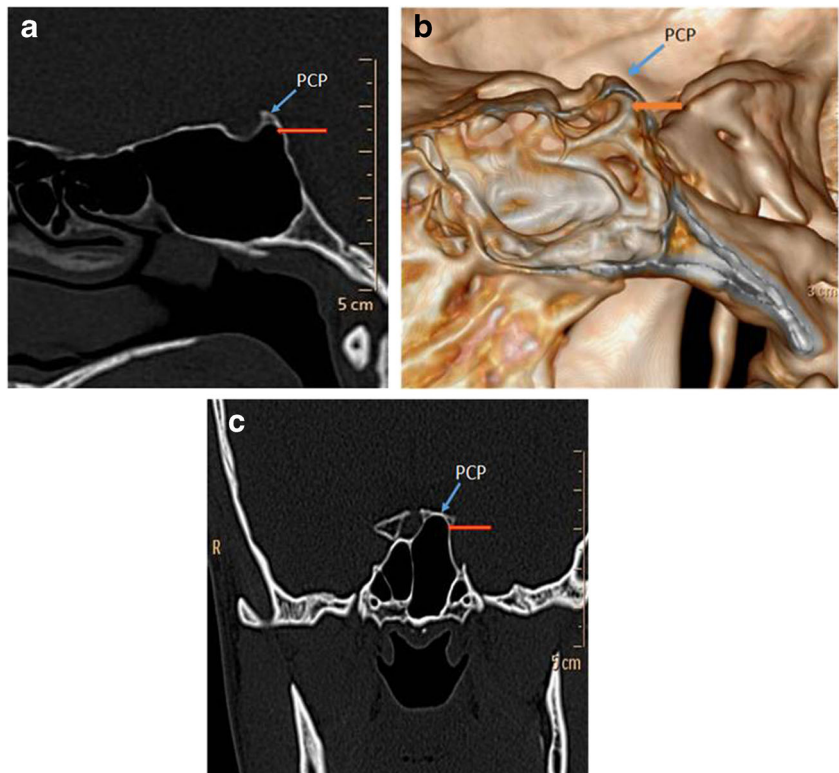
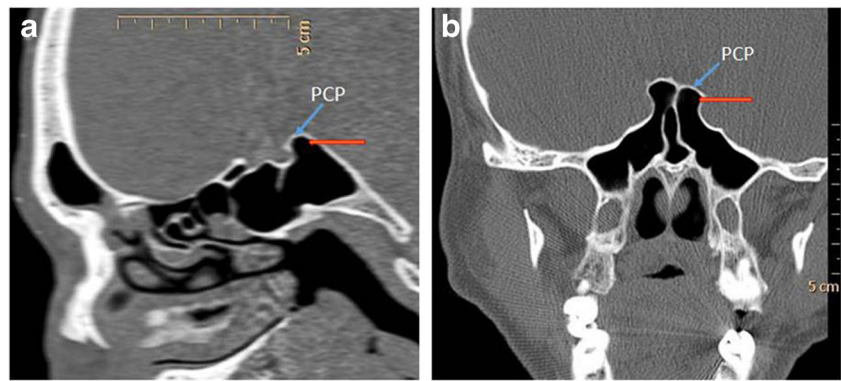


Fig. 4 **a** Sagittal and **b** coronal paranasal computed tomography images demonstrate bilateral type III posterior clinoid process pneumatization (red arrow) and posterior clinoid process (PCP, blue arrow)



right, left, and bilateral pneumatizations separately, type I pneumatization was the most detected pneumatization type with the ratio of the 70.4, 65.2, and 50.0 %, respectively. Type II pneumatizations were detected in the second order, and type III pneumatizations were detected in the third order ($p > 0.05$) (Table 3).

Types of the anterior clinoid process pneumatization in males and females are shown in Table 3. In males, type I (61.7 %), and in females, type I (60.6 %) pneumatizations were detected more. Type II and type III pneumatizations were detected in decreasing order in both groups ($p > 0.05$) (Table 4).

Spearman correlation rho efficient test results showed that in younger subjects, pneumatization of posterior clinoid process was found as higher, and in older subjects, PCP pneumatization was found as lower ($p = 0.036$, $r = -0.090$). In older subjects, the type of PCP pneumatization got lower and type I pneumatization was detected most ($p = 0.033$, $r = -0.092$).

PCP pneumatization was significantly higher in males compared to females ($p = 0.001$, $r = 0.137$).

Discussion

The degree of the pneumatization in the sphenoid sinuses may change from absent to broad [10]. Pneumatization reaches out into the surrounding bones and also in the anterior and posterior clinoid process [11, 12]. As the pneumatization increase, the bone over the optic nerve, vidian nerve, or carotid arteries can be thin or absent. In this condition, these vital structures can be exposed to the iatrogenic traumas [13].

Anterior clinoid process pneumatization was reported in a lot of studies in the literature [14–18]. However, PCP pneumatization has not been reported yet. In the present study, PCP pneumatization was detected in 20.7 % of the males and 11.5 % of the females. Right, left, and bilateral PCP pneumatizations were detected in 7.9, 5.7, and 7.0 % of the males and 2.9, 3.2, and 4.5 % of the females, respectively.

PCP pneumatization of the males is significantly higher than the females. The most detected type of pneumatization was type I (61.2 %) for all groups. In right, left, and bilateral pneumatizations separately, type I pneumatization was the most detected pneumatization type with the ratio of the 70.4, 65.2, and 50.0 %, respectively. In males, type I (61.7 %), and similarly in females, type I (60.6 %) pneumatizations were detected more. Type II and type III pneumatizations were detected in decreasing order in both groups. In younger subjects, pneumatization of posterior clinoid process was found as higher, and in older subjects, PCP pneumatization was found as lower.

The PCP is an anatomic boundary to tumors situated in the retrosellar territory and interpeduncular cistern region [19, 20], and its expulsion could encourage presentation of these areas [21]. The PCPs and the dorsum sellae are the primary bony structures that obscure the view of the upper



Fig. 5 Coronal paranasal computed tomography shows type III (red arrow) and type II (green arrow) posterior clinoid process pneumatization and posterior clinoid process (PCP, blue arrow)

Table 2 Posterior clinoid process pneumatization in males and females

Posterior clinoid process pneumatization		Males (<i>n</i> = 227)		Females (<i>n</i> = 314)		<i>p</i> value ^a
		<i>n</i>	%	<i>n</i>	%	
Absent		180	79.3	281	89.5	<i>p</i> = 0.007 $\chi^2 = 11.971$
Present	Right	18	7.9	9	2.9	
	Left	13	5.7	10	3.2	
	Bilateral	16	7.0	14	4.5	
Total		227	100.0	314	100.0	

^a*p* Value shows the results of the chi-squared test

Table 3 Types of the posterior clinoid process pneumatization according to the sides

	Type I		Type II		Type III		Total		<i>p</i> value ^a
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Right (<i>n</i> = 27)	19	70.4	6	22.2	2	7.4	27	100.0	<i>p</i> = 0.115 $\chi^2 = 2.487$
Left (<i>n</i> = 23)	15	65.2	5	21.7	3	13.0	23	100.0	
Bilateral (<i>n</i> = 30)	15	50.0	10	33.3	5	16.7	30	100.0	
Total (<i>n</i> = 80)	49	61.2	21	26.2	10	12.5	80	100.0	

^a*p* Value shows the results of the chi-squared test

2/5 of the basilar artery [22]. Therefore, resection of the PCP is an important surgical stage in aneurysms of the basilar bifurcation. Furthermore, in highly located or giant aneurysms, removal of the PCP is required [23–25].

PCP is very important in operations relevant to internal carotid artery in which PCP is usually drilled. It is also defined as clinoidectomy. Nutik [26] described the reach into the dorsum sella and the cavernous sinus by PCP clinoidectomy. They have suggested this method for basillary artery tip aneurysms. Related to the surgical techniques, third cranial nerve and posterior communicating artery injury can occur. Additionally, bleeding from carotid artery and/or cavernous venous plexus may happen after PCP clinoidectomy [27, 28]. Because of these risks, PCP clinoidectomy ought not to be performed if there is type III PCP pneumatization. Because in this type of PCP pneumatization, CSF fistula

develops 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 PCP pneumatization. To prevent CSF fistulas, posterior clinoidectomies should be avoided in patients with type III PCP pneumatization [18].

Because of the anatomic variations of PCP and superficial petrosal sinus, surgeons need to have good anatomic information about internal carotid artery and tentorium cerebelli. The literature related to PCP abnormalities is less. The clinical significance of PCP pneumatization can be said that transclinoidal surgery may pose a lot of risks during clinoidectomy process including the drilling of the PCP. For example, to reach the basilar artery and to expose it, PCP pneumatization has a great importance. Clinoidectomy

Table 4 Types of the posterior clinoid process pneumatization in males and females

Posterior clinoid pneumatization		Males (<i>n</i> = 47)		Females (<i>n</i> = 33)		<i>p</i> value ^a
		<i>n</i>	%	<i>n</i>	%	
Present	Type I	29	61.7	20	60.6	<i>p</i> = 0.984 $\chi^2 = 0.033$
	Type II	12	25.5	9	27.3	
	Type III	6	12.8	4	12.1	
	Total	47	100.0	33	100.0	

^a*p* Value shows the results of the chi-squared test

provides a wider area to access oculomotor nerve and the carotid artery. There is little literature on the upper front area of the posterior fossa; therefore, this region has remained hidden.

In neurosurgical procedures, to enter the trochlear, oculomotor, or cavernous sinus regions, the distance between the PCP and these structures should be measured preoperatively to avoid complications. Any bone bridge that connects to the surrounding structures to PCP has been recognized as being particularly dangerous for clinoidectomy operations. Preoperative cranial CT planning is advised in advance of such operations. PCP's dural layer may be strained because of abnormalities involving this region. Resection of the abnormal PCP may cause unnecessary tears in the dura. At this time, the internal carotid artery, oculomotor, and trochlear nerves are also injured accidentally. Before the operations for basilar aneurysm under the PCP, a detailed plan should be performed before the surgery.

In this study, we presented the ratio of PCP pneumatization which is higher in males and in younger subjects. When getting older, possible sclerosis process may cause lower PCP pneumatization rates.

Conclusion

Structure of the surrounding regions of PCP is important for the surgical procedures related to cavernous sinus, basilar apex aneurysms, and mass lesions. Preoperative radiological examinations are useful for operative planning. Any anomalies to PCP can cause unnecessary injury to the neurovascular complex structure around the cavernous sinus or postclinoidectomy CSF fistulas. Posterior clinoidectomies should be avoided in patients with type III PCP pneumatization to prevent CSF fistulas.

Author contributions Veysel Burulday: Planning, designing, data collection, and literature survey.

Mehmet Hüseyin Akgül: Planning, designing, data collection, and literature survey.

Nuray Bayar Muluk: Planning, designing, literature survey, statistical analysis, and writing.

Mehmet Faik Ozveren: Literature survey.

Ahmet Kaya: Data collection.

Compliance with ethical standards This study is retrospective. Ethics committee approval was obtained, and there is no need to take informed consent because the data was evaluated retrospectively.

Conflict of interest The authors declare that they have no conflict of interest.

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