ANEURYSMS OF THE POSTERIOR CIRCULATION: SURGICAL MANAGEMENT

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ABSTRACT — The management of aneurysm in the vertebrobasilar circulation post difficult challenges in complex approaches. The preparation of the patient should proceed with an initial thorough medical and neurological assessment to establish a clear and trouble-free pathway to the surgical procedure. A careful monitoring of hemodynamic properties of the systemic circulation, normalization of all cardiac function and optimization of medical condition is required. An arterial line, central venous line, a Swan-Ganz catheter, the recording of cardiac output, cardiac index, urinary output, and cerebral perfusion pressure are considered very important in the management of these patients. Different surgical alternatives including supratentorial approaches via the pterional or the subtemporal area, suboccipital approaches through a midline, lateral, transmastoid or asterional approach and transbasilar approaches through the clivus, petrous bone or mastoid are described. Risks and potential complications are reviewed and alternatives are discussed.

Key words — Vertebrobasilar circulation, posterior fossa aneurysms, surgical treatment.

SINOPSE

ANEURISMAS DA CIRCULAÇÃO POSTERIOR: TRATAMENTO CIRÚRGICO

O manejo dos aneurismas da circulação vertebrobasilar impõe desafios complexos pela complexidade das abordagens. A preparação do paciente começa com uma avaliação clínica e neurológica, assim permitindo visualizar uma abordagem cirúrgica sem complicações. Para tanto, é essencial a monitorização cuidadosa das propriedades hemodinâmicas da circulação sistêmica, normalização da função miocárdica e estabilização dos problemas clínicos, utilizando-se punção venosa central e arterial, cateter de Swan-Ganz, medidas de débito e índice cardíaco, fluxo urinário e pressão de perfusão cerebral. São descritas as diferentes abordagens, como, pela via supratentorial, as abordagens pterional ou subtemporal; pela via suboccipital, através da linha média ou lateral, transmasoide ou asterional ou, ainda, a abordagem transbasilar através do clivo, oso petroso ou mastoide. De todas as abordagens, são discutidos os riscos e complicações potenciais.

Palavras-chave — Circulação vertebro-basilar, aneurismas da fossa posterior, tratamento cirúrgico, complicações.

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INTRODUCTION

Aneurysms arising in the posterior circulation present difficult problems of approach due to limited accessibility of the vertebrobasilar system, potential problems of ischemia from damage to the vessels from which the aneurysms arise, or damage to the smaller perforating vessels which originate in the vicinity. Great attention to detail, and clear understanding of the operative anatomy of the vertebrobasilar system, facilitate the safe and successful approach to these aneurysms. The surgical approaches can be divided in three categories: 1) Supratentorial; 2) Infratentorial; and 3) Transbasal. The various factors that determine the preoperative preparation for patients with vertebrobasilar aneurysms, the intraoperative procedures used to facilitate the operations, the three operative categories used to treat these aneurysms, and the potential complications that may develop in the management of aneurysms arising from the posterior circulation will be reviewed. Observations made from the surgical procedures and complications encountered will be analyzed to facilitate an understanding of occurrence and mode of prevention.

PREOPERATIVE CONSIDERATIONS

Patients with vertebrobasilar aneurysms may present for evaluation either after an event of subarachnoid
hemorrhage, or following a cerebral angiogram or computed tomography (CT) scan obtained for other reasons. These patients should have a thorough medical and neurological evaluation including complete cerebral angiography, CT scan and or magnetic resonance (MRI) scan imaging of the brain. Patients who suffered a subarachnoid hemorrhage require preoperative admission to an Intensive Care Unit (ICU) for evaluation, and preparation for surgery.

A complete medical evaluation should be made in elderly patients in preparation for surgery to prevent the possible development of intraoperative cardiac, respiratory or renal complications that may develop from hypotension or hypotension induced intentionally during surgery, blood loss, or the use of cardiac suppressants such as barbiturates or lidocaine, or the use of diuretics such as mannitol.

Intraoperative hypotension is not a condition generally required by the surgeon, but can occur frequently during the induction of anesthesia. Hypotension may not only induce rupture of the aneurysm prior to the performance of the craniotomy, but may also cause myocardial infarction from the increased tension of the myocardial wall, in relation to the pressure in the coronary arteries. Careful monitoring of the arterial blood pressure with an indwelling arterial line placed in the ICU, will facilitate the pre and intraoperative management of the blood pressure, and prevent any undesirable fluctuations.

Intraoperative hypotension was proposed by Drake to facilitate the dissection of cerebral aneurysms, and to prevent the onset of intraoperative rupture. Myocardial ischemia may develop in patients with chronic hypertension, and marginal cardiac function subject to hypotension, or in patients with severe coronary artery disease. Patients with vertebral-basilar aneurysms are best managed with a Swan-Ganz catheter placed to monitor their cardiac function during surgery. An optimum intravascular blood volume may be established preoperatively by the administration of intravenous albumin, and the careful monitoring of the cardiac output and cardiac index.

Severe hypotension may occur during induction of anesthesia in patients who have received antihypertensive medication chronically. The hypotension in these patients is generally the result of a relative state of hypovolemia, which may be compounded by the sudden vasodilatation that follows the induction of anesthesia. This may be prevented by the judicious administration of fluids in the preoperative period. Severe intraoperative bleeding may also be followed by severe hypotension in patients who are chronically hypertensive, or in patients who are normotensive. This problem may only be anticipated by securing blood preoperatively.

The intraoperative administration of barbiturates and lidocaine in preparation for the application of temporary clips has potential problems with myocardial perfusion and respiratory suppression. The sudden administration of these agents may be followed by immediate hypotension, which if prolonged, may result in myocardial ischemia. Chronically hypertensive patients and patients with coronary artery disease are more susceptible to hypotension when barbiturates are given. A slow intravenous infusion of barbiturates is less likely to result in significant hypotension. Barbiturates and lidocaine may also result in the onset of hypoventilation and CO₂ retention in the immediate postoperative period. A careful preoperative evaluation of patients with chronic obstructive pulmonary disease, or with previous pulmonary problems may include securing arterial blood gases or pulmonary function tests, in addition to a chest X ray.

Mannitol has been used to decrease the volume of the brain during surgery, and to decrease brain retraction. Susuki promoted the use of mannitol in aneurysm surgery because it may protect the brain during brief periods of vessel occlusion. Mannitol acts as a membrane stabilizer and free radical quencher, in addition to its diuretic properties. Mannitol must be used carefully in patients with marginal renal function, because it can potentiate the development of renal insufficiency from dehydration and crystallization of the mannitol in the renal tubules. Mannitol may precipitate the onset of acute myocardial insufficiency in patients with marginal cardiac function, since it produces a transient volume overload prior to the onset of its diuretic effect.

A selective four vessel cerebral angiogram must be completed in all patients to determine the location of the aneurysm, to exclude the presence of multiple aneurysms which occur in 20% of cases, and to rule out the presence of cerebral vasospasm. A conventional selective arteriogram is the most common form of evaluation, but a selective digital arteriogram is rapidly becoming the preferred form of evaluation. The critical aspect of the arteriogram is the precise acquisition of the arterial anatomy, including small vessels and perforating arteries, and the detailed study of the nature of the aneurysmal neck. It is advisable to obtain selective arterial injections
of the extracranial vessels in some patients, in anticipation for an extracranial to intracranial anastomosis (26). Computerized tomography and magnetic resonance imaging are necessary to exclude the presence of intracranial anastomosis, extent of the subarachnoid hemorrhage, presence of hydrocephalus, and the possibility of intraaneurysmal clot formation. A partially thrombosed giant aneurysm is potentially a problem because of the possibility of intraoperative embolization, and the potential difficulty in securing complete clipping of the aneurysm. A false sense of security may be gained from an angiogram which reveals a small amount of dye filling the aneurysm, when in reality the aneurysm is large, and mostly filled with clot (26).

The form of presentation of the patient can determine the potential for evaluation and preoperative preparation that may be performed. Patients presenting without a subarachnoid hemorrhage may have a more gradual and planned evaluation than patients who present after they have bled. The patient who presents with a subarachnoid hemorrhage may require an operation sooner. The decision to proceed with surgery should be based on the clinical condition of the patient, including the neurological evaluation and the medical condition of the patient. Patients with a poor medical condition, but with good neurological status, should not be operated on any sooner than the patient with a poor neurological condition but a favorable medical state. A poor condition in either case would likely lead to a poor outcome. The success of the operation depends on careful preoperative planning, as well as, the execution of the operation.

**INTRAOPERATIVE PROCEDURES**

The intraoperative preparation of the patient begins in the preinduction area and ends in the recovery room (27). Patients with posterior circulation aneurysms require careful monitoring of their cardiovascular, pulmonary, and renal functions throughout their stay in the operating room. Several drugs may be administered during surgery as cerebral protecting agents, or in anticipation for arterial clipping or hypotension.

Cardiovascular monitoring is essential in the intraoperative management of patients with vertebralbasilar aneurysms. A radial arterial catheter must be placed in preparation for surgery, and continuous intraarterial pressure measurements must be maintained throughout the surgical procedure. Cardiovascular function should be correlated in these patients by the placement of a Swan-Ganz catheter to record myocardial function. Intraoperative measurements of central venous pressure, pulmonary arterial pressure, pulmonary wedge pressure, cardiac output and cardiac index, facilitate the careful planning of the surgical procedure. The intraoperative intervention with drugs that may affect cardiovascular function can then be monitored, and changes in cardiac performance corrected appropriately (28).

The preoperative evaluation of the patient with possible pulmonary problems will allow the neuroanesthesiologist to anticipate possible problems with ventilation or gas exchange. Patients with vertebralbasilar aneurysms require, like other neurosurgical patients, a mild state of hyperventilation to keep the PCO₂ around 30 to 35 mmHg. Lowering the PCO₂ below this level will not induce any more cerebral relaxation by vasodilatation, and may in fact be detrimental since it will induce cerebral ischemia. The severity of hyperventilation must also be carefully planned in patients who have any amount of residual vasospasm. Inducing severe hyperventilation in these patients will be followed by cerebral ischemia because of the combined effect of the vasospasminduced by the two mechanisms. The possibility of hypoventilation during surgery from intubation in the right main-stem bronchus must be anticipated and prevented by careful planning. Postoperative hyperventilation in the recovery room from early extubation or from too much anesthetic, must also be kept in mind in these patients who would otherwise do very well if their respiratory control was properly coordinated (28).

Adequate renal function is essential in patients who will undergo a craniotomy. The intraoperative administration of diuretics facilitates cerebral retraction, especially in patients who have an aneurysm in the territory of the basilar artery. Furosemide given 20-40 mg at the time of induction fosters the onset of diuresis, prevents the development of renal tubular casts, and prevents the possible occurrence of myocardial overload from the administration of mannitol. An accurate hourly account of urinary output must be maintained with an indwelling Foley catheter. Immediate replacement of fluids is necessary once the aneurysm has been clipped and the retraction of the brain is no longer needed.

Anesthesia is induced with intravenous thiopental and maintained with nitrous oxide-oxygen and isoflurane. During induction the patient receives intravenous Diphenhydantoin 15 mg per kg, Vancomycin 1000 mg, Dexamethasone 10 mg, Gentamycin 80 mg, Furosemide
20-40 mg, and Mannitol 0.5 gm per kg. Spinal fluid drains are not used in these patients, since drainage of spinal fluid from the cisterns has been effective in achieving cerebral relaxation. Arterial blood gases, end expiratory CO₂ recordings and pulse oximetry are monitored throughout the operation. Arterial PCO₂ is maintained at about 30-35 mm Hg, PO₂ around 95 mm Hg, and oxygen saturation at about 100%. Temperature is maintained at normal with a warming blanket. Arterial pressure is maintained as close to preoperative values as possible. Intraoperative hypotension is seldom used, generally only when proximal control of the basilar artery cannot be accomplished with a temporary clip.

OPERATIVE APPROACHES

The surgical management of aneurysms in the vertebrobasilar circulation has been difficult and fraught with many potential intraoperative problems. The location of the basilar artery immediately adjacent to the clivus, and the proximity of the brainstem and cranial nerves have prevented the direct approach of these aneurysms. Drake⁶,¹⁰ was the first to consistently operate on these aneurysms arising from the basilar artery, and developed techniques and approaches that have been subsequently followed and modified by many. Approaches to aneurysms arising in the vertebrobasilar circulation depend on the anatomical location of the aneurysm. The operative routes that are favored now are the supratentorial approach to aneurysms of the tip and distal half of the basilar artery, the suboccipital approach for aneurysms of the venticular artery and some vertebrobasilar junction aneurysms, and the transbasal approaches for aneurysms arising from the vertebrobasilar junction and mid portion of the basilar artery.

1. Supratentorial Approaches

The surgical management of aneurysms arising from the tip of the basilar artery through the subtemporal approach was made popular by Drake⁶,¹⁰, Yasargil³⁰ preferred the trans-sylvian approach, believing that one could obtain better control of the basilar artery and its bifurcation through this route. Sano¹¹,¹² combined both of these approaches and developed a mixed trans-sylvian subtemporal approach, which some people call the "one-and-a-half approach".

2. Subtemporal Approach

The patient is placed with the head in a lateral position, placing the body also in a lateral decubitus, or supine with the right shoulder elevated by a roll. A vertical incision is made generally in the right preauricular area and extended to just above the level of insertion of the temporalis muscle. The skin incision may also be made in a reverse question mark following the hair line. The temporalis muscle is incised vertically along its fibers, and the fibers are transected across the base of the zygoma, to facilitate the exposure of the entire squamosal portion of the temporal bone. A round or quadrangular free bone flap is elevated, with the most inferior portion of the bone flap lying flat with the floor of the temporal fossa. The dura is incised in a cruciate manner, and the temporal lobe is elevated to exposing the tentorial incisura, taking care to preserve the vein of Labbe. The tentorial incisura is either retracted with sutures to expose the midbrain, or is transected and then retracted. The third nerve is left adherent to the uncus of the temporal lobe by not releasing it from the arachnoid that binds it to the temporal lobe. This facilitates the upward displacement of the third nerve and the ipsilateral posterior cerebral artery, with the temporal lobe retraction. The fourth nerve is identified and preserved as it enters the edge of the tentorium and traverses parallel with the superior cerebellar artery⁶,¹⁴,¹⁷.

The superior cerebellar artery is followed anteriorly and medially until the basilar artery is identified. The junction of the ipsilateral superior cerebellar, the proximal posterior cerebral (P-1), and the basilar artery can be seen clearly from this approach. Aneurysms arising from the basilar bifurcation and from the superior cerebellar artery area can be exposed and clipped. It is generally necessary to place a retractor on the cerebral peduncle to expose the interpeduncular area, and see the origin of the perforating arteries arising from the basilar artery⁶,¹⁵. Careful dissection of the perforators is necessary to separate them from the dome of the aneurysm, and to allow proper placement of the clip. Aneurysms of the basilar bifurcation require a fenestrated clip to preserve the ipsilateral P-1. Visualization of the contralateral P-1 and superior cerebellar arteries is difficult from this approach, and has resulted in their occlusion by the clip. Drake⁶,¹⁰ recommends the use of clips that are tailored to the exact width of the neck of the aneurysm. To tailor the clip it is necessary to measure the neck and then cut off the portion of the clip that is longer than required. This technique is successful in occluding the aneurysms without clipping the opposite P-1, but the mechanical cutting of an aneurysm clip changes the ferromagnetic properties of the clip, and may lead to its eventual failure⁶,¹⁰.
The subtemporal approach is quick and requires minimal dissection of the surface structures to reach the area of the midbrain. The perforators arising from the basilar artery are easy to identify through this approach and can generally be totally preserved when dissected away from the aneurysm dome. However, there is considerable limitation in the ability to expose the contralateral P-1 and superior cerebellar arteries. It is not always possible to obtain proximal control of the basilar artery because of the limited space available. A distinct advantage to this approach is the ability to perform an intracranial-to-extracranial anastomosis to the superior cerebellar or the posterior cerebral artery, in preparation for the complete occlusion of the basilar artery \( ^{15,39,40} \).

The subtemporal approach has been used in a few cases to reach aneurysms arising from the distal half of the basilar artery \( ^{9,17} \). This exposure is gained through a standard temporal craniotomy, elevating the entire temporal lobe, and transecting the tentorium from the point of entry of the fourth nerve to the level of insertion of the tent on the petrous portion of the temporal bone. This permits the exposure of the fifth nerve, gasserian ganglion and fossa, and the superior portion of the pons. It is necessary to place a retractor on the pons to expose the basilar artery, and then identify the aneurysm, which is generally located against the clivus. In some cases, the superior border of the petrous apex may be removed behind the gasserian fossa and in front of the cochlea \( ^{9} \). This is a very restrictive approach, with limited proximal control of the basilar artery, and with potential of rupture of the aneurysm when retracting the belly of the pons. The location of the fourth and fifth nerves generally make the placement of the aneurysm clip very difficult \( ^{11,38} \).

\( b ) \) Trans-Sylvian Approach

The patient is placed supine in a reclining position, with the head rotated 15° to the opposite side, and with 15° of head extension supported by skeletal fixation. An incision is made along the frontal hairline from the level of the zygoma to a point approximately level with the ipsilateral mid-pupillary line. The skin and muscle are reflected in one single flap, exposing the entire squamous portion of the temporal bone, the frontalis process of the lateral orbital wall and the vertical portion of the frontal zygomatic area. Yarzargil \( ^{23} \) recommended a complex muscle incision disinserting the temporalis muscle from its anterior attachment, and retracting it posteriorly, after separating the fatty tissue containing the frontalis branch of the facial nerve. This dissection lengthens the operation, and does not offer any more protection to the nerve than the combined elevation of the skin and muscle in a single flap.

A free bone flap is elevated with a craniotome, centering the craniotomy on the pteron. The pteron is drilled down until the meningo-orbital branch of the middle meningeal artery is exposed. The dura is sutured to the skull prior to its opening, to prevent epidural bleeding from leaking into the depth of the wound. The dura is opened in a semicircular manner with the base on the pteron, and sutured to the temporalis muscle. The operating microscope is brought into the field and the sylvian fissure is opened widely to expose the entire course of the internal carotid and its bifurcation, the optic nerve and optic chiasm, the proximal portion of the anterior cerebral artery, and the trunk and bifurcation of the middle cerebral artery to the level of the limen insulae. All arachnoidal bands are released with sharp dissection, to obtain maximum brain relaxation with minimal brain retraction, and to allow spinal fluid drainage from the cisterns. Additional CSF may be obtained from opening the lamina terminalis above the chiasm.

The anterior temporal lobe is retracted laterally, while preserving the sylvian veins draining into the sphenopetrosal sinus. The third nerve is identified as it courses through the ambient cistern to the superior orbital fissure. The arachnoid bands around the third nerve are released, and the Membrane of Lilliquist is opened, exposing the basilar artery and its bifurcation by simply following the third nerve to the mesencephalon, or following the posterior communicating artery to the posterior cerebral artery. The basilar bifurcation is found immediately medial to either of these two structures as they reach the cerebral peduncle. The perforating arteries arising from the posterior communicating artery, and from the carotid bifurcation must be carefully dissected and preserved.

Exposure of the basilar artery may be gained through one of four areas of access depending on the anatomy of the carotid artery. When the carotid artery is normal in length or longer than normal before it bifurcates, the carotid may be retracted laterally and the optic nerve medially, thus gaining access to the basilar artery between the two \( ^{16,25} \). When the carotid artery is shorter than normal to the origin of the bifurcation, or the artery is filled with atheroma preventing its retraction, access can be gained to the basilar artery through a
more lateral approach between the third nerve and the carotid artery. When this is not possible, the basilar bifurcation may be reached by separating the perforators of the carotid bifurcation, and gaining access to the basilar artery between the trunks of the anterior and middle cerebral arteries. Further if this is not possible, and the posterior communicating artery is either hypoplastic or has few branches, the basilar artery may be reached through a more lateral approach, after the posterior communicating artery has been clipped and transected. This last alternative is the least desirable of all, because of the potential to develop ischemic changes in the territory of the perforators of the posterior communicating artery.

c) Combined “One and a Half” Approach

Sanots described the combined approach which allows access to the basilar bifurcation through either a pure trans-sylvian route, or through a more subtemporal route depending on the circumstances. The skin incision and flap are basically the same as for the trans-sylvian approach described above, although the skin incision is extended to about one centimeter below the level of the zygoma. The bone flap is extended to the floor of the middle fossa to develop a flat plane extending from the pterion to the area of the trigus. The pterion is resected in a similar manner to the trans-sylvian approach, extending the resection to the floor of the middle fossa. In some cases it will be necessary to transect the orbitomeningeal branch to allow the total removal of the lesser wing of the sphenoid. This maneuver will permit a clear and unobstructed entry to the microscope light. The dura is opened to create a flap, based anteriorly. The sylvian fissure and carotid artery area are dissected as described above. The temporal veins are transected, and the tip of the temporal lobe is retracted superior and posterior, to expose the entire floor of the middle fossa. When the dissection is performed correctly, one can access the area of the basilar bifurcation through a pure trans-sylvian approach, or through a subtemporal approach by merely rotating the patient to the contralateral side about 15°. The exposure of the third nerve, lateral aspect of the carotid artery and cavernous sinus is better through this approach. The basilar artery can generally be visualized well through this route, permitting the application of temporary clips whenever necessary.

When the basilar bifurcation is located below the level of the dorsum sellae, the bifurcation may be reached by removing the posterior clinoid process, and opening the tentorial incisura farther laterally. When the basilar bifurcation is located much higher than the level of the dorsum sellae, there are two alternatives to reach the bifurcation through this approach. One is to resect the inferior surface of the temporal lobe, to allow exposure of the proximal portion of the neck of the aneurysm. This alternative is not desirable, because the resection would generally include the most medially portion of the temporal lobe, the uncus and a portion of the hippocampus. A different alternative is to resect the zygoma and remove the floor of the middle fossa, and if necessary perform a superior and lateral orbitotomy, as described by Maroon for resection of intraorbital tumors. This later alternative allows the direct exposure of the mammillary body region, with minimal retraction of the brain. Since the resection of bone is more extensive, this permits a shorter distance from the surface of the wound to the area of the basilar bifurcation. For this approach to be effective, it is necessary to make a wide dissection of all the basal cisterns, to minimize brain retraction.

2. Suboccipital Approach

The suboccipital approach is the first approach used to treat aneurysms of the vertebral artery and verteobasilar junction. This approach permits wide exposure of the medulla and lateral pons, but is limited in the possible access to the more distal and medially located aneurysms. The cranial nerves are very limiting in the accessibility of the verteobasilar junction.

The patient is positioned generally prone on chest rolls, with the head supported on skeletal fixation. The sitting position is seldom used anymore because of the potential of significant air embolism and hypotension associated with its use. The exposure may be obtained in one of two ways, through a pure midline incision, or through a unilateral approach. Through a midline incision, the dissection is extended from the level of the inion to about the level of C2-3, separating the paravertebral muscles to expose the entire occipital squama. The dissection is carried farther laterally on the side of the aneurysm, to expose the tip of the mastoid process. A cranietomy is completed removing the occipital bone exposed, across the midline, but predominantly on the side of the pathology. The bone resection is extended through the fora men magnum, to the tip of the mastoid on the side of the aneurysm, and to the edge of the transverse sinuses superiorly. It is generally not necessary to remove the posterior arch of the atlas. The dura is opened in Y fashion, and sutured to the muscle. The cisterna magna is incised, allowing copious drainage of CSF prior to
attempting retraction of the cerebellum or dissection of the vertebral artery.

The vertebral artery is identified proximally as it enters through the dural ring, and courses ventrally and medially through the fascicles of the eleventh and twelfth nerves. The vertebral artery may be followed medially by applying gentle retraction on the cerebellar tonsil. When the aneurysm originates from the posterior inferior cerebellar artery (PICA), the aneurysm will be found immediately in front of the olivary prominence of the medulla. Care must be taken to dissect all small cranial nerve fascicles from the aneurysm, as well as, all small perforating branches arising from PICA to the medulla.

Aneurysms in this location can generally be clipped without much difficulty, especially when a temporary clip is placed on the vertebral artery prior to the application of the clip on the aneurysm. Large aneurysms, and giant aneurysms of PICA may require trapping of the vertebral artery to achieve satisfactory exclusion from the circulation. The midline approach is not ideal for large or giant aneurysms, and is not used as much anymore.

The lateral or retromastoid approach is the preferred approach for vertebral artery aneurysms. The patient is placed generally in the lateral or park bench position, although some prefer the prone position. A hockey stick incision is placed half way between the mastoid process and the midline, from about five centimeters above the level of the mastoid, to the level of C2-3. The paravertebral muscles are incised and retracted, exposing the lamina of C2 and C3, the dorsal arch of the atlas, the mastoid process, the suboccipital area and posterior edge of the foramen magnum. A cranectomy is completed to expose the sigmoid sinus, the transverse sinus, to the midline and through the foramen magnum. It is not necessary to remove the arch of C1. The vertebral artery is identified extracranially as it courses over the arch of C1 and penetrates the atlantooccipital membrane. A large vein is generally located in that area and should be coagulated carefully before the vertebral artery may be exposed totally. The dura is opened in a cruciate manner, basing the superior and lateral flaps on the transverse and sigmoid sinus.

The cisternal magna is incised to allow drainage of CSF, and gentle retraction on the lateral portion of the cerebellar tonsil. In large or giant aneurysms it may be necessary to resect a portion of the cerebellum, to prevent postoperative swelling from excessive retraction. The vertebral artery is dissected in its intradural portion, and followed to the origin of PICA. The retraction of the cerebellum is generally less through the lateral exposure, and control of the proximal vertebral artery is also better. A temporary clip may be applied more easily through this exposure. Reaching the distal portion of the vertebral artery in the case of a large or giant aneurysm of PICA, is not always possible. In those cases Drake recommends the permanent ligation of the vertebral artery proximal to the aneurysm. If the vertebral artery to be ligated is the dominant vessel, a vessel loop is placed about the vertebral artery, and exteriorized so that the vertebral artery may be occluded when the patient is awake. If the vertebral artery is small or there is a good contralateral vertebral artery, the artery may be occluded directly with a permanent clip. Some aneurysms arising from the verteobasilar junction may be reached through this approach. The dissection has to be extended to separate all fascicles of the cranial nerves from seventh through twelfth, to allow gentle retraction of the brainstem away from the clivus. Access to the clivus area is difficult through this exposure and successful obliteration of distal vertebral aneurysms is variable because of the limited space available to dissect the aneurysm, and to apply a clip across the neck.

3. Trans Basal Approaches

The approach of the midbasilar region is the most difficult and most taxing for satisfactory and safe obliteration of aneurysms in this area. Sano described the transoral approach, but Drake discouraged its use because of the potential for infection, and the development of CSF leaks. More recently, with the increasing interest of access to the posterior fossa through a transmastoid translabyrinthine approach, Giannotta described the transmastoid presigmoid approach to the verteobasilar junction. As a result of more aggressive approaches to skull base tumors, it is possible to approach aneurysms of the verteobasilar junction through a combined transmastoid supra and infratentorial approach, which may be more appropriately called the asterional approach.

a) Transcerebellar Approach

The patient is positioned supine and the head is supported with skeletal fixation. The oropharyngeal area is approached through a Dingman retractor that allows the mouth to open widely and the tongue to be displaced inferiorly. An orotracheal tube is required in these cases, although some prefer to perform a tracheostomy prior to the beginning of the case. The soft palate may be reflected into the nasopharynx through a suture placed
in the uvula and anchored to a red Robinson catheter passed down from one of the nostrils. In cases where the reflection of the soft palate is insufficient to expose the area of the clivus, the soft palate is incised starting lateral to the uvula, and extending the incision to the midline until the hard palate is reached. The flaps of soft palate are then reflected laterally and sutured to the tonsillar pillars.

The posterior pharyngeal wall is incised in the midline from the most superior portion of the clivus to and through the anterior rim of the foramen magnum. It is not necessary to extend the incision below the level of the body of C2. The pharyngeal mucosa is reflected from the midline, and sutured to the lateral pharyngeal walls. A Crockard retractor may be used to reflect the pharyngeal flaps also. The attachment of the longus colli muscles and the attachments of the criculate ligament are removed from the anterior surface of the clivus, and the clivus is drilled off with a high speed drill. In most cases it is possible to reach the inferior two thirds of the clivus through this approach. When this is not possible, it is necessary to access the superior portion of the clivus through a combined transnasal and transoral approach, creating a LeForte One disarticulation of the maxilla. A more radical and wiser exposure may be obtained by performing a rhinotomy, displacing the nasal pyramid laterally on a vascularized pedicle, performing a maxillectomy and freeing the entire anterior surface of the clivus from the sphenoid sinus to the arch of C1.

Drilling the clivus down allows a field of exposure which is limited to approximately 3.5 cms. in vertical length, and one centimeter in cross sectional diameter. The dural surface is opened in the midline, and the vertebral basilar junction and proximal basilar artery are generally in the middle of the field. Unfortunately, the aneurysms are also in the middle of the field, and applying a clip is difficult. The wound is closed in layers. To repair the dural surface it is necessary to use a fat or fascial graft, fastened with a few sutures, and secured to the dural wall with fibrin glue. A spinal CSF drain is necessary for at least ten days to prevent the development of a leak of spinal fluid.

b) Transmastoid Presigmoid Approach

The transmastoid approach is performed through a mastoidectomy incision placed directly over the mastoid with enough room to expose the entire sigmoid sinus, the most lateral portion of the posterior fossa just below the tentorium. The mastoid is drilled off by an otolaryngologist who can carefully identify and preserve the intrapetrous portion of the seventh nerve, and the semicircular canals. Once the dura has been exposed, the mastoidectomy resection is extended to include the most lateral portion of the occipital bone. This permits the exposure of the sigmoid sinus in the middle of the wound, through a bony exposure of approximately four centimeters in diameter. The dura in front of the sigmoid sinus is incised, and the anterolateral surface of the pons is exposed. When this exposure is not sufficient, the sigmoid sinus is ligated and transected. This step of the operation requires to have planned the operation on the side of the non dominant sigmoid sinus, confirmed by preoperative cerebral angiography with a prolonged venous phase. Once the sinus is transected, the area of the anterior surface of the pons can be exposed with a small retractor placed on the pons. The basilar artery and verteobasilar junction can be accessed through this method, although the room available for exposure and dissection of the basilar artery and the aneurysm is limited. Proximal control of the basilar artery is not always possible through this exposure.

c) Asterional Approach

The retromastoid presigmoid or "asterional approach" is performed through a hockey stick incision placed directly over the mastoid region, extending about five centimeters above the mastoid and to the level of C1. The peristeum is reflected off the mastoid, and the insertion of the sternocleidomastoid muscle is separated in its majorit from the mastoid groove. The dissection is extended until the digastric groove is identified. A free bone flap is reflected, centered on the asterion, and straddling the transverse and sigmoid sinus. To complete the elevation of the bone flap it is necessary to place burr holes on either side of the transverse sinus anterior and posteriorly, and to connect these holes with a power saw. The resection of the mastoid is then extended to approximately five millimeters posterior to the external or membranous ear canal. The resection is continued to the level of the dura, until the entire sigmoid sinus is exposed from the level of the superior petrosal sinus, to the jugular bulb. A large mastoid emissary vein is frequently found as the dissection progresses and must be cauterized and transected to permit access to the entire course of the sigmoid sinus.

The dura is sutured to the bone, and opened in front of the sigmoid sinus first above and then below the tentorium. The incision above the tent is placed anterior to the vein of Labbe. The superior petrosal sinus is dissec-
ed, ligated between two sutures and transected. The infratentorial incision is then extended to the level of the jugular bulb. The tentorium is incised completely, until the fourth nerve can be seen in the ambient cistern. This exposure allows gentle retraction of the temporal lobe superiorly, and the belly of thepons posteriorly. The nerve fascicles of the fifth, seventh, and eighth nerves are gently dissected and separated. The most inferior margin of the exposure is the foramen jugulare, superiorly the temporal lobe, anteriorly the dorsum of the petrous apex and clivus, and posteriorly the belly of thepons and medulla.

The distal vertebral artery may be followed into the vertebrobasilar junction, and the basilar artery can be seen clearly to just below the origin of the superior cerebellar arteries. Proximal control of both vertebral arteries and distal basilar artery, may be obtained through this approach. Small and large aneurysms of the mid basilar portion may be accessed this way, without sacrificing a major venous sinus. Gentle retraction may be applied on the pons without problems, and the cranial nerves traversing the area do not interfere with the placement of temporary or permanent clips. Potential problems from this approach consist mostly in the possible damage to the facial nerve in its intrapetrous portion, or damage to the sinicircular canals, or the cochlea with permanent hearing loss.

**CLINICAL MATERIAL AND RESULTS**

Forty-five patients presenting with vertebrobasilar aneurysms have been evaluated since 1979. There were 33 women and 12 men of ages ranging from 23 to 67 years. Mode of presentation included subarachnoid hemorrhage in 24, incidental angiographic finding in 15, CT finding in 5. Hunt-Hess grades of subarachnoid hemorrhage were: I 17; II 5; and III 3. All patients were angiogrammed immediately after their subarachnoid hemorrhage. Location of aneurysms were: Basilar tip 27; Basilar Trunk 7; PCA 8; Superior Cerebellar 2; and Posterior Cerebral 1. CT scan findings were: Subarachnoid hemorrhage 24; Possible aneurysm 6; and Mass effect 4. All patients were maintained in the intensive care unit until their symptoms subsided, and operated on generally two to six weeks after their hemorrhage. There was one patient who rebled during the period of observation, and died. Complications included: Hemiparesis 3 (basilar tip); Permanent Cranial Nerve Palsy 3 (trunk 2, PCA 1); and Mortality 3 (trunk). All other patients have returned to their preoperative neurological condition or back to normal.

**CONCLUSION**

Surgery for aneurysms in the vertebrobasilar system remains the most difficult and challenging aspect of vascular neurosurgery. The high risk of injury to the brainstem and cranial nerves make any approach used fraught with danger. Basilar tip aneurysms are probably best handled through a one and a half approach; a modified pterional trans-sylvian approach to include the anterior and mid temporal areas. Vertebral aneurysms and PICA aneurysms can be handled well through a retromastoid suboccipital approach in cases where the aneurysm is not of giant dimensions. Giant PICA aneurysms, as well as aneurysms of the vertebrobasilar junction and trunk of the basilar artery are best approached through an arteriolar approach. However, small aneurysms in these areas may also be handled through a transmastoid presigmoid approach. The advent of interventional techniques with intra-aneurysmal platinum coils will probably change the surgical approaches now considered to be satisfactory.

**REFERENCES**


