Giant brain aneurysms of anterior circulation. Surgical anatomy

Paulo Henrique Aguiar[1,2], Carlos Alexandre Zicarelli[1,3,4], Gustavo Isolan[2], Apio Claudio Antunes[2]
1 Clinic of Neurology and Neurosurgery of Pinheiros, São Paulo, Brazi.l
2 Federal University of Rio Grande do Sul, Rio Grande do Sul, Brazil.
3 Department of Neurosurgery of Santa Casa, Londrina, Brazil.
4 Pontifícia Universidade Católica do Paraná, Brazil.

Rev. Chil. Neurocirugía 39: 150 - 156, 2013

Abstract

Giant aneurysms are defined as an aneurysm must measure more than 2.5 cm at the largest diameter. The natural history of giant aneurysms shows that the mortality rate between 2 and 5 years after diagnosis is 68% and 85% respectively. The giant aneurysms originated from the carotid artery or the basilar tip must be approached through skull base techniques. To treat these complex lesions the deep knowledge of the cavernous sinus anatomy is paramount. The authors show the microsurgical anatomy, diagnostic evaluation, surgical approaches and the complications of the surgery of the giant anterior circulation aneurysms.

Key words: Giant Aneurysms, anterior circulation.

Introduction

Giant aneurysms are defined as an aneurysm must measure more than 2.5 cm at the largest diameter[1]. They are classified in saccular, fusiform or dolichoectatic aneurysms. These last has been described by some authors as separated disease from giant aneurysms[2].

The natural history of giant aneurysms shows that the mortality rate between 2 and 5 years after diagnosis is 68% and 85% respectively[3,4]. The giant aneurysms may be discovered incidentally, however the majority of them cause symptoms as the result of compression, irritation of neural tissue causing seizures, thromboembolism, or less frequent subarachnoid haemorrhage. Hydrocephalus can occur due to compression by the large aneurysm. The rupture of giant aneurysm in the cavernous segment of the internal carotid artery (ICA) can lead to carotid – cavernous fistulae or epistaxis if the rupture is not under control and extends into the sphenoid or ethmoid sinus[5].

Epidemiology

The giant aneurysms occur mostly in females and the peak of age of diagnosis is 40 to 60 years of age. Most of them occur in the anterior circulation along the ICA (cavernous, ophthalmic, and paraclinoid segments), middle cerebral artery (MCA), and anterior cerebral artery (anterior communicating complex - AcommA)[3,6,7,8,9,10,11,12,13]. In the posterior circulation, the giant aneurysms involve the basilar artery apex, followed by vertebrobasilar junction, peripheral segments of the posterior cerebral artery (PCA), posterior inferior cerebellar artery (PICA), and the trunk of basilar artery[3,6,7,8,9,10,11]. They could be multiple[14] and on Fox`s series of 693 patients, multiple giant aneurysms could be found in 7% of patients[7].

Diagnostic Evaluation

During the operative procedure for carotid cavernous aneurysms, patients are routinely monitored with electroencephalography (EEG) by using standard scalp electrodes placed through the craniotomy site. Continuous transcranial doppler (CTD) is used the monitor the cerebral blood flow (CBF) and is useful in monitoring the clipping of complex aneurysms[15]. Angiography with occlusion test may be used to find out about the tolerance of the patient an acute ligation of the internal carotid artery. The balloon occlusion test (BOT) to confirm that determined patient can tolerate the sacrifice of the ICA is a sophisticated test it is imperative to be used before planning to sacrifice isolated parent vessel. The BOT along with adjuncts (xenon cerebral blow flow test (Xe CT-CBF) and induced hypotension) can be used to help select patients who may tolerate sacrifice of parents vessels.

A change in EEG or clinical outcome with carotid occlusion also indicates that the patient will not tolerate chronic internal carotid ligation. In either such case, a bypass graft is indicated. A saphenous vein bypass graft is preffered over temporal artery bypass pedicles in treating these patients simply because it delivers a larger volume of flow[15,16].

Magnetic resonance (MR) angiography and computed tomographic (CT) angiography are useful to adjuncts to angiography.Three dimensional CT (3-D-CT) angiography can help determine the lobularity and three dimensional conformation of the aneurysms. (Figures 1 and 2).

Microsurgical Anatomy

The giant aneurysms originated from the carotid artery or the basilar tip must be approached through skull base techniques. To treat these complex lesions the deep knowledge of the cavernous sinus (CS) anatomy is paramount.

The development and understanding of the Cavernous Sinus anatomy that began with Parkinson[17], Dolenc[18,19,20,21,22], Taptas[23], Umansky[24] and Harris and Rhoton[25] emphasizes the necessity of a deep knowledge of the complex microanatomy of this region before approach lesions sit here. The cranial base related to the CS can be divided in 10 triangular spaces in and around it, belong only four of those triangular space to the CS itself[26]. These spaces constitute natural corridors to approach lesions situated here. However, in some pathologies, principally giant aneurysms, these geometrical spaces can be distorted and unconventional and the choice of the approach and intraoperative decisons are better done through one or a combination of one of the four walls of the CS (lateral, medial, superior and posterior) before based on the ecstatic anatomy of the triangles. There is no doubt, however, that a three-dimensional knowledge of the normal triangles anatomy is undispensable to recognize the distorted patterns caused by tumors or vascular lesions.

Cavernous sinus anatomy

The lateral wall of the CS is formed by two layers (inner or endosteal and outer or meningeal) loosely attached to each other. After peeling the middle fossa and the outer layer on the CS, the III, IV, V1, V2, V3, greater and lesser petrosal nerves and venous channels of the CS are identified covered by the inner layer. In the CS, the III, IV and V1 are visualized trough the semitransparent outer part of the inner layer. At the level of the Meckel's cave the lateral sinus wall blends into the dura covering it. The entering into the CS trough this wall can be trough the triangular spaces between the oculomotor and trochlear nerves (supratrochlear triangle) or between the trochlear nerve and the upper edge of V1 (Infratrochlear or Parkinson's triangle). The outer layer is more adherent to the nerves around the entry point these in the respective foramens. Because this, the dissection of the outer layer from the inner layer is not so easy around the superior orbital fissure, oval and round foramen.

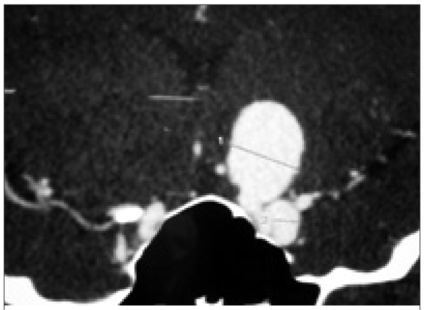

Figure1. Angio CT shows a giant paraclinoid aneurysm projected upwardand a intracavernous aneurysm below.

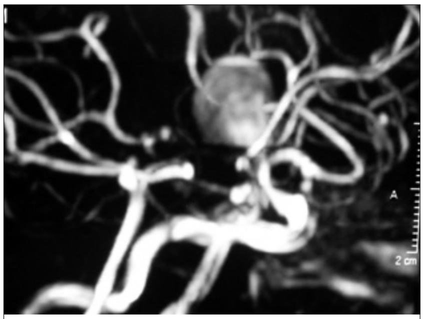

Figure 2. AngioMRI showing the volumous giant aneurysm.

The medial wall of the CS is located in the body of the sphenoid bone and is formed by the inner part of the endosteal layer. Its limits are the superior orbital fissure (anterior), the dorsum sellae (posterior), the superior margin of the maxillary nerve (inferior), and the diaphragma sellae (superior). There is a plane of cleavage between the pituitary gland capsule and the medial wall. In our specimens was not found any dural defect in this wall with high microscope magnification. The dura is very thin and can not be separated in layers. The intracavernous internal carotid artery is in direct contact with the capsule of the pituitaty gland in some specimens. The medial wall has two well identifiable parts, one in relation to the pituitary gland and other in relation to the carotid sulcus.

The superior wall is formed by two layers, being the inner layer more thin. It can be divided in two triangles, the clinoidal (anterior) and the oculomotor (posterior). The anterior part of the superior wall is delimited by the optic nerve confined within the optic canal, the medial aspect of the third cranial, and the dura extending between the dural entry point of the third cranial nerve and the optic nerve. After drilling the anterior clinoidal process the clinoidal segment of the ICA is identified between the upper and lower rings surrounded by the carotid collar. The clinoidal segment of the ICA belongs to the CS considering the fact that there is venous blood under the carotid collar that communicates with the venous channels of the CS. The lower dural ring is formed by the dura that surround the ICA and is called carotidoculomotor membrane. The posterior part of the superior wall is delimited by the anterior and posterior petroclinoid and the interclinoid dural folds, which forms the sides of the oculomotor triangle. The oculomotor and trochlear nerves enter in the posterior part of the superior wall of the CS but after they course in the lateral wall (the oculomotor above the trochlear nerve, both inside the inner layer) and then enter in the superior orbital fissure.

We considered the posterior wall limits according with Rhoton[27]. The posterior petroclinoid dural fold (superior), the dura of the medial edge of the trigeminal porus (lateral), the upper margim of petroclival fissure (inferior) and the lateral edge of the dorsum sellae (medial). The sixth nerve enters into the CS trought the Dorello's canal. The superior limit of it is the petrosphenoidal ligament of Grüber, that is a fibrous bundle that extends from the apex of the petrous bone to the upper clivus[27].

The intracavernous carotid artery can be divided in five segments, that are posterior vertical, posterior bend, horizontal, anterior bend and anterior vertical. It has usually three main branches: the meningohipophyseal trunk, the inferior artery of the cavernous sinus and the McConnell's artery. The major branch is often the meningohipophyseal trunk. Its origin is the posterior bend of the ICA. It has three branches: tentorial artery, dorsal meningeal artery and the inferior hipophyseal artery. The inferior artery of the cavernous sinus (inferolateral trunk) arises inferolaterally or lateral to the horizontal portion of the cavernous ICA. The McConnell´ artery has its origin in the medial surface of the cavernous ICA and supplies the pituitary capsule, but is seldom identified. The ophthalmic artery came from intracavernous carotid artery in few cases[26].

The CS has four venous spaces that are defined in relation to the intracavernous carotid artery. These spaces are the medial, lateral, anteroinferior and posterosuperior. Medially, the CS of both sides communicated one each other trough the intercavernous sinus. The afferent vessel to the CS are the inferior and superior ophthalmic vein, sphenoparietal sinus, superficial sylvian vein and middle meningeal vein. The efferent are basilar plexus end inferior petrosal sinus. Laterally, can have a communication with the pterygoid plexus trough an emissary sphenoid foramen or oval foramen.

Treatment

There are many techniques to treat the giant aneurysms as microsurgical clipping, ligation of ICA, trapping, superficial temporal artery - middle cerebral artery anastomosis (STA-MCA), saphenous venous graft by pass, wrap or reinforced, endovascular treatment[11]. Contralateral ICA and AcommA aneurysms, the presence of vasospasm (after aneurismal subarachnoid haemorrhage -SAH), and artherosclerosis of the contralateral ICA or common carotid artery are contraindications to ICA occlusion. Beyond any doubt, the basilar artery should not be occluded electively if aneurysms are placed on the posterior communicating arteries. (PcommA).

Indications for surgery

Not all patients with giant aneurysms arising from the cavernous portion of the internal carotid artery need undergo surgery. There are many many patients in their eighth decade of life who have a giant aneurysm but have only isolated extracranial nerve palsies and do not suffer from severe pain. Because these lesions seldom cause a subarchnoid haemorrhage and do not often serve as a source of emboli, we recommend conservative management for those individuals.

We recommend surgery only when there is progressive growth of the aneurysm and the development of pain.

Generally speaking the main indications for surgical or endovascular treatment are threefold:

1- Exclusion of the aneurysm from the circulation.
2- Preservation of distal blood flow.
3- Decompression of neural structures.

Indications for endovascular treatment

Based on the series of Guglielmi et al[28] and Gobin et al[29], it seems that endovascular treatment for giant aneurysms is most effective for aneurysms with small necks or those with favourable neck to fundus ratios.

Aneurysmal endosaccular coiling can be considered to temporize ruptured giant aneurysms, however in our opinion we prefer to use the endosaccular coil occlusion of giant aneurysms only in patients who are too unstable, and require medical stabilization after an SAH. Unclippable aneurysms of posterior circulation due to brain edema, and difficulty location we prefer the endosaccular coil occlusion. Complex and giant aneurysms could be treated using Calcium alginate polimer with success, avoiding a high rate of recanalization when compared with packed coils[30].

Surgical approach to carotid cavernous aneurysms

The success of surgery for aneurysms arising from the intracavernous portion of the internal carotid artery is dependent upon the surgeon`s working knowledge of the anatomy of the cavernous sinus and of the various surgical approaches available for exploration of the carotid artery in this area. Parkinson[17] and Dolenc[18,19] must be recognized for their important contribution toward a description of the surgical anatomy and surgical approaches to this region[20].

Dolenc[21] has described the surgical approach to the lateral and cavernous sinus, including skeletonizing the internal carotid artery in the carotid canal lateral to the fifth nerve. This is an important approach, but should be avoided by anyone who has not practiced the technique extensively in autopsy room or anatomic laboratory. We have exposed the cervical internal carotid artery rather than to isolate the internal carotid artery in the middle fossa[11]. However, occasionally an aneurysm arising in the canal and projecting from the floor of the middle fossa requires isolation of the internal carotid artery laterally.

Surgical technique for giant anterior circulation aneurysms

Giant aneurysms and cavernous sinus

In general, for vascular lesions that involve the intracavernous carotid artery endovascular techniques are first considered, but there are some examples of lesions that must be treated with direct surgery such as a fusiform and large aneurysm and a traumatic aneurysm located in the anterior loop of the ICA[19,20]. The pioneer and revolutionary works of Dolenc about CS anatomy, in special about the clinoidal segment of intracavernous carotid artery, became the approach of the paraclinoid aneurysms safer[18,19,21]. Evidently that the indication must always be individualized according with patient conditions and the experience of the surgeon, but clipping occlusion of an aneurysm is superior to the endovascular techniques. The CS anatomical knowledge is crucial also for the aneurysms arising from the ophthalmic segment of the carotid artery because the neck of the aneurysm is often hidden by the anterior clinoid process. If these aneurysms have a superior or superomedial projection, the anterior clinoid process must be drilled intradurally under direct visualization, because sometimes a broad neck of the aneurysms can penetrate the clinoidal space. In relation to the basilar tip aneurysms, sometimes, trough the posterior part of the superior wall is necessary drilling out the posterior clinoid process to approach the basilar aneurysm neck when it is hidden behind the dorsum sellae[31,32,33].

So important such the anatomy of these corridors in the CS is the surfaces of the CS (medial, lateral, superior, posterior and inferior) because larges aneurysms may distorted the triangles. The consideration of the walls is more important than the triangles itself when the approaches are considered.

Extradural approach

The area of the anterior clinoid process is most conveniently approached by beginning the resection of the lesser wing of the sphenoid bone laterally. The interfascial approach to the pterion gives the surgeon better access to this area than does muscle-splitting incision[31]. After the resection of the lateral portion of the lesser wing of the sphenoid bone, the orbital roof is removed as far medially as the optic canal, which serves as convenient landmark and reference point during the remaining portion of the dissection. Bone can be removed from the superior and inferior aspects of the optic nerve, but the surgeon ought to be careful about resecting bone inferior to the nerve because doing so, results in entrance of sphenoid sinus and risk of infection. This aperture may be occluded with muscles packs and fibrin glue, nevertheless leakage of cerebral spinal fluid (CSF) through the sphenoid bone in this area can occur.

After the bone between the optic canal and the anterior clinoid process has been removed, the clinoid is anchored to bone only through the optic strut. The optic strut marks the anterior loop of internal carotid artery. This strut is removed by using the diamond bit of diamond air drill. Once, the optic strut has been removed, the anterior clinoid is free of supportive bone. The anterior clinoid process is then removed by strippong the dura away from its margins against traction being supplied through small Kelly instrument. (An illustrative case is shown by Figures 3, 4, 5 y 6).


Figure 3. Postion of head for craniotomy and cervicotomy exposing the carotid artery.

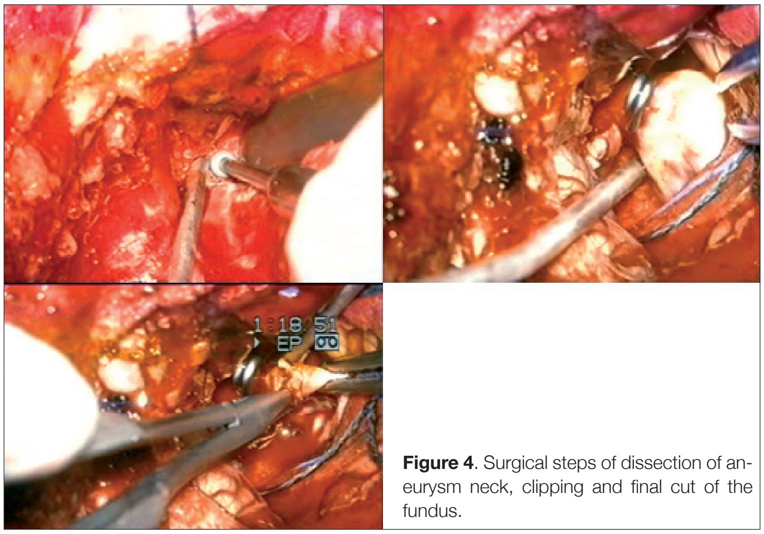

Figure 4. Surgical steps of dissection of an-eurysm neck, clipping and final cut of the fundus.

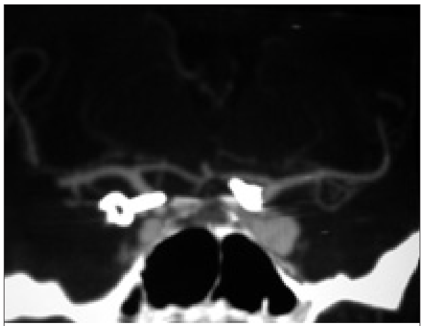
Figure 5. Final results of the clipping showed by means of Angio CT.


Figure 6. Patient after 1 year of followup.

Intradural approach

A curvilinear incision is made in the dura and the dura is retracted anteriorly with Prolene 4-0 line suture and fix to temporal muscle or fascia. The Sylvian fissure is opened in the usual fashion and the dissection is extended medially. Then, the arachnoid overlying the optic nerve and internal carotid artery is incised. A single blade of the Sugita retractor (Mizuho, Japan) is used to elevate and rotate the frontal lobe posteriorly, giving the surgeon a good view to the area occupied previously by the anterior clinoid process, which is now soft. If the surgeon has elected to leave a portion of the anterior clinoid process intact, a dural incision is made over the anterior clinoid process at this time, and the remaining portion of the clinoid is removed by using high speed air drill. If the air drill with the diamond burr is used at at this point in the procedure, the surgeon should be careful to remove all cottonoid packing from the wound, lest the packing be swept up into the drill, converting a microsurgical instrument a high - speed eggbeater.

The dense dural ring that encircles the internal carotid artery where that vessel pierces the dura is incised with the tip of a special knife (Mizuho Knife) with a N° 11 blade. A good plane of dissection is generally identifiable between this dural ring and the internal carotid artery.

Paraclinoid Aneurysms

The medial aspect of the base of the typical paraclinoid aneurysms lies just inferior to the optic nerve as it enters the optic canal. This aspect of the aneurysm is not identifiable until the anterior clinoid process has been removed. In many cases, the aneurysm has eroded into the bone in this region and thus the point of the origin is more proximal than it would be in patients who have a normal anatomy. Posteriorly and inferiorly, the wall of the aneurysm can be separated from the trunk of the internal carotid artery quite readily. In many circumstances, this aneurysm has grown to quite large proportions, indenting and displacing the internal carotid artery inferiorly. Most of these aneurysms can be repared by direct techniques. However sometimes the aneurysm is fusiform, which makes it necessary to use a saphenous vein bypass graft. In this case the graft is placed into the M2 segment of the middle cerebral artery (MCA).

Intracavernous Aneurysms

The typical intracavernous aneurysm projects either from the anterior loop of the internal carotid artery within the cavernous sinus or from its horizontal segment. These aneurysms usually project laterally, less often they project medially and, in contrast to paraclinoid aneurysms which usually project superiorly or inferiorly.

In order to approach these aneurysms, the lesser sphenoid wing bone together with the anterior clinoid process are removed extradurally, as just mentioned before. After the dura has been incised over the area previously occupied by the anterior clinoid process, the surgeon`s attention is focused posteriorly, on the region of the posterior clinoid process where the third nerve enters the dura. An incision is made in the dura overlying the third nerve and is brought forward until it communicates with the dural incision over the area of the anterior clinoid process. The dura containing the third and fourth nerves is reflected laterally. Bleeding from the cavernous sinus is controlled with small pledgets of Surgicel (Johnson & Johnson, MI, USA).

Surgical technique for giant posterior circulation aneurysms

The spatial 3D anatomical knowledge of the CS is important to approached lesions in the interpeduncular fossa trough a transcavernous approach, in special upper basilar artery aneurysms[34,35,36]. The cranial-orbito-zigomatic approach COZ is ideal to reach this area. Another approaches are also described. A pretemporal approach can be used and the lateral wall expose by middle fossa peeling. In the intradural lesions (aneurysm, meningioma) the superior wall of the CS is opened from the groove of the sphenoid wing to the oculomotor triangle to permit mobilization of this nerve. The posterior clinoid process must be drilling to permit proximal control in basilar artery aneurysm in a low basilar artery bifurcation, that is hidden by the posterior clinoid process[31,32,33,34] or lesions localized anteriorlly to the upper pons or upper prepontine cistern[34]. The transcavernous approach and its variations to the basilar tip aneurysms began with Dolenc in 1987[20], who described a transcavernous-transsellar approach where the ICA is retracted medially . Another series relate the use of the follows approaches: extradural temporopolar[37], pretemporal transcavernous[36] and pretemporal transzygomatic transcavernous[35].

In the posterior circulation, exposure of aneurysms arising from the basilar apex or the superior cerebellar artery is facilitated by using skull base approaches[38]. The main used approaches include: subtemporal, pterional transsylvian and COZ.

Additional gain of space is reached drilling and removing the posterior clinoid process and a portion of the superolateral clivus, thereby obtaining exposure of the neck of lower -lying basilar apex aneurysms.

Hypothermic circulatory arrest has added important results in order to improve the time of temporary clipping of proximal vessels, mainly in the case of basilar apex aneurysms. Circulatory arrest frequently allow the manipulation of perforating arteries, and dissection of them from the dome of the aneurysm, clipping the neck and eventual reconstruction of the parent vessel[39].

"Cranio-orbito-zygomatic approach"-COZ

The head is turned 30 degrees and a frontotemporal scalp incision is made from the level of the lower en of the tragus to the contralateral superior temporal line with anterior reflection of the pericranium. The scalp flap is reflected anteriorly. The subfascial dissection in done in the temporal muscle beginning 1 cm above the upper edge of the zygomatic bone and running parallel to this bone. The supraorbital nerve is localized and dissected from its foramen or incisura. The zygomatic arch is cut obliquely posteriorly and then anteriorly and displaced all the way down. The craniotomy begins with the keyhole, that is medial to the frontozygomatic suture and exposes the dura mater of the anterior fossa superiorly and the periorbita inferiorly separated by the orbital roof. An osteotomy is done on the lateral orbital rim. A second and a third hole are done, respectively, in the temporal bone just above the posterior portion of the zygomatic root, and above the supraorbital rim and a little laterally to the midline. These burr holes are connected. From the frontal burr hole, an osteotomy is done inferiorly and medially in the orbital roof. The last osteotomy is through the orbital roof at the keyhole and extended medially. The intrapetrous portion of the ICA is exposed in the middle fossa and the subclinoid portion of the ICA is exposed after drilling the anterior clinoid process extradurally. The bony roof of the optic canal is drilled. The anterior clinoid process is disconnected and removed by subperiosteal dissection to expose the clinoidal segment of the carotid artery between the proximal and distal dural rings, carotidoculomotor membrane, optic canal, optic strut and superior orbital fissure.

Complications

Several complications have been described in the literature. The main complications of giant aneurysm surgery are related to perforating damage, intraoperative rupture of aneurysms, lesion of brain tissue during retraction and small exposition of aneurysmal dome[40].

The rupture of aneurysm during the neck

dissection frequently lead to severe hemorrhage, and the initial management is to put a high power suction aspirator with the tip inserted directed to the hole in the domus and with another hand try to complete the dissection or clip the neck. According to Leipizig et al, 2005, the intraoperative rupture has a low frequency and is probable to happen in PICA aneurysms, Acoa, ACop. The risk of rupture is 7.9% per surgery, 6.7% per aneurysm and 8.9% per patient, and if we exclude small hemorrhages these rates decrease to 3.2% per surgery, 3.2% per aneurysm and 4.3% per patient, and this risk increases with aneurysms with anterior bleeding than aneurysms without anterior bleeding, 10.7% against 1.2%. Using temporary clips this rate is lower than when we do not use them, 3.1% against 8.6%, and there was no difference between the aneurysms treated till the third day after SAH and the aneurysms treated after the third day, 11,1% against 10,0%, p = 0,6234[41]. Now a days the anesthesiologist has to decrease the CBP to allow the secure clipping. Many drugs have been used with this finality, including the intravenous adenosine during the clipping period.

Recibido: 14 de febrero de 2013
Aceptado: 24 de marzo de 2013

Bibliografía

1. Morley TP, Barr HWK. Giant intracranial aneurysms: diagnosis, course, and management. Clin Neurosurg 1969; 16: 73-94.
2. Anson JA, Lawton MT, Spetzeler RF. Characteristics and surgical treatment of dolichoectatic and fusiform aneurysm. J Neurosurg 1996; 84: 185-193.
3. Kodama N, Suzuki J. Surgical treatment of giant aneurysms. Neurosurg Rev 1982; 5: 155 -160.
4. Peerless SJ, Wallace MC, Drake CG. Giant intracranial aneurysms. In: Youmans JR ed. Neurological Surgery: A comprehensive reference guide to the diagnosis and management of neurosurgical problems. 3nd. Philadelphia: wb Saunders;1990; 1742-1763.
5. Vishteh AG, David CA, Spetzler RF. Giant aneurysms. In: Atlas of neurosurgical techniques, Sekhar LN, Fessler R (eds) Stuttgart,Thieme Voll, 2006; pp 212-221.
6. Drake CG, Peerless SJ, Ferguson CG. Hunterian proximal arterial occlusion for giant aneurysms for the carotid circulation. J Neurosurg 1994; 81: 656-665.
7. Fox JL. Giant aneurysms. In: Fox JL (ed) Intracranial aneurysms. New York, Springer Verlag 1983; pp 149-154.
8. Hosobuchi Y. Direct surgical treatment of giant intracranial aneurysms. J Neurosurg 1979; 51: 743-756.
9. Lawton MT, Spetzeler RF. Surgical management of giant intracranial aneurysms: experience with 171 patients. Clin Neurosurg 1979; 42: 245 -266.
10. Shibuya M, Sugita K. Intracranial giant aneurysms. In: Youmans JR, ed Neurological surgery: A comprehensive reference guide to diagnosis and management of neurosurgical problems.4th ed Philadelphia: WB Saunders; 1996; pp 1310-1319.
11. Sundt TM Jr. Surgical techniques for saccular and giant intracranial aneurysms. Baltimore, Williams & Wilkins, 1990.
12. Sugita K. Aneurysm. In: Microneurosurgical Atlas, Sugita K (ed), Springer Verlag, Berlin, 1985, Chapter III, pp10-60.
13. Suzuki J. Cerebral aneurysms: experience with 1000 directly operated cases. Neuron, Tokyo, 1979.
14. Kobayashi S, Sugita K, Nakagawa F. An approach to a basilar aneurysm above the bifurcation of the internal carotid artery. Case report. J Neurosurg 1983; 59: 1082-1084.
15. Aguiar, PH, Fontes RBV, Simm R, Sawada JR, Valiengo L, Tavares W, Hirsch R, Morubayashi L. Clip rotation and blow flow reduction complication after giant cerebral aneurysm clipping. Rev Chil Neurocirugia, 2006.
16. Sekhar LN, Sen CN, Jho HD. Saphenous vein graft bypass of the cavernous internal carotid artery. J Neurosurg 1990; 72: 35-41.
17. Parkinson D. A surgical approach to the cavernous portion of the carotid artery. Anatomical studies and case report. J Neurosurg 1965; 23: 474-483.
18. Dolenc VV. Direct microsurgical repair of intracavernous vascular lesions. J Neurosurg 1983; 58: 824-831.
19. Dolenc VV. A combined epidural -subdural direct approach to carotid ophthalmic artery aneurysms. J Neurosurg 1985; 62: 667-672.
20. Dolenc VV, Skrap M, Sustersic J, Skrbec M, Morina A. A transcavernous-transsellar approach to the basilar tip aneurysms. Br J Neurosurg 1987; 1: 251-259.
21. Dolenc VV. Anatomy and surgery of the cavernous Sinus. Springer Verlag, Wien, 1989.
22. Dolenc VV. Surgery of vascular lesions of the cavernous sinus. Clin Neurosurg 1990; 36: 240-255.
23. Taptas JN. The so-called cavernous sinus: a review of the controversy and its implications for neurosurgeons. Neurosurgery 1982; 11: 712-717.
24. Umansky F, Nathan H. The lateral wall of the cavernous sinus with special reference to the nerves related to it. J Neurosurg 1982; 56: 228-234.
25. Harris FS, Rhoton AL Jr. Anatomy of the cavernous sinus: A microsurgical study. J Neurosurg 1976; 45: 169-180.
26. Isolan GR, de Oliveira E, Mattos JP. The arterial compartment of cavernous sinus - analysis of 24 cavernous sinus. Arq. Neuropsiq (São Paulo). 2005; 63: 250-264,
27. Rhoton AL Jr: The supratentorial cranial space: Microsurgical anatomy and surgical approaches. Neurosurgery 21[Suppl 1]: 2002; 375-410.
28. Guglielmi G, Viñuela F, Duckwiler G. Coil induced thrombosis of intracranial aneurysms. In: Maciunas RJ (ed) Endovascular neurological intervention. Park Ridge, IL:American Association of Neurological Surgeons;1995; pp 179-185.
29. Gobin YP, Viñuela F, Gurian JH. Treatment of large and giant fusiform intracranial aneurysm with Guglielmi detachable coils. J Neurosurg 1995; 84: 55-62.
30. Soga Y, Preul MC, Furuse M, Becker T, MC Dougall CG. Calcium alginate provides a high degree of embolization in aneurysm models: A specific comparison to coil packing. Neurosurgery 2004; 55: 1401-1409.
31. Yasargil MG. Microneurourgery, Clinical considerations, Surgery of the Intracranial Aneurysms and Results Stuttgart, Georg Thieme, 1984; Vol I.

32. Yasargil MG. Microneurosurgery: Clinical considerations, Surgery of the Intracranial Aneurysms and Results. Stuttgart, Georg Thieme, 1984; Vol II.
33. Yasargil MG, Antic J, Laciga R, Jain K, Hodosh R, Smith R. Microsurgical pterional approach to aneurysms of the basilar bifurcation. Surg Neurol.
34. Krisht A. Transcavernous approach to diseases of the anterior upper third of the posterior fossa. Neurosurg Focus 2005; 19: E2.
35. Krisht A, Kadri PA. Surgical clipping of complex basilar apex aneurysms: a strategy for successful outcome using the pretemporal transzygomatic transcavernous approach. Neurosurgery 2005; 56: 261-273.
36. Seone E, Tedeschi H, de Oliveira E, Wen HT, Rhoton AL jr. The pretemporal transcavernous approach to the interpeduncular and prepontine cisterns: Microsurgical anatomy and technique application. Neurosurgery 2000; 46: 891-899.
37. DeMonte F, Smith HK, Al-Mefty O. Outcome of aggressive removal of cavernous sinus meningeomas. J Neurosurg 1994; 81: 245-251.
38. Kobayashil S, Kakizawa Y, Sakai K, Tanaka Y. Multiple paraclinoid aneurysms of the internal carotid artery. In: Neurosurgery of complex vascular lesions and tumors. Kobayashi S, Sakail K (eds), Thieme, New York, 2005; pp 3-6.
39. Lawton MT, Raudzens PA, Zambramski JM, et al. Hypothermic circulatory arrest in neurovascular surgery: envolving indications and predictors of patient outcome. Neurosurgery 1998; 43: 10-21.
40. Heros RC, Nelson PB, Ojemmann RG. Large and giant paraclinoid aneurysms:surgical techniques, complications, and results. Neurosurgery 1983; 12: 153-163.
41. Leipizig TJ, Morgan J, Horner TG, Payner T, Redelman K, Johnson CS. Analysis of intraoperative rupture in the surgical treatment of 1694 saccular aneurysms. Neurosurgery 2005; 56: 455-468.