Sinir Sistemi Cerrahisi Derg 4(1):1-8, 2014
doi:10.5222/sscd.2014.001

Derleme

Surgical Access to the Paraclinoid Segment of the Internal Carotid Artery: A Technical Review

Bülent GÜÇLÜ [1], Marc SİNDOU [2]

[1] Neurosurgery Clinic, Ministry of Health, Sevket Yilmaz Research and Training Hospital, Bursa
[2] Department of Neurosurgery, Hopital Neurologique Pierre Wertheimer, Université Claude-Bernard De Lyon, Lyon

Surgical access to the paraclinoid segment of the internal carotid artery is important for safe surgical clipping of paraclinoid carotid aneurysms such as carotid-ophthalmic aneurysms and for the surgical treatment of tumors of the anterior clinoid process (ACP), anterior part of cavernous sinus and the wall of the orbital apex. Anterior clinoidectomy is useful during the surgical access to the paraclinoid segment of the internal carotid artery (ICA). The extensive surgical field gained after anterior clinoidectomy allows lesser brain retraction and increases mobilization of the intracranial ICA and optic nerve. In this report, the authors describe the anatomy of the internal carotid artery and its various segments. Anatomy of the anterior clinoid process and its relation to the internal carotid artery are reviewed. The basic principles of anterior clinoidectomy, the risks and possible complications are also discussed.

Key words: Anterior clinoid process, anterior clinoidectomy, cavernous sinus meningiomas, intracranial internal carotid artery, paraclinoid carotid aneurysms

J Nervous Sys Surgery 2014; 4(1):1-8

İnternal Karotid Arterin Paraklinoid Segmentine Cerrahi Yaklaşım: Teknik Derleme

Paraklinoid karotid anevrizmaların (karotid-oftalmik anerizma gibi) güvenli kliplenebilmesi, anterior klinoid çıkıntı (AKÇ), anterior kavernöz sinüs ve orbital apeks duvarı tümörlerinin cerrahi tedavilerinin yapılabilmesi için, internal karotid arterin paraklinoid segmentine cerrahi yaklaşım çok önemlidir. Anterior klinoidektomi internal karotid arterin (İKA) paraklinoid segmentine cerrahi yaklaşımda çok faydalıdır. Anterior klinoidektomi yapıldıktan sonra kazanılan geniş cerrahi alan, daha az beyin retraksiyonu yapılmasına izin verir, intrakranial İKA'nın ve optik sinirin mobilizasyonunu arttırır. Bu yazıda, yazarlar internal karotid arterin anatomisini ve değişik segmentlerini anlatıyor. Anterior klinoid çıkıntının anatomisi ve internal karotid arter ile ilişkisi gözden geçiriliyor. Anterior klinoidektominin temel prensipleri, riskleri ve komplikasyonları tartışılıyor.

Anahtar kelimeler: Anterior klinoid çıkıntı, anterior klinoidektomi, kavernöz sinüs meninjiyomları, intrakranial internal karotid arter, paraklinoid karotid anevrizma

J Nervous Sys Surgery 2014; 4(1):1-8

Alındığı tarih: 13.01.2013
Kabul tarihi: 01.10.2013
Yazışma adresi: Uzm. Dr. Bülent Güçlü, Sağlık Bakanlığı Şevket Yılmaz Eğitim ve Araştırma Hastanesi, Nöroşirürji Kliniği, Yıldırım 16310 Bursa
e-mail: guclubulent@hotmail.com

Surgical access to the paraclinoid segment of the internal carotid artery is important to know for surgical treatment of aneurysms of the paraclinoid, carotid-ophthalmic and/or anterior cavernous segments of the inter-

nal carotid artery (ICA), and also for tumors of the anterior clinoid process (ACP), anterior part of the cavernous region and orbital apex. Understanding the anatomy and various segments of ICA is therefore very important for successful surgical access to this region. To reach the paraclinoid segment of the ICA, surgical removal of the anterior clinoid process is necessary. This report reviews the basic principles of anterior clinoidectomy, together with its applications, risks and possible complications.

Segments of the Internal Carotid Artery

The classic description of the segments of the internal carotid artery was introduced in 1938 by Fischer who published a seminal paper describing five segments of the ICA that were designated C1 through C5 [13]. According to Fischer's nomenclature, segmentation is based on the angiographic course of the intracranial ICA rather than its arterial branches or anatomic compartments (Figure 1). In the original Fischer system, segments of the ICA were numbered opposite to the direction of blood flow, beginning at the carotid terminus. The ICA from the carotid terminus to the posterior communicating artery was C1, from the posterior communicating artery to the distal dural ring was C2, from distal dural ring to proximal dural ring was C3, from the proximal dural ring to medial loop of the ICA was C4, from the medial loop of ICA to foramen lacerum was C5.

A new anatomically based nomenclature for the internal carotid artery was recently proposed by Bouthillier in 1996 [5]. Although this nomenclature is the most recent one, it has gained great acceptance. According to this nomenclature, the internal carotid artery has seven distinct segments (Figure 2). The first segment of the ICA is the cervical segment (C1) which begins at the level of the common carotid artery bifurcation and runs inside the carotid sheath with the internal jugular vein and the vagus nerve. The cervical segment of the ICA ends where it enters the carotid canal of the petrous bone. The second segment of the ICA is called the petrous segment (C2). This segment begins at the entrance of carotid canal and ends at the posterior edge of the foramen lacerum. The petrous segment consists of a vertical portion, a bend (posterior loop of ICA) and a horizontal portion. The third segment is the lacerum segment (C3) which begins where the carotid canal ends. The lacerum segment ends at the superior margin of the petrolingual ligament which runs between the lingula of the sphenoid bone anteriorly and the petrous apex posteriorly. The forth segment of the ICA is the cavernous segment (C4) which begins at the su-

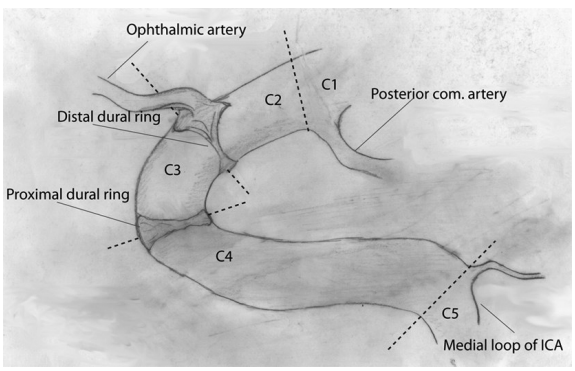

Figure 1. Fischer's classification of carotid artery [13]. ICA from carotid terminus to posterior communicating artery is C1, from posterior communicating artery to distal dural ring is C2, from distal dural ring to proximal dural ring is C3, from proximal dural ring to medial loop of ICA is C4, from medial loop of ICA to exit of ICA from petrous bone is C5.

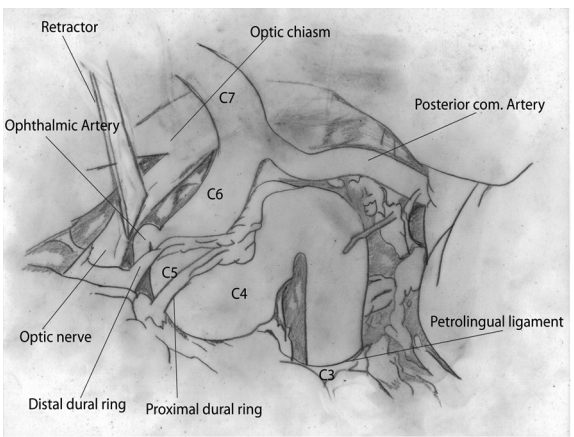

Figure 2. Bouthillier's classification of carotid artery [5]. Carotid artery is divided into 7 segments. First and second segments are not shown in this drawing.

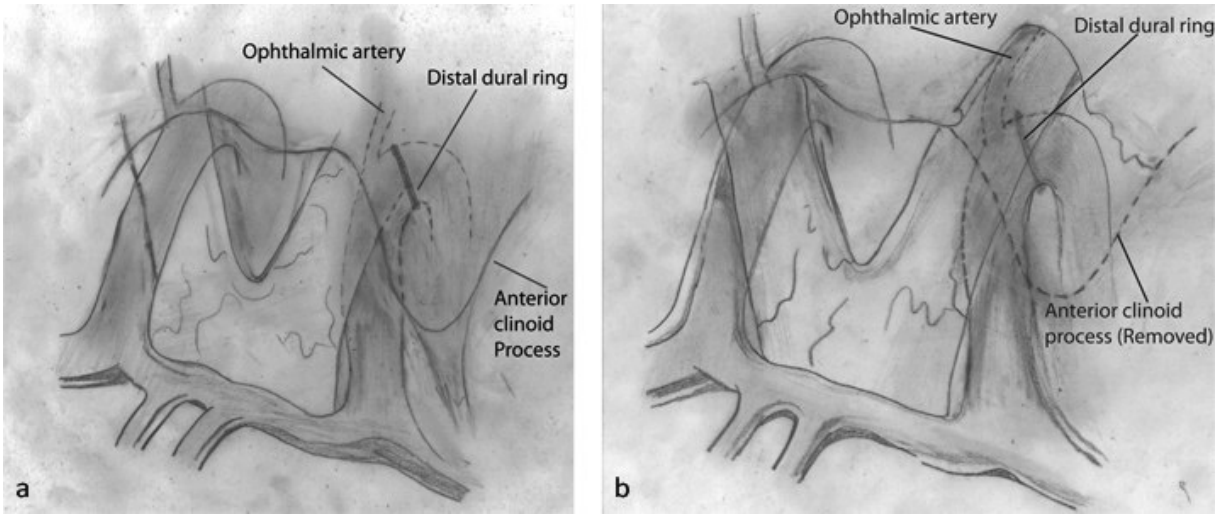

Figure 3. (a) The anterior clinoid process obscures the origin of ophthalmic artery and distal dural ring. (b) After anterior clinoidectomy (dotted curved line), origin of ophthalmic artery and distal dural ring are better visualized.

perior margin of the petrolingual ligament. This segment has a vertical portion, a posterior bend, a horizontal portion, and an anterior bend. The cavernous segment ends at the proximal dural ring which is formed by the junction of the medial and inferior periosteum of the anterior clinoid process. The clinoid segment (C5) which is the fifth segment of the ICA begins at the proximal dural ring and ends at the distal dural ring. This segment is short and extra-cavernous. The ophthalmic segment (C6) which is the sixth segment of the ICA begins at the distal dural ring and ends just proximal to the origin of the posterior communicating artery. The ophthalmic and superior hypophyseal arteries arise from this segment. The anterior clinoid process obscures the lateral surface of the proximal ophthalmic segment. The seventh segment (C7) which is the communicating segment begins just proximal to the origin of the posterior communicating artery and ends at the ICA bifurcation.

Description of Anterior Clinoid Process

Understanding the surgical anatomy of anterior clinoid process is necessary to perform proper and safe anterior clinoidectomy and to expose the paraclinoid ICA. The anterior clinoid process (ACP) is a bony projection located on the medial extremity of the posterior border of the lesser sphenoid wing and is a part of the lesser sphenoid bone [18,24]. The anterior clinoid process masks the origin of ophthalmic artery (Figure 3). Surgical removal of the ACP is called anterior clinoidectomy. ACP which is part of the sphenoid bone is a posterior and medial continuation of the lesser sphenoid wing. ACP appears as a triangular mass when viewed superiorly with the tip projecting medioposteriorly [18]. Anteriorly, its base continues with the medial end of the sphenoid ridge. Medially, the base connects to the body of the sphenoid bone by anterior and posterior roots. The anterior (which is also superior) root is flat, forms the roof of the optic canal, and continues as the planum sphenoidale. The posterior root (which is also inferior), called the optic strut, forms the lateral and inferior walls of the optic canal and connects the lesser sphenoid wing with the basisphenoid bone [17]. Sometimes, the ACP unites with either the middle or posterior clinoid process by a fibrous or osseous bridge. If the ACP unites with the middle clinoid process completely, a caroticoclinoid foramen forms. Inferolaterally the ACP is contiguous with oculomotor and trochlear nerve, ophthalmic divisions of the trigeminal nerve and the abducens nerve,

as these structures run forward to superior orbital fissure with the oculomotor nerve being closest [7,18,24]. Inferomedially there is a dural layer and under it there is a region called the clinoid space [18].

Surgical Technique

Surgical technique: After the patient was given nasotracheal anesthesia, and placed on the table in supine position, his/her head should be turned 30 degree to on side. An arc-shaped incision suitable for pterional craniotomy should be made in the frontotemporal area. After performing pterional craniotomy, the orbital rim should be removed to gain space. Dura mater opening suitable for sylvian dissection should be made and dura mater should be suspended. Under microscopic examination, two retractors should be used to have access to opticocarotid area, one for the frontal lobe and one for the temporal lobe. After sylvian dissection, the opticocarotid and the opticochiasmatic cisterns should be opened. Anterior clinoidectomy is very important for surgical approach to the paraclinoid segment of internal carotid artery. Anterior clionidectomy can be done with high speed drill or en-block [33]. Both techniques have some drawbacks. Drilling of the ACP may produce heat, and this may cause injury to the optic nerve. En bloc removal of the ACP would likely require additional manipulation and this action may damage oculomotor nerve, which runs close to the lateral undersurface of the ACP. Anterior clinoidectomy can be done extradurally or intradurally. Extradural anterior clioidectomy is preferred for cavernous sinus meningiomas [19,28,30,34]. For extradural anterior clinoidectomy, anterior clinoid process should be disengaged from its three supporting structures namely: 1) the lesser wing of the sphenoid bone; 2) the roof of the optic canal; and 3) the optic strut. Intradural anterior clioidectomy is preferred for infraclinoidal aneurysms, and for aneurysms originating fom proximal internal carotid artery [25,26,32]. For carotid-ophthalmic aneurysms intradural or extradural anterior clinoidectomy or combined approach can be appropriate [9,10]. In intradural anterior clinoidectomy, origin of the ophthalmic artery is found. Distal dural ring, the falciform ligament and the dura over the optic nerve are -dissected from surrounding structures for better exposure of the carotid artery and ophthalmic artery (Figure 4). Then the optic nerve is gently retracted medially in order to -enlarge opticocarotid window significantly (Figure 5). Sometimes anterior clinoid process

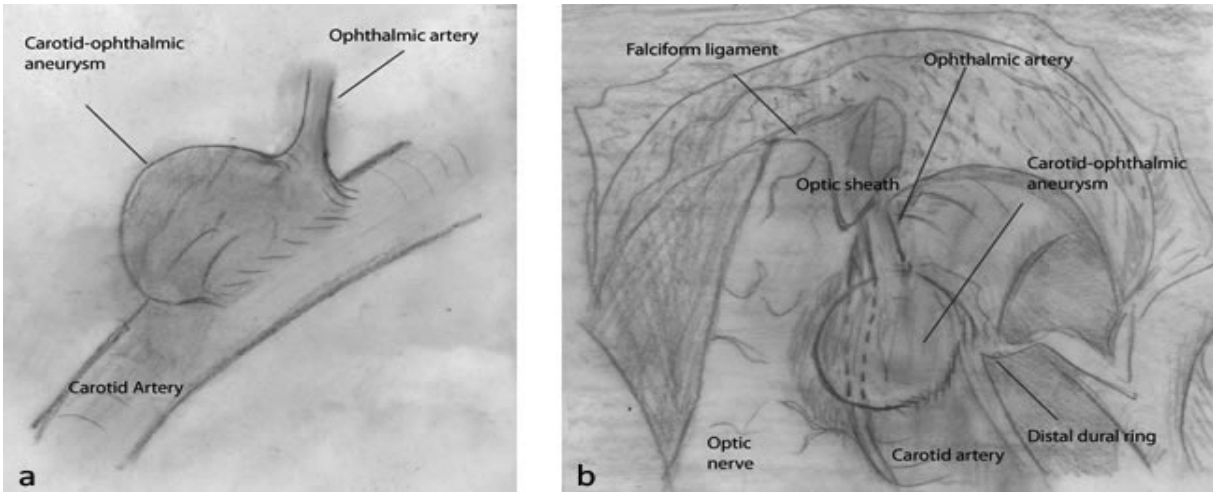

Figure 4. Schematic drawings showing a right carotid-ophthalmic aneurysm with broad neck including ostium of the ophthalmic artery (a), optic nerve with its dural sheath and falciform ligament, carotid artery, ophthalmic artery and carotid-ophthalmic aneurysm, after anterior clinoidectomy and cutting distal dural ring (b).

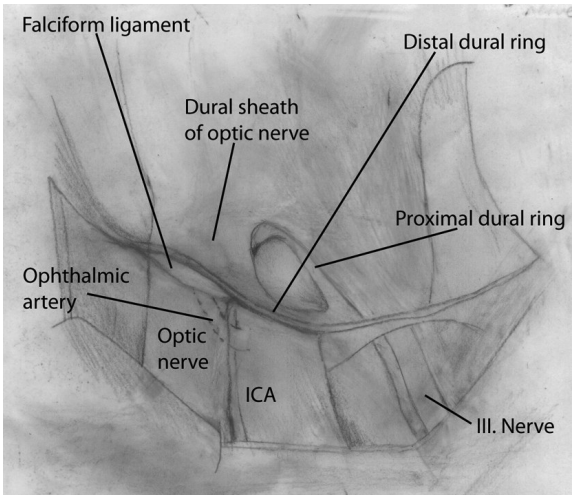

Figure 5. Drawing showing proximal dural ring, distal dural ring, falciform ligament and dural sheath of optic nerve.

is pneumatized. After pneumatization of the anterior clinoid process, mucosa of the ethmoid or sphenoid is encountered which must be protected and not opened. If it is opened a small piece of fat tissue must be taken from the subcutaneous area and put on the pneumatization site of anterior clinoid process.

Risks and Complications of Anterior Clinoidectomy

The surgeon needs to be aware of the risks and complications of anterior clinoidectomy before performing the procedure. Complications include visual disturbances, oculomotor paresis, injury to the optic nerve or internal carotid artery, opening of the paranasal sinuses with consequent rhinorrhea and pneumocephalus, occlusion of the ophthalmic artery, and intraoperative rupture of an aneurysm. The patient's vision can be impaired -during the surgical approach to a cavernous sinus menigioma after anterior clinoidectomy [19].

As noted above, one of the complications of the anterior clinoidectomy is opening of the paranasal sinuses and the concomitant risk of cerebrospinal rhinorrhea [23]. Sometimes the ACP

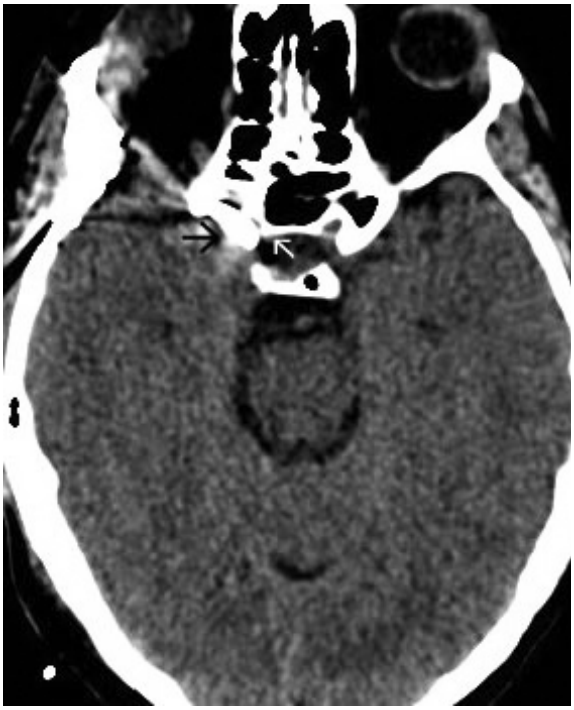

Figure 6. Postoperative cranial CT of a patient showing margins of right anterior clinoidectomy (white arrow) and position of the two aneurysm clips placed easily after anterior clinoidectomy(black arrow).

is pneumatized and contains air cells that communicate with the paranasal sinuses. The origin of pneumatization can be the sphenoid sinus, the ethmoid sinus, or both. Pneumatization of the ACP can be via the anterior root, posterior root, or both. The frequency of rhinorrhea after an anterior clinoidectomy was between 2.7 and 7 % in reported series [16,25,33]. In healthy people, 4 to 29.3 % of ACPs were pneumatized in different series [2,4,6,8,14,23,27,31]. Thus, closing the opening of the paranasal sinus is mandatory. Keeping the mucous membrane intact and pushing it into the paranasal sinus may decrease the probablity of rhinorrhea. This can be managed by drilling pneumatized ACP with a diamond burr. Bone reconstructed preoperative CT assessments is helpful to evaluate pneumatization of the ACP.

Surgical Applications

Surgical access to paraclinoid segment of the internal carotid artery through anterior cli-

noidectomy is useful when performing surgical removal of cavernous sinus menigiomas or surgical clipping of paraclinoid aneurysms. During surgery for meningiomas of the anterior clinoid process or cavernous sinus, extradural anterior clinoidectomy allows freeing of the dural sheath of the optic nerve completely and exposing the paraclinoid portion of the ICA after its exit from cavernous sinus roof. Anterior clinoidectomy also achieves significant devascularization of the meningioma and contributes to less bleeding by interrupting the feeder vessels coming from the paraclinoid segment of ICA and the ophthalmic artery.

Carotid cave aneurysms which arise ventrally from the internal carotid artery and other clinoid segment aneurysms are a rare subtype of paraclinoid aneurysms. Carotid cave aneurysms localized in the carotid cave are typically small, grow ventromedially, and extend into the cavernous sinus. They project medially on the anteroposterior view of the angiogram and posteriorly on the lateral view of the angiogram [20]. The most common paraclinoid carotid aneurysms are carotid-ophthalmic aneurysms [3]. Aneurysms arising from the internal carotid artery between the ophthalmic artery and the posterior communicating artery are called carotid-ophthalmic aneurysms [9]. The percentage of the carotid-ophthalmic aneuryms among all intracranial aneurysms in different series varies between 1.5 and 8 percent [11,15,21,22]. The most common site for carotid-ophthalmic aneurysms is the superior surface of internal carotid artery near the origin of ophthalmic artery [3]. The first direct approach to carotid-ophthalmic aneurysms was described in 1968 by Drake [11]. Dolenc proposed a combined epi- and subdural approach to carotid-ophthalmic artery aneurysms in 1985 [9]. His method of removing the orbital roof and then performing an anterior clinoidectomy for exposure of carotid-ophthalmic aneurysms has become popular. Later he developed a combined transorbital-transclinoid and transsylvian approach for operating on large and giant carotid-ophthalmic aneurysms [10]. Insufficient exposure of the neck of carotid-ophthalmic aneurysm is one of the major causes for incompleteness of surgical clipping [29] (Figure 6). After anterior clinoidectomy, the ophthalmic artery and proximal neck of the aneurysm are visualized better, the optic nerve is decompressed and mobilized easier, and more satisfactory surgical exposure is achieved [1,12,33]. In addition, after anterior clinoidectomy, dissection of the distal dural ring, falciform ligament and dura from the optic nerve enables lesser retraction which in turn allows mobilization of the intracranial ICA and optic nerve.

CONCLUSION

Surgical access to the paraclinoid segment of the internal carotid artery is important for safe surgical clipping of paraclinoid carotid aneurysms and for surgical treatment of tumors of the anterior clinoid, anterior part of cavernous sinus and wall of the orbital apex. The extensive surgical field gained after anterior clinoidectomy increases mobilization of the intracranial ICA and optic nerve. Anterior clinoidectomy is also very important for devascularization of the skull base meningiomas with feeders coming from the paraclinoid segment of the ICA and from the ophthalmic artery.

REFERENCES

1. **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;148:971-5. http://dx.doi.org/10.1007/s00701-006-0862-x
2. **Arslan H, Aydinlioğlu A, Bozkurt M, Egeli E.** Anatomic variations of the paranasal sinuses: CT examination for endoscopic sinus surgery. *Auris Nasus Larynx* 1999;26:39-48. http://dx.doi.org/10.1016/S0385-8146(98)00024-8
3. **Barami K, Hernandez VS, Diaz FG, Guthikonda M.** Paraclinoid Carotid Aneurysms: Surgical Management,

Complications, and Outcome Based on a New Classification Scheme. *Skull Base* 2003;13:31-41. http://dx.doi.org/10.1055/s-2003-37551

4. **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. http://dx.doi.org/10.1288/00005537-199101000-00010
5. **Bouthillier A, van Loveren HR, Keller JT.** Segments of the internal carotid artery: a new classification. *Neurosurgery* 1996;38:425-33.
6. **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;18:173-8.
7. **Collignon F, Link M.** Paraclinoid and cavernous sinus regions: measurement of critical structures relevant for surgical procedure. *Clin Anat* 2005;18:3-9. http://dx.doi.org/10.1002/ca.20053
8. **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;17:669-75.
9. **Dolenc VV.** A combined epi- and subdural direct approach to carotid-ophthalmic artery aneurysms. *J Neurosurg* 1985;62:667-72. http://dx.doi.org/10.3171/jns.1985.62.5.0667
10. **Dolenc VV.** A combined transorbital-transclinoid and transsylvian approach to carotid-ophthalmic aneurysms without retraction of the brain. *Acta Neurochir Suppl* 1999;72:89-97.
11. **Drake CG, Vanderlinden RG, Amacher AL.** Carotid-ophthalmic aneurysms. *J Neurosurg* 1968;29:24-31. http://dx.doi.org/10.3171/jns.1968.29.1.0024
12. **Evans JJ, Hwang YS, Lee JH.** Pre-versus post-anterior clinoidectomy measurements of the optic nerve, internal carotid artery, and opticocarotid triangle: a cadaveric morphometric study. *Neurosurgery* 2000;46: 1018-23.
13. **Fischer E.** Die Lageabweichungen der vorderen hirnarterie im gefassbild. *Zentralbl Neurochir* 1938;3:300-31.
14. **Gean AD, Pile-Spellman J, Heros RC.** A pneumatized anterior clinoid mimicking an aneurysm on MR imaging. Report of two cases. *J Neurosurg* 1989;71:128-32. http://dx.doi.org/10.3171/jns.1989.71.1.0128
15. **Guidetti B, La Torre E.** Management of carotid-ophthalmic aneurysms. *J Neurosurg* 1975;42:438-42. http://dx.doi.org/10.3171/jns.1975.42.4.0438
16. **Hoh BL, Carter BS, Budzik RF, Putman CM, Ogilvy CS.** Results after surgical and endovascular treatment of paraclinoid aneurysms by a combined neurovascular team. *Neurosurgery* 2001;48:78-90.
17. **Hunnargi S, Ray B, Pai SR, Siddaraju KS.** Metrical and non-metrical study of anterior clinoid process in South Indian adult skulls. *Surg Radiol Anat* 2008; 30:423-28. http://dx.doi.org/10.1007/s00276-008-0346-1
18. **Huynh-Le P, Natori Y, Sasaki T.** Surgical anatomy of the anterior clinoid process. *J Clin Neurosci* 2004;11:283-87. http://dx.doi.org/10.1016/j.jocn.2003.08.005
19. **Jacob M, Wydh E, Vighetto A, Sindou M.** Visual outcome after surgery for cavernous sinus meningioma. *Acta Neurochir (Wien)* 2008;150:421-9. http://dx.doi.org/10.1007/s00701-008-1554-5
20. **Kobayashi S, Kyoshima K, Gibo H, Hegde SA, Takemae T, Sugita K.** Carotid cave aneurysms of the internal carotid artery. *J Neurosurg* 1989;70:216-21. http://dx.doi.org/10.3171/jns.1989.70.2.0216
21. **Kothandaram P, Dawson BH, Kruyt RC.** Carotid-ophthalmic aneurysms. A study of 19 patients. *J Neurosurg* 1971;34:544-48. http://dx.doi.org/10.3171/jns.1971.34.4.0544
22. **Locksley HB, Sahs AL, Sandler R.** Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. 3. Subarachnoid hemorrhage unrelated to intracranial aneurysm and A-V malformation. A study of associated diseases and prognosis. *J Neurosurg* 1966;24:1034-56. http://dx.doi.org/10.3171/jns.1966.24.6.1034
23. **Mikami T, Minamida Y, Koyanagi I, Baba T, Houkin K.** Anatomical variations in pneumatization of the anterior clinoid process. *J Neurosurg* 2007;106:170-4. http://dx.doi.org/10.3171/jns.2007.106.1.170
24. **Noguchi A, Balasingam V, Shiokawa Y, McMenomey SO, Delashaw JB Jr.** Extradural anterior clinoidectomy. Technical note. *J Neurosurg* 2005;102:945-50. http://dx.doi.org/10.3171/jns.2005.102.5.0945
25. **Nutik SL.** Removal of the anterior clinoid process for exposure of the proximal intracranial carotid artery. *J Neurosurg* 1988;69:529-34. http://dx.doi.org/10.3171/jns.1988.69.4.0529
26. **Perneczky A, Knosp E, Vorkapic P, Czech T.** Direct surgical approach to infraclinoidal aneurysms. *Acta Neurochir (Wien)* 1985;76:36-44. http://dx.doi.org/10.1007/BF01403827
27. **Sapçi T, Derin E, Almaç S, Cumali R, Saydam B, Karavuş M.** The relationship between the sphenoid and the posterior ethmoid sinuses and the optic nerves in Turkish patients. *Rhinology* 2004;42:30-4.
28. **Sindou M.** Surgical strategy for cavernous sinus tumors. *Neurochirurgie* 1995;41:208-23.
29. **Sindou M, Acevedo JC, Turjman F.** Aneurysmal remnants after microsurgical clipping: classification and results from a prospective angiographic study (in a consecutive series of 305 operated intracranial aneurysms). *Acta Neurochir* 1988;140:1153-9. http://dx.doi.org/10.1007/s007010050230
30. **Sindou M, Wydh E, Jouanneau E, Nebbal M, Lieutaud T.** Long-term follow-up of meningiomas of the cavernous sinus after surgical treatment alone. *J Neurosurg* 2007;107:937-44. http://dx.doi.org/10.3171/JNS-07/11/0937
31. **Sirikci A, Bayazit YA, Bayram M, Mumbuç S, Güngör K, Kanlikama M.** Variations of sphenoid and related structures. *Eur Radiol* 2000;10:844-8.

http://dx.doi.org/10.1007/s003300051016

32. Sundt TM Jr, Piepgras DG. Surgical approach to giant intracranial aneurysms. Operative experience with 80 cases. *J Neurosurg* 1979;51:731-42. http://dx.doi.org/10.3171/jns.1979.51.6.0731

33. Takahashi JA, Kawarazaki A, Hashimoto N. Intradural en-bloc removal of the anterior clinoid process. *Acta Neurochir* 2004;146:505-9. http://dx.doi.org/10.1007/s00701-004-0249-9

34. Yonekawa Y, Ogata N, Imhof HG, Olivecrona M, Strommer K, Kwak TE, et al. Selective extradural anterior clinoidectomy for supra- and parasellar processes. Technical note. *J Neurosurg* 1997;87:636-4. http://dx.doi.org/10.3171/jns.1997.87.4.0636