VAN TIP DERGİSİ Medical Journal

CLINICAL RESEARCH / KLİNİK ÇALIŞMA

Van Tıp Derg 30 (4):439-445, 2023
DOI: 10.5505/vtd.2023.69741

Evaluation of Anterior and Posterior Clinoid Process Pneumatization with Sphenoid Sinus Types

Anterior ve Posterior Klinoid Proses Pnömotizasyonunun, Sfenoid Sinüs Tipleri ile Birlikte Değerlendirilmesi

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Abstract

Introduction: Anterior clinoid process (ACP) and posterior clinoid process (PCP) are usually excised for access to lesions in the surgery of sellar and parasellar tumors or aneurysms. Anatomical variations of these structures should be well known for a safe clinoidectomy. This study aimed to investigate the variations in pneumatization of ACP, PCP, and the sphenoid sinus.

Materials and Methods: The study was conducted by evaluating the images acquired by axial, coronal, and sagittal plane reconstructions of cranial computed tomography (CT) of 500 (245 female and 255 male) patients aged 15-93 years. Evaluating ACP, PCP, and sphenoid sinus pneumatization and pneumatization patterns, the concurrent occurrence of these variations was examined.

Results: ACP pneumatization was identified in 24% of the patients, with 8.8% being on the right, 6.4% on the left, and 8.8% bilaterally. PCP pneumatization was observed in 7% of the patients, with 2.2% being on the right, 2.2% on the left, and 2.6% bilaterally. The prevalence of concurrent CP and PCP pneumatization was 5.8%. ACP and PCP pneumatization was most frequently noted in patients with postsellar sphenoid sinus pneumatization, with rates of 19.2% and 6.6%, respectively.

Conclusion: The knowledge of variations in pneumatization of ACP, PCP and sphenoid sinus prevents neurovascular injuries that may occur during clinoidectomy and the formation of post-clinoidectomy cerebrospinal fluid (CSF) fistulas. These structures should be evaluated with preoperative cranial CT. Clinoidectomy should be avoided in order to prevent the formation of CSF fistulas, especially in cases of type 3 ACP and PCP pneumatization.

Keywords: Anterior clinoid process; posterior clinoid process; sphenoid; pneumatization.

Özet

Amaç: Sellar ve parasellar bölge tümörlerinin veya anevrizmalarının cerrahisinde, lezyonlara ulaşabilmek için, anterior klinoid proses(ACP) ve posterior klinoid proses(PCP) genellikle eksize edilmektedir. Güvenli bir klinoidektomi için bu yapıların anatomik varyasyonlarının iyi bilinmesi gerekmektedir. Çalışmamızda ACP, PCP ve sfenoid sinüsünün pnömotizasyonları ile ilgili varyasyonları araştırmayı amaçladık.

Gereç ve Yöntem: Çalışma 15-93 yaş arası, 500 (245 kadın+ 255 erkek) olgunun, bilgisayarlı beyin tomografilerinin (BT) aksiyal, koronal ve sagittal planda rekonstrüksiyonu ile elde edilen görüntülerinin değerlendirilmesi ile gerçekleştirildi. Olguların ACP, PCP, sfenoid sinüs pnömotizasyonlarını ve pnömotizasyon tiplerini değerlendirilerek, bu varyasyonların birlikteliklerine bakıldı.

Bulgular: Total olguda ACP pnömotizasyonu %24 olarak saptandı. ACP pnömotizasyonu, sağ %8.8, sol %6.4, bilateral %8.8 olarak olarak izlendi. Total olguda PCP pnömotizasyonu %7 saptandı. PCP pnömotizasyonu sağ %2.2, sol %2.2, bilateral %2.6 olarak olarak izlendi. ACP ve PCP pnömotizasyonu birlikteliği %5.8 olarak tespit edildi. ACP ve PCP pnömotizasyonları ise en sık, postsellar sfenoid sinüsü olan olgularda sırasıyla %19.2 ve %6.6 oranlarıyla tespit edildi.

Sonuç: ACP, PCP ve sfenoid sinüsün pnömotizasyonlarındaki varyasyonların bilinmesi, klinoidektomi sırasında oluşabilecek nörovasküler yaralanmaları ve postklinoidektomi beyin omurilik sıvısı(BOS) fistüllerinin oluşmasını önler. Bu yapıların preoperatif BT ile değerlendirilmeleri gerekir. Özellikle ACP ve PCP tip 3 pnömotize olgularda, BOS fistüllerinin oluşmaması için klinoidektomilerden kaçınmak gerekir.

Anahtar Kelimeler: Anterior klinoid proses; posterior klinoid proses; sfenoid; pnömotizasyon.

Introduction

The sellar and parasellar regions are the most common sites of involvement for intracranialtumors and cerebral aneurysms.The structures that make up the region have very rich anatomical variations. Among these, ACP is one of the most important structure in neurosurgical interventions (1-3). Surgical excision

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Received:14.04.2023, Accepted:17.07.2023

of ACP (anterior clinoidectomy) is an important step in gross total resection of sellar and parasellar tumors. The surgery of aneurysms originating from the clinoidal segment and paraclinoid branches of ICA, ophthalmic artery, and basilar artery can be performed with anterior clinoidectomy (2,4). A safe anterior clinoid resection requires knowledge of the variations of this anatomical structure. One of these variations is the non-extension of sphenoid sinus pneumatization to ACP or extension at different degrees (5). The anterior border of the pituitary fossa is formed by ACP, while the posterior border is formed by the dorsum sellae, which is adjacent to the clivus. The superolateral aspects of the dorsum sellae rise bilaterally to form PCP (6). Surgical excision of PCP (posterior clinoidectomy) is often required in the surgical approach to the superior basilar artery region and posterior aspect of the pituitary fossa (7). Posterior clinoidectomy provides access to the interpeduncular cistern, so that safe clipping of basilar tip aneurysms can be performed (8). For all these reasons, the knowledge of variations of PCP before surgery is important in surgical strategy. Preoperative evaluation of pneumatization of PCP, one of these variations, prevents complications secondary to neurovascular injury that may occur intraoperatively. The sphenoid sinus is a more posterior sinus cavity, which is located in the center of the skull base within the sphenoid bone and is more challenging to access than other paranasal sinuses. In neurosurgery practice, it is the most common intervention pathway used to access many skull base pathologies (9). The sphenoid sinus has very important adjacent structures, and its variations are complex and highly variable. ICA, bilateral cavernous sinuses, optic nerve, and the maxillary branch of the trigeminal nerve along with the Vidian nerve are among these important adjacent structures. These important structures are at risk in skull base surgeries performed using the transsphenoidal approach (10). Reducing the mortality and morbidity rates by decreasing the complication rate in these surgeries depends on knowing the anatomical variations of the sphenoid sinus well. The knowledge of the existence and patterns of sphenoid sinus pneumatization, which is one of these variations, contributes to safe surgery. In our study, we aimed to provide a broad perspective on the variations related to the pneumotization of these three anatomical structures.

Materials and Methods

This study is a retrospective study conducted between January 2020 and November 2022, using the radiology database from the archive of the Department of Radiodiagnostics and evaluating cranial CT images. All data were obtained from cranial CT images with a slice thickness of 1.50 mm that were acquired with a 16-slice CT (MSCT; Somatom Emotion 16, Siemens, Germany) in the supine position, without contrast agent administration. Images acquired with 120 kVp and 210 mAs technical specifications were formatted in the bone window and reconstructed in axial, coronal, and sagittal planes. The study included 500 patients, of whom 245 (49%) were female and 255 were male (51%). The age range of the patients was 15-93 years, with a mean age of 54.30±21.50 years. The mean age of female patients was 55.42 ± 20.66 years and the mean age of male patients was 55.96±22.28 years . Patients aged 15 years and older were included in the study. It was ensured that these patients did not have craniofacial trauma, endocrinological problems, bone pathologies, previous trauma or surgery history, and cranial or pituitary tumor. ACP pneumatization and pneumatization patterns were evaluated in the axial, coronal, and sagittal planes. ACP pneumatization was evaluated as absent or present (right, left, bilateral). Of the patients with pneumatization, those with pneumatization below 50% were classified as type 1, those with >50% pneumatization as type 2, and those with total pneumatization as type 3 (Figure 1).

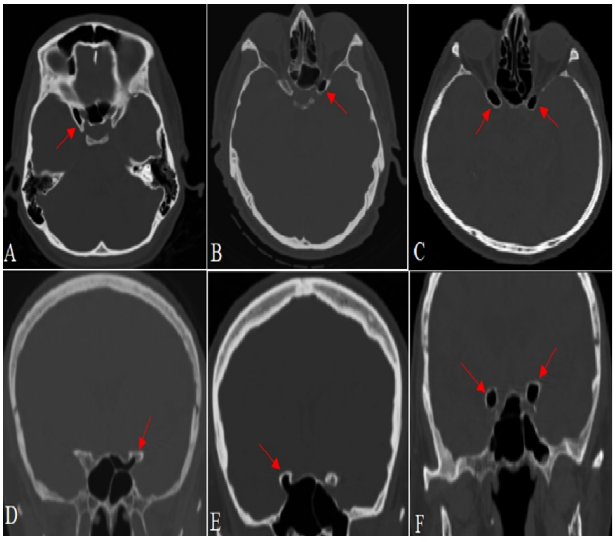

Figure 1. A) Right ACP pneumatization. B) Left ACP pneumotization. C) Bilateral ACP pneumotization. D) Type I ACP pneumatization. E) Type II ACP pneumotization F) Type III ACP pneumotization. **ACP=** Anterior Clinoid Process

This classification was based on the current classification in the literature (11). The classification of PCP pneumatization was performed similarly to the classification of ACP pneumatization. PCP pneumatization was evaluated as absent or present (right, left, bilateral). Of the patients with pneumatization, those with pneumatization below 50% were classified as type 1, those with >50% pneumatization as type 2, and those with total pneumatization as type 3 (Figure 2).

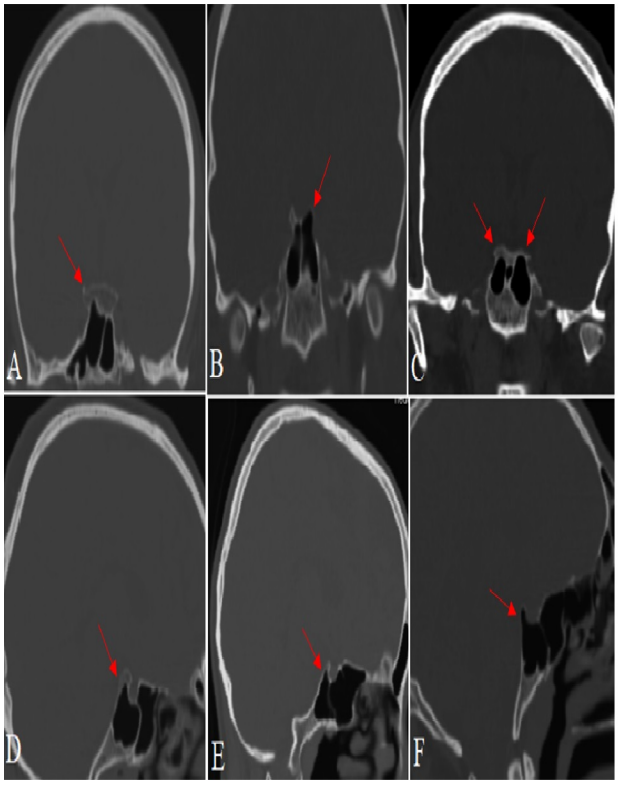

Figure 2. A) Right PCP pneumotization. B) Left PCP pneumotization. C) Bilateral PCP pneumotization. D) Type I PCP pneumotization. E) Type II PCP pneumotization F) Type II PCP pneumotization. **PCP=** Posterior Clinoid Process

This classification was based on the current classification in the literature (12). The Guldner classification, which also defines hyperpneumatized sinuses that completely surround the sella, was used for the classification of sphenoid sinus pneumatization (13). Sinuses without pneumatization were considered to be of the conchal type, while those with a posterior border of pneumatization not exceeding the anterior wall of the sella were considered to be of the presellar type. Sinuses with pneumatization reaching the posterior wall of the sella but not extending beyond that were considered to be of the sellar type, while sinuses with pneumatization extending behind the posterior wall of the sella were considered to be of the postsellar type (Figure 3).

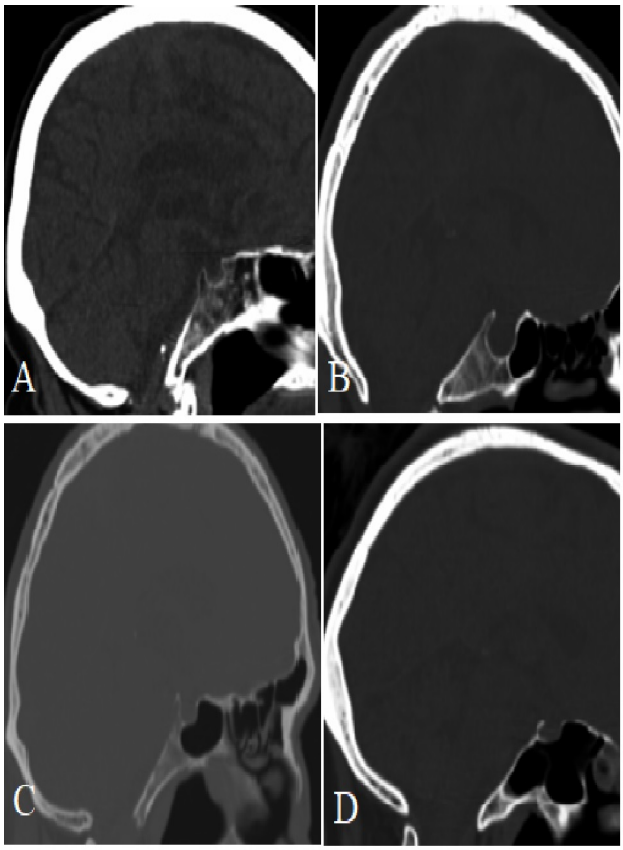

Figure 3. A) Conchal type of sphenoid sinus. B) Presellar type of sphenoid sinus. C) Sellar type of sphenoid sinus. D) Postsellar type of sphenoid sinus.

Ethical approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Clinical Research Ethics Committee of the Afyonkarahisar Health Sciences University Hospital, Faculty of Medicine (Date and Decision No. 06. 01. 2023, 2023/ 28).

Statistical analysis: SPSS version 20.0 (SPSS Inc, Chicago, Illinois, USA) software was used for descriptive statistics of all of the patients and patients in the relevant groups such as numerical quantity (frequency), proportion (percentage), central tendency (arithmetic mean), and measures of dispersion/variability (standard deviation, minimum-maximum values). The chi-square test was performed using the same statistical software package to test whether the proportions of ACP or PCP pneumatization in the comparison groups (for example, women and men) have a statistically

significant difference. In these tests, a p-value <0.05 was considered statistically significant.

Results

ACP pneumatization and its distribution between male and female patients with their mean age are shown in Table 1.

Table 1: ACP pneumatization and gender distribution

	Results
ACP pneumatization	120 (24%)
Male	69 (27%)
Female	51 (20.8%)
Age (years)	16-93 (54.94±22.49)

ACP=Anterior Clinoid Process

ACP pneumatization was identified in 44 (8.8%) patients on the right, 32 (6.4%) patients on the left, and 44 (8.8%) patients bilaterally. For right ACP, type 1 pneumatization was detected in 21 (47.7%) patients, type 2 pneumatization in 12 (27.3%) patients, and type 3 pneumatization in 11 (25%) patients. For left ACP, type 1 pneumatization was observed in 20 (62.5%) patients, type 2 pneumatization in 8 (25%) patients, and type 3 pneumatization in 4 (12.5%) patients. Bilateral type 1 ACP pneumatization was detected in 10 (22.7%) patients, type 2 pneumatization in 6 (13.6%) patients, and type 3 pneumatization in 13 (29.5%) patients. Patients with bilateral ACP pneumatization but with different patterns of pneumatization on the right and left sides were classified as the bilateral heterogeneous type of pneumatization. The bilateral heterogeneous type of pneumatization was identified in 15 (34.2%) patients (Figure 4).

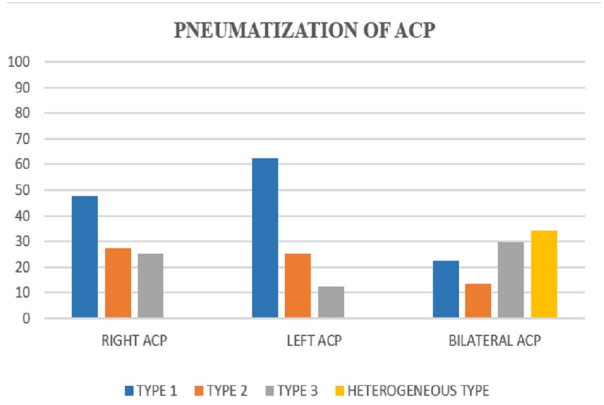

Figure 4. Rates of right, left, and bilateral anterior clinoid process pneumatization **ACP=** Anterior Clinoid Process

There was no statistically significant difference in ACP pneumatization between the genders (p=0.102). There was no statistically significant difference in the right (p=0.419) and left (p=0.804) ACP pneumatization rates between the genders. PCP pneumatization and its distribution between male and female patients with their mean age are shown in Table 2.

Table 2: PCP pneumatization and gender distribution

	Results
PCP pneumatization	35 (7%)
Male	28 (11%)
Female	7 (2.9%)
Age (years)	15-91 (44.6±25.93)

PCP= Posterior Clinoid Process

PCP pneumatization was identified in 11 (2.2%) patients on the right, 11 (2.2%) patients on the left, and 13 (2.6%) patients bilaterally. For right PCP, type 1 pneumatization was detected in 6 (54.5%) patients, type 2 pneumatization in 3 (27.3%) patients, and type 3 pneumatization in 2 (18.2%) patients. For left PCP, type 1 pneumatization was observed in 4 (36.4%) patients, type 2 pneumatization in 3 (27.3%) patients, and type 3 pneumatization in 4 (36.4%) patients. Bilateral type 1 PCP pneumatization was noted in 4 (30.8%) patients, type 2 pneumatization in 2 (15.4%) patients, type 3 pneumatization in 1 (7.7%) patients, and bilateral heterogeneous type of pneumatization in 6 (46.1%) patients (Figure 5).

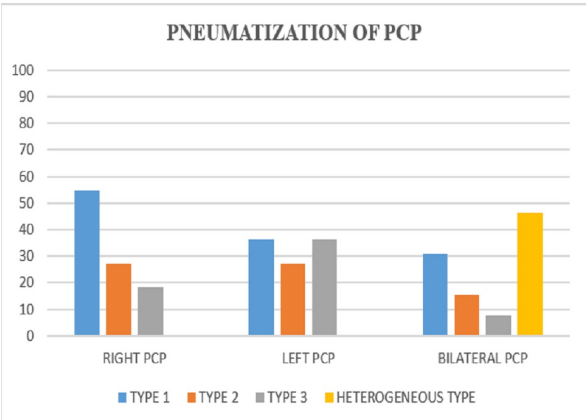

Figure 5. Rates of right, left, and bilateral posterior clinoid process pneumatization **PCP=** Posterior Clinoid Process

There was a statistically significant difference in PCP pneumatization between the genders, in favor of the male gender (p=0.012). There was no statistically significant difference in right PCP pneumatization rates between the genders (p=0.145); however, the rate of left PCP pneumatization was statistically significantly higher in male patients (p=0.007). The coexistence of ACP and PCP pneumatization was observed in 29 (5.8%) patients, of whom 7 (2.9%) were female and 22 (8.6%) were male. There was a statistically significant difference in the coexistence of ACP and PCP pneumatization between the genders, in favor of male patients (p=0.006). The analysis of the patterns of sphenoid sinus pneumatization revealed conchal type in 7 (1.4%) patients, presellar type in 56 (11.2%) patients, sellar type in 221 (44.2%) patients, and postsellar type in 216 (43.2%) patients. The sellar type was the most frequent pattern in women with 117 (47.8%) patients, while the postsellar type was the most prevalent varian in men with 117 (45.9%) patients. There was no statistically significant difference in any pattern between the genders (p>0.05). ACP and PCP pneumatization was most frequently noted in patients with postsellar sphenoid sinus pneumatization, with rates of 19.2% and 6.6%, respectively.

Discussion

Anterior clinoidectomy is one of the important surgical steps in the resection of clinoidal meningiomas and giant pituitary tumors, exposure of paraclinoid and upper basilar artery lesions, and cavernous sinus interventions. This procedure provides mobilization of ICA and the optic nerve with minimal brain retraction in the surgery of ophthalmic artery aneurysms (14). Anatomically, ACP is inferolaterally adjacent to the third, fourth, sixth cranial nerves and the ophthalmic branch of the trigeminal nerve. After anterior clinoidectomy, the clinoidal segment of ICA is exposed between the distal and proximal dural rings (15). Considering the anatomical adjacent structures of ACP, the complications that may develop during anterior clinoidectomy include injury to ICA, ophthalmic artery, and rupture of aneurysms in this region. On the other hand, visual loss may occur due to injury to the optic nerve along with the third, fourth, and sixth cranial nerves. Moreover, rhinorrhea and pneumocephalus due to opening of the paranasal sinus may complicate the surgical outcomes and cause serious complications ranging from infection of the central nervous system to sepsis (16). Given the catastrophic results that may occur with these complications, it is very important to know the variations associated with pneumatization of ACP and to evaluate it preoperatively. Our study revealed a prevalence of 24% for ACP pneumatization. Considering the literature, this rate ranges from 4% to 29.3%. The prevalence of ACP pneumatization was reported as 12% by Arslan et al., 6% by Bolger et al., 29.3% by Citardi et al., 13.3% by Mikami et al., 4% by DeLano et al., and 23.4% by Sirikci et al. (17,18,7,5,19, 20). In our study, the prevalence of ACP pneumatization in all patients is similar to the results of other studies. In their study, Korosue et al. reported the rates of right, left, and bilateral ACP pneumatization to be 12%, 7%, and 9%, respectively (21). In our study, ACP pneumatization was identified in 24% of the patients, with 8.8% being on the right, 6.4% on the left, and 8.8% bilaterally. The analysis of the pneumatization patterns in our study revealed type 1 pneumatization as the most common pattern with rates of 47.7% in patients with right ACP pneumatization and 62.5% in patients with left ACP pneumatization. Patients with bilateral ACP pneumatization were classified as type 1, type 2, and type 3. However, there was a need to define an additional type in our classification for patients with bilateral pneumatization but different patterns of pneumatization on the right and left sides. This type was defined as the bilateral heterogeneous type of pneumatization. In our study, the bilateral heterogeneous type of pneumatization was most frequently identified in patients with bilateral ACP pneumatization with a rate of 34.2%. PCP is a border site for tumors of the interpeduncular and postsellar regions. Posterior clinoidectomy provides a wide view of the surgical field and safe resection in the surgery of these tumors (22). In addition, PCP and the dorsum sella are important bone structures that hide the pathologies of the upper 2/3 of the basilar artery during the surgical procedure. Therefore, posterior clinoidectomy is an important surgical step in the surgical treatment of vascular pathologies at the level of the basilar bifurcation. Excision of PCP is required, especially in basilar apex aneurysms with a superior location (6). If posterior clinoidectomy is required in these cases, preoperative evaluation is important. Posterior clinoidectomy should be avoided in such cases because of the high risk of developing a CSF fistula after the procedure, especially considering that fistulas develop in all cases of type 3 pneumatization (23). In our study, PCP pneumatization was observed in 7% of the patients, with 2.2% being on the right, 2.2% on

the left, and 2.6% bilaterally. PCP pneumatization was identified in 11% of male patients and 2.9% of female patients, with a statistically significant difference, in favor of the male gender. Considering the results of our study on pneumatization patterns, type 1 pneumatization was the most frequent type in patients with right PCP pneumatization with 54.5%, followed by type 1 pneumatization and type III pneumatization with equal rates of 36.4% in patients with left PCP pneumatization, whereas the heterogeneous type of pneumatization was the most frequent type in patients with bilateral pneumatization with 46.1%. We could not find many publications on the pneumatization rates of PCP in the literature. Burulday et al. found a PCP pneumatization rate of 20.7% in men and 11.5% in women (12). In our study, PCP pneumatization was identified in 11% of male patients and 2.9% of female patients.

In our study, the coexistence of ACP and PCP pneumatization was observed in 5.8% of the patients, with rates of 2.9% in female patients and 8.6% in male patients. There was a statistically significant difference in the coexistence of ACP and PCP pneumatization between the genders, in favor of males (p=0.006). In our study, the sellar type of pneumatization was the most frequent type among the pneumatization patterns of the sphenoid sinus with a rate of 44.2%. Previous studies have found a rate ranging from 21% to 59% for the sellar type. Our results are consistent with the results of other studies (24-26). The coexistence of ACP pneumatization and sphenoid sinus patterns was most frequently observed in the postsellar type with 19.2%, while the coexistence of PCP pneumatization and sphenoid sinus patterns was most frequently identified in the postsellar type with 6.6%.

Study limitations: The limitation of the study is that patients under the age of 15 were not included in the study.

Conclusion

ACP, PCP, and the sphenoid sinus are important anatomical structures in the surgical treatment of sellar, parasellar tumors, and aneurysmatic lesions. Variations in pneumatization of these interconnected structures are quite rich. These variations should be well known by neurosurgeons in surgeries for the treatment of lesions in this region. Preoperative evaluation of these variations with CT will reduce neurovascular injuries and the formation of CSF fistulas during surgery. The data obtained from this study on the pneumatization of ACP, PCP, and sphenoid sinus will contribute to neurosurgeons to better understand the regional anatomy and its variations and will help avoid complications in neurosurgery.

Ethical approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Clinical Research Ethics Committee of the Afyonkarahisar Health Sciences University Hospital, Faculty of Medicine (Date and Decision No. 06. 01. 2023, 2023/ 28). This study was designed retrospectively, and informed written consent was received from none of the patients.

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

Financial disclosure: This study was not financially supported.

Author contribution: Concept: ED, ÖD; Design: E.D, Ö.D; Control: ED, ÖD, KYG; Data Collection and Processing: ED, ÖD, SBÖ; Analysis and Interpretation: ED, ÖD, KYG; Literature Review: ED, ÖD, SBÖ; Writing-Original Draft: ED, ÖD; Writing Review and Revision: ED, KYG, SO; Critical Review: ED, ÖD, KYG, SO; Software and Visualization: ED, SBÖ.

References

1. Dolenc VV. Parasellar compartment. J Neurosurg 2010; 113: 1043-1044.
2. Andaluz N, Beretta F, Bernucci C, Keller JT, Zuccarello M. Evidence for the improved exposure of the ophthalmic segment of the internal carotid artery after anterior clinoidectomy: Morphometric analysis. Acta Neurochir 2006; 148: 971-975.
3. Dolenc VV. Approaches to and techniques of surgery within the cavernous sinus. In: Torrens M, Al-Mefty O, Kobayashi S, editors. Operative Skull Base Surgery. New York: Churchill Livingstone; 1997. p. 207-236
4. Hayashi N, Masuoka T, Tomita T, Sato H, Ohtani O, Endo S. Surgical anatomy and efficient modification of procedures for selective extradural anterior clinoidectomy. Minim Invasive Neurosurg 2004; 47:355-358.
5. Mikami T, Minainida Y, Koyanagi L, Baba T, Houkin K. Anatomical variations in pneumatization of the anterior clinoid process. J. Neurosurgi 2007; 106 (1) 170-174.
6. Chanda A, Nanda A. Anatomical study of the orbitozygomatic transsellar-transcavernous transclinoidal approach to the basilar artery

bifurcation. J Neurosurg 2002; 97(1):151–160.
7. Citardi MJ, Gallivan RP, Batra PS, Maurer CR Jr, Rohlfing T, Roh HJ, et al. Quantitative computer-aided computed tomography analysis of sphenoid sinus anatomical relationships. Am J Rhinol 2004; 18:173-178.
8. Youssef AS, van Loveren HR. Posterior clinoidectomy: Dural tailoring technique and clinical application. Skull Base 2009; 19:183-191.
9. Locatelli M, Di Cristofori A, Draghi R, Bertani G, Guastella C, Pignataro L, et al. Is Complex Sphenoidal Sinus Anatomy a Contraindication to a Transsphenoidal Approach for Resection of Sellar Lesions? Case Series and Review of the Literature. World Neurosurg 2017; 100:173-179.
10. Xiao SX, Ma YH, Zhan RY, Wen L. Sella Turcica Anatomy by Three-Dimensional Computed Tomography for an Endonasal Transsphenoidal Approach to Pituitary Adenoma. Minim Invasive Neurosurg 2011; 54(04):162-166.
11. Abuzayed B, Tanriover N, Biceroglu H, Yüksel O, Tanriover O, Albayram S, et al. Pneumatization degree of the anteriorclinoid process a new classification. Neurosurg Rev 2010; 33 (3) 367-373.
12. Burulday V, Akgül MH, Muluk NB, Ozveren MF, Kaya A. Evaluation of posterior clinoid process pneumatization by multidetector computed tomography. Neurosurg Rev 2016; s10143 016-0794-8.
13. Guldner C, Pistorius SM, Diogo I, Bien S, Sesterhenn A, Werner JA. Analysis of pneumatization and neurovascular structures of the sphenoid sinus using cone-beam tomography (CBT). Acta Radiol 2012; 53(2):214-9.
14. Youssef AS, Abdel Aziz KM, Kim EY, Keller JT, Zuccarello M, van Loveren HR. The carotid-oculomotor window in exposure of upper basilar artery aneurysms: a cadaveric morphometric study. Neurosurgery 2004; 54:1181-1189.
15. Phuong Huynh-Le P, Natori Y, Sasaki T. Surgical anatomy of the anterior clinoid process. J Clin Neurosci 2004; 11(3):283-287.
16. Nutik SL. Removal of the anterior clinoid process for exposure of the proximal intracranial carotid artery. J Neurosurg 1988; 69: 529-534.
17. Arslan H, Aydinlioglu A, Bozkurt M, Egeli E. Anatomic variations of the paranasal sinuses: CT examination for endoscopic sinus surgery. Auris Nasus Larynx 1999; 26:39–48.
18. Bolger WE, Butzin CA, Parsons DS. Paranasal sinus bony anatomic variations and mucosal abnormalities: CT analysis for endoscopic sinus surgery. Laryngoscope 1991; 101:56-64.
19. DeLano MC, Fun FY, Zinreich SJ. Relationship of the optic nerve to the posterior paranasal sinuses: a CT anatomic study. AJNR Am J Neuroradiol 1996; 17:669–675.
20. Sirikci A, Bayazit YA, Bayram M, Mumbuc S, Gungor K, Kanlikama M. Variations of sphenoid and related structures. Eur Radiol 2000; 10:844–848.
21. Korosue K, Heros RC. "Subclinoid" carotid aneurysm with erosion of the anterior clinoid process and fatal intraoperative rupture. Neurosurgery 1992; 31: 356-359.
22. Salma A, Wang S, Ammirati M. Extradural endoscopeassisted subtemporal posterior clinoidectomy: a cadaver investigation study. Neurosurgery 2010; 67: 43-48.
23. Burulday V, Muluk NB, Akgül MH, Kaya A, Öğden M. Presence and types of anterior clinoid process pneumatization, evaluated by multidetector computerized tomography. Clin Invest Med 2016; 39(3):E105–E110.
24. Raseman J, Guryildirim M, Beer-Furlan A, Jhaveri M, Tajudeen BA, Byrne RW, et al. Preoperative Computed Tomography Imaging of the Sphenoid Sinus: Striving Towards Safe Transsphenoidal Surgery. J Neurol Surg B Skull Base 2020; 81(3):251-62.
25. Tomovic S, Esmaeili A, Chan N.J, Shukla P.A, Choudhry O.J, Liu J.K, et al. High resolution computed tomography analysis of variations of the sphenoid sinus. J Neurol Surg B Skull Base 2013; 74(2):82-90.
26. Halawi AM, Simon PE, Lidder AK, Chandra RK. The relationship of the natural sphenoid ostium to the skull base. Laryngoscope 2015; 125(1):75-9.