Qualitative and Quantitative Radio-Anatomical Variation of the Posterior Clinoid Process

Asem Salma, M.D.,¹ Nishanta B. Baidya, M.D.,¹ Benjamin Wendt, B.S.,¹ Francisco Aguila, B.S.,² Steffen Sammet, M.D.,² and Mario Ammirati, M.D., M.B.A.¹

ABSTRACT

This study was conducted to investigate the radiological anatomy of the posterior clinoid process (PCP) to highlight preoperative awareness of its variations and its relationships to other skull base landmarks. The PCPs of 36, three-dimensional computed tomographic cadaveric heads were evaluated by studying the gross anatomy of the PCP and by measuring the distances between the PCP and other skull base anatomical landmarks relevant to transnasal or transcranial skull base approaches. PCP variations were found in five specimens (14%): in two the dorsum sellae was absent, in one the PCP and the anterior clinoid process (ACP) were connected unilaterally and in two bilaterally. The mean distance between the right/left PCP and the crista galli was 45.14 ± 4.0 standard deviation (SD)/ 46.24 ± 4.5 SD, respectively, while the distance to the middle point of the basion at the level of the foramen magnum was 40.41 ± 5.1 SD/ 41.0 ± 5.2 SD, respectively. The mean distance between the PCP and the ACP was 12.03 ± 3.18 SD on the right side and 12.11 ± 2.77 SD on the left. The data provided highlights the importance of careful preoperative evaluation of the PCP and of its relationships to other commonly encountered skull base landmarks. This information may give an idea of the exposure achievable through different transcranial and transnasal approaches. This is especially relevant when neuronavigation is not available.

KEYWORDS: Radio-anatomical study, posterior clinoid processes, skull base surgery, transnasal approaches

Surgical management of basilar tip aneurysms, as well as lesions in the interpeduncular fossa is challenging. This is partially due to the topographic location of the posterior clinoid process (PCP), which poses a discrete anatomical barrier that constricts anterior and middle fossa approaches to the interpeduncular fossa.^{1–8} The same is

true for extended transnasal endoscopic approaches to the retrodorsal area that require dealing with the PCP.⁹

The PCP has received less attention than its anterior counterpart, the anterior clinoid process (ACP), and its anatomy has been sparingly documented in the neurosurgical literature.^{1,10–13}

Departments of ¹Neurological Surgery and ²Radiology, Ohio State University Medical Center, Columbus, Ohio.

Address for correspondence and reprint requests: Mario Ammirati, M.D., M.B.A., Department of Neurological Surgery, N1025 Doan Hall, 410 W. 10th Avenue, Columbus, OH 43210 (e-mail: mario.ammirati@osumc.edu).

Skull Base 2011;21:373–378. Copyright © 2011 by Thieme

Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

Received: April 18, 2011. Accepted: July 11, 2011. Published online: September 27, 2011.

DOI: <http://dx.doi.org/10.1055/s-0031-1287678>.

ISSN 1531-5010.

Goal of our study was to fill that knowledge gap by investigating the anatomic variations of the PCP from a radiological perspective using reconstructed three-dimensional computed tomography (CT) scans.

MATERIALS AND METHODS

We evaluated the radiological anatomy of the PCP region in 36 adult cadaveric heads. Each specimen underwent a high resolution CT scan with the following parameters: slice thickness, 1 mm, contiguous nonoverlapping slices; gantry setting, 0 degrees; scan window diameter, 225 mm; pixel size, $>0.44 \times 0.44$).

TeraRecon software (TeraRecon, Inc., San Mateo, CA) was used to generate three-dimensional reconstructions. The three-dimensional reconstructed CT scans of the clinoid regions were reviewed to look for anatomical variation of the PCP.

We evaluated qualitatively the gross anatomy of the PCP including any clearly visible anomaly. Quantitatively, we measured the distances between the PCP and selected anatomical skull base structures; these structures were selected mainly based on their relevance for extended transsphenoidal approaches, as well as on their relevance for transcranial access to the interpeduncular fossa.

We measured the following distances (Figs. 1 and 2):

- Between the posterior edge of the crista galli (CG) and the lateral-most extension of the PCP
- Between the lateral-most extension of the PCP and the middle point of the basion at the level of the foramen magnum

Figure 1 Three-dimensional reconstructed computed tomography of the skull base anatomy. A, anterior; ACP, anterior clinoid process; BO, middle point of the basion at the level of the foramen magnum; CG, posterior edge of the crista galli; FO, foramen ovale; L, left; P, posterior; PCP, posterior clinoid process; R, right.

- Between the lateral-most extensions of the ACP and the PCP
- Between the lateral-most extension of the PCP and the posteromedial edges of the superior orbital fissure
- Between the lateral-most extension of the PCP and the posteromedial edge of the foramen rotundum
- Between the lateral-most extension of the PCP and the posteromedial edge of the foramen ovale

RESULTS

Qualitative Analysis

We found variation in the gross anatomy of the PCP in five specimens (14%). Two specimens did not have the dorsum sellae (absent PCP) (Fig. 3a, b). In one specimen the ACP and PCP were connected on the right side and in two specimens they were connected bilaterally (Figs. 4 and 5).

Figure 2 This figure depicts how the measurements were taken. (A) Distance between the posterior clinoid process and the crista galli; (B) Distance between the posterior and the anterior clinoid process; (C) Distance between the posterior clinoid process and the superior orbital fissure; (D) Distance between the posterior clinoid process and the foramen rotundum; (E) Distance between the posterior clinoid process and the foramen ovale; (F) Distance between the posterior clinoid process and the middle point of the basion at the foramen magnum. A, anterior; ACP, anterior clinoid process; BO, middle point of the basion at the level of the foramen magnum; CG, posterior edge of the crista galli; FO, foramen ovale; FR, foramen rotundum; L, left; P, posterior; R, right; SOF, superior orbital fissure. All the lines converge on the posterior clinoid process.

Figure 3 (a) The dorsum sellae and the posterior clinoid processes are missing. (b) Normal anatomy for comparison. DS, dorsum sellae; PCP, posterior clinoid process.

Figure 4 Three-dimensional reconstructed computed tomography of the skull base. The arrow points to the fused anterior and posterior clinoid process on the right side.

Figure 5 Three-dimensional reconstructed computed tomography of the skull base, right superolateral view. The arrows show the fused anterior and posterior clinoid processes bilaterally.

Table 1 Distances between the Posterior Clinoid Process and Relevant Skull Base Landmarks

Distances in mm	Right				Left			
	Mean $\pm$ SD	Maximum	Median	Minimum	Mean $\pm$ SD	Maximum	Median	Minimum
Between the PCP and the ACP	12.03 $\pm$ 3.18	24.30	12.08	8.9	12.11 $\pm$ 2.77	20.09	12.20	7.89
Between the PCP and the CG	45.14 $\pm$ 4.0	58.16	45.21	36.14	46.24 $\pm$ 4.5	57.49	46.34	35.40
Between the lateral-most extension of the PCP and the SOF	21.40 $\pm$ 4.46	30.22	21.39	11.86	21.83 $\pm$ 3.4	32.75	21.75	15.93
Between the lateral-most extension of the PCP and the FR	19.10 $\pm$ 4.37	28.28	18.92	14.06	20.73 $\pm$ 3.7	28.13	20.72	13.43
Between the lateral-most extension of the PCP and the FO	22.02 $\pm$ 3.41	29.76	22.06	16.06	22.42 $\pm$ 3.43	30.32	22.36	16.84
Between the PCP and the BO	40.41 $\pm$ 5.1	47.83	40.64	27.52	41.0 $\pm$ 5.2	47.99	40.50	28.57

ACP, anterior clinoid process; BO, middle point of the basion at the foramen magnum; CG, posterior edge of the crista galli; FR, foramen rotundum; FO, foramen ovale; PCP, posterior clinoid process; SOF, superior orbital fissure.

Quantitative Analysis

Table 1 shows the measurements performed as detailed in the Materials and Methods section.

DISCUSSION

Surgical Relevance of the PCP

The PCP is a bony prominence at the superolateral aspect of the dorsum sellae; together with the anterior and middle clinoid processes of the sphenoid bone it contributes to the boundary of the sella turcica. Topographically, the anterior boundary of the sella turcica is formed by the tuberculum sellae in the middle and by the ACP laterally. 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 PCPs. From a developmental point of view, the sella turcica appears as a shallow depression in the sphenoid body in the newborn, because the dorsum sellae has not yet fully developed and ossified. In early childhood the sella is still shallow and the dorsum sellae appears short, as the PCP is not yet ossified. After about 4 years of age the dorsum sellae increases in width and the PCP begins to ossify. The dorsum increases in size until puberty after which no significant change takes place.^{7,14,15}

Significant wide variations in the PCP in different individuals and even between the opposite sides of the same individual have been reported, such as fusion of the ACP and PCP through an ossified interclinoid

ligament.^{9,10} One study reported bilateral complete ossification of the interclinoid ligament in 6% of autopsy cases.¹² Other authors have described an exostosis arising from the lateral aspect of the PCP at the level of the oculomotor trigone.¹⁰ Exostosis of the PCP is a rare entity and its presence should be considered in approaching the parasellar regions.¹⁰

The tentorium cerebelli attaches to the PCP,¹³ and therefore, any anomalies of the PCP may be linked to different angles of the tentorium and that again may be relevant to transtentorial middle fossa approaches to the tentorial hiatus and to posterior fossa targets.

Clearly a thorough awareness of PCP anomalies may help in preventing injuries to the topographical related important structures such as the internal carotid, the basilar and the posterior communicating arteries, the superior petrosal sinus, and the oculomotor and trochlear nerves.¹¹

The Significance of the Current Study

Surgical operations on basilar aneurysms below the PCP are demanding. The removal of the PCP and of part of the dorsum sellae has been described as a possible method to operate on low-lying distal basilar artery aneurysms.¹⁻⁸ Anatomical variations of the PCP may also encroach into the pituitary gland to cause resultant symptoms.¹¹

Our study demonstrated significant variations in the gross anatomy of the PCP. Not only did we notice

these variations in different specimens but we also demonstrated significant variations between the two sides in the same specimen.

Two specimens did not have the dorsum sellae and hence the PCPs were absent while the ACP and the PCP were connected bilaterally in one specimen and unilaterally in two specimens.

The quantitative data we provided in this study could be useful in predicating the potential dimensions of the surgical exposures when certain transcranial or transnasal skull base approaches are performed. The PCP has a unique location in the center of skull base, which makes it a useful cornerstone for building an anatomical map of the skull base. Hence the distances we measured give a general idea of the extension of certain commonly used skull base approaches. For example, the CG is the most anterior border of transnasal approaches,^{16–18} and the distance between the PCP and the CG roughly equates the dimension of the surgical exposure associated with the anterior extended transnasal approaches. Likewise, the dimension of the surgical exposure associated with posterior extended transnasal approaches can be roughly appreciated by measuring the distance between the PCP and the middle point of the basion at the anterior aspect of the foramen magnum which is considered to be the most posterior border of extended posterior transnasal approaches.¹⁹ On other hand, the superior orbital fissure, the foramina rotundum, and ovale correspond to V1 (ophthalmic), V2 (maxillary), and V3 (mandibular) nerves, which represent the most lateral borders of extended transnasal approaches; therefore, the distances between the PCP and these anatomical landmarks represent the limits of the lateral surgical exposure achievable with the lateral extended transnasal approaches.^{20–22}

Furthermore, during transcranial approaches to the interpeduncular fossa, the relationships between the PCP and the ACP, superior orbital fissure, foramen ovale, and foramen rotundum are highly important qualitatively and quantitatively, because vital anatomical structures are located between the PCP and these anatomical landmarks (cavernous sinus with the intracavernous carotid artery and the associated cranial nerves).^{1–8,23}

Also, in this article we highlighted the usefulness of using three-dimensional reconstructed CT that may yield valuable preoperative information regarding the PCP anatomy that may be usefully incorporated into surgical planning. Due to its unique location, at the center of the skull base, the knowledge of the detailed anatomy of the PCP and its relation to the other skull base landmarks could increase the surgical orientation, which may lead to correct executions of surgical approaches (transnasal or transcranial) to the skull base. This is especially relevant when neuronavigation is not available.

CONCLUSION

The three-dimensional reconstructed CTs of the clinoid regions are useful for in-depth understanding and preoperative evolution of the anatomy of the PCP. The data provided in this article may bear significant practical implications in transcranial approaches and extended transnasal approaches. Indeed knowing the possible variations of the PCP demonstrated in this article may alert the surgeon to carefully watch for them in his/her preoperative planning of surgical approaches to this area.

REFERENCES

1. Aziz KM, van Loveren HR, Tew JM Jr, Chicoine MR. The Kawase approach to retrosellar and upper clival basilar aneurysms. *Neurosurgery* 1999;44(6):1225–1234; discussion 1234–1236
2. Figueiredo EG, Zabramski JM, Deshmukh P, Crawford NR, Preul MC, Spetzler RF. Anatomical and quantitative description of the transcavernous approach to interpeduncular and prepontine cisterns. Technical note. *J Neurosurg* 2006; 104(6):957–964
3. Sugita K, Kobayashi S, Takemae T, Tada T, Tanaka Y. Aneurysms of the basilar artery trunk. *J Neurosurg* 1987;66(4): 500–505
4. Inoue T, Rhoton AL Jr, Theele D, Barry ME. Surgical approaches to the cavernous sinus: a microsurgical study. *Neurosurgery* 1990;26(6):903–932
5. Sekhar LN, Burgess J, Akin O. Anatomical study of the cavernous sinus emphasizing operative approaches and related vascular and neural reconstruction. *Neurosurgery* 1987;21(6): 806–816
6. Nutik SL. Pterional craniotomy via a transcavernous approach for the treatment of low-lying distal basilar artery aneurysms. *J Neurosurg* 1998;89(6):921–926
7. Youssef AS, van Loveren HR. Posterior clinoidectomy: dural tailoring technique and clinical application. *Skull Base* 2009; 19(3):183–191
8. Salma A, Wang S, Ammirati M. Extradural endoscope-assisted subtemporal posterior clinoidectomy: a cadaver investigation study. *Neurosurgery* 2010;67(3, Suppl Operative):ons43–ons48; discussion ons48
9. Kassam AB, Prevedello DM, Thomas A, et al. Endoscopic endonasal pituitary transposition for a transdorsum sellae approach to the interpeduncular cistern. *Neurosurgery* 2008;62(3, Suppl 1):57–72; discussion 72–74
10. Nagasawa S, Ohta T. Exostosis of the posterior clinoid process. *Acta Neurochir (Wien)* 1994;126(2–4):195–197
11. Paul S, Das S. Anomalous posterior clinoid processes and its clinical importance. *Columbia-Médica* 2007;38(3):301–304
12. Ozdogmus O, Saka E, Tulay C, Gurdal E, Uzun I, Cavdar S. Ossification of interclinoid ligament and its clinical significance. *Neuroanatomy* 2003;2:25–27
13. Ono M, Rhoton AL Jr, Barry M. Microsurgical anatomy of the region of the tentorial incisura. *J Neurosurg* 1984; 60(2):365–399
14. Berger PE, Harwood-Nash DC, Fitz CR. The dorsum sellae in infancy and childhood. *Pediatr Radiol* 1976;4(4):214–220
15. Tubbs RS, Salter EG, Oakes WJ. Quantitation of and measurements utilizing the sphenoid ridge. *Clin Anat* 2007; 20(2):131–134

16. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part I. Crista galli to the sella turcica. *Neurosurg Focus* 2005;19(1):E3
17. Wang Q, Lan Q, Lu XJ. Extended endoscopic endonasal transsphenoidal approach to the suprasellar region: anatomic study and clinical considerations. *J Clin Neurosci* 2010;17(3):342–346
18. Song M, Zong X, Wang X, et al. Anatomic study of the anterior skull base via an endoscopic transnasal approach. *Clin Neurol Neurosurg* 2011;113(4):281–284
19. Kassam A, Snyderman CH, Mintz A, Gardner P, Carrau RL. Expanded endonasal approach: the rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. *Neurosurg Focus* 2005;19(1):E4
20. Kassam AB, Prevedello DM, Carrau RL, et al. The front door to Meckel's cave: an anteromedial corridor via expanded endoscopic endonasal approach- technical considerations and clinical series. *Neurosurgery* 2009;64(3, Suppl):71–82; discussion 82–83
21. Cavallo LM, Cappabianca P, Galzio R, Iaconetta G, de Divitiis E, Tschabitscher M. Endoscopic transnasal approach to the cavernous sinus versus transcranial route: anatomic study. *Neurosurgery* 2005;56(2, Suppl):379–389; discussion 379–389
22. Abuzayed B, Tanriover N, Gazioglu N, Ozlen F, Cetin G, Akar Z. Endoscopic anatomy and approaches of the cavernous sinus: cadaver study. *Surg Radiol Anat* 2010;32(5):499–508
23. Ziyal IM, Bilginer B, Ozcan OE, Basar R, Sekhar LN, Ozgen T. Course and relationship of cranial nerves from end organs through foramina to root entry zones. How far can they be mobilized: an anatomical study. *Neuroanatomy* 2004;3:46–50