Ligation of the vertebral (unilateral or bilateral) or basilar artery in the treatment of large intracranial aneurysms

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The author reports the use of vertebral artery ligation, unilateral and bilateral, for the treatment of large vertebral-basilar aneurysms in 14 patients with one delayed death. Extracranial ligation was carried out unilaterally with a Selverstone clamp in three patients. In two, where the aneurysm filled only from one vertebral artery, there was extensive thrombosis within the sac and dramatic clinical improvement after decompression. Extracranial ligation was done bilaterally in three patients, temporarily in two. A 14-year-old boy is well after 5 years but the bilateral vertebrobasilar aneurysm did not undergo extensive thrombosis until both vertebral arteries were occluded at their intracranial entrance above collateral flow. In two others, the clamp had to be reopened on the second artery. In one patient, death from delayed thrombosis of a huge aneurysm and pontine infarction might have been prevented with anticoagulants. In the other, the aneurysm ruptured again fatally 18 months later.

Unilateral intracranial occlusion of a vertebral artery was done in eight cases, with no morbidity and complete or nearly complete thrombosis in all but one aneurysm. Seven patients had excellent or good results while one showed little recovery from an existing medullary syndrome.

Occlusion of the basilar artery was done in seven cases. In five it was used deliberately as the only treatment, but in two it was forced when an aneurysm burst during dissection. Only two of the patients in the first group and one of the second group have made complete recoveries.

The results of vertebral artery occlusion are encouraging and the technique deserves further consideration. Extensive collateral circulation enhances the safety of cervical vertebral artery occlusion but can be of a degree to make the occlusion ineffective. For intracranial occlusion knowledge of the size and distribution of each vertebral artery is essential. Occlusion of the basilar artery is dangerous, although it seems to be effective in producing extensive thrombosis in the aneurysm. It should probably be done under anesthesia only when the artery fills spontaneously from the carotid circulation. Otherwise, even when reasonable posterior communicating arteries are demonstrated, it is best to test occlusion under local anesthesia.

Key Words: giant aneurysm • ligation • occlusion • vertebral artery • basilar artery • clip

Although a vast literature on carotid ligation has accumulated, the experience with surgical occlusion of the vertebral artery in the treatment of aneurysms has been limited. Only 20 cases have been described even though vertebral angiography is widely used to facilitate diagnosis of posterior fossa aneurysms. An excellent review of the literature to 1972 was contained in a recent case report. The major
reason for cautiousness with this technique has probably been doubt of the effectiveness of occlusion of a single vertebral artery. In the only human study, no measurable drop in pressure was found in the vertebral or posterior inferior cerebellar (PICA) arteries distal to occlusion of one vertebral trunk. These authors concluded that occlusion of a vertebral artery is not likely to aid in the treatment of aneurysms on this vessel. Dandy's celebrated experience, "the fastest death I have ever seen," also may have been a deterrent to many surgeons.

As far as the basilar artery is concerned, there have been only two previous reports of its deliberate occlusion.

Case Reports

In over 270 vertebral and basilar aneurysms, there were 21 cases in which, because of size and position, it was deemed advisable to occlude one or both vertebral arteries or the basilar artery (Table 1).

We deliberately occluded the vertebral artery in the neck, unilaterally in three cases and bilaterally in three; in two cases the second occlusion was temporary. In eight cases we occluded one vertebral artery intracranially; in two of these it was included with the clip on the aneurysm.

Extracranial Unilateral Vertebral Artery Ligations

Case 1. This 37-year-old man presented in June, 1969, with a 6-month history of paresthesia of the right hand and a slowly progressive right hemiparesis, dysarthria, and dysphasia. The fusiform aneurysm filled only from the large right vertebral artery, although the left vertebral injection filled the vertebro-basilar system well (Fig. 1). On July 18, 1969, the right vertebral artery was occluded without incident in the vertebral triangle of the neck with a Selverstone clamp. Postoperative angiography showed a considerable reduction in size of the proximal fusiform enlargement of the vertebral artery by thrombosis, but the saccular portion persisted at or near the union of the vertebral arteries with the basilar artery. Six months later, in January, 1970, the numbness and hemiparesis had disappeared but the patient remained mildly ataxic. In July, hemiparesis recurred with hypealgesia below T-7 on the right. The patient was more ataxic and had to use a cane. Repeat angiography showed the aneurysm to be slightly larger and there was collateral flow now filling the right vertebral artery from the thyrocervical trunk. A subtemporal transtentorial exploration was carried out by Dr. Phanor Perot to assess the possibility of clipping the right vertebral artery in a trapping procedure. However, the basilar artery appeared to be emerging from the aneurysm so that nothing more was done. The patient was discharged with a mild improvement in the hemiparesis. It was suggested that if the regression continued, ligation of the other vertebral artery might be considered. However, he died suddenly on August 18, 1973, presumably from rupture of the aneurysm. There was no postmortem examination.

Case 2. This 15-year-old girl was seen in April, 1971, with a 1-year history of occipital headache with exercise and true vertigo and vomiting. The headache gradually became more severe and intractable, and was associated with diplopia, right-sided numbness, dysphasia, dysarthria, and ataxia. On examination, she was dysarthric and choking with palatal palsy and there was nystagmus in all directions of gaze with bilateral reduction of the corneal reflexes and gross ataxia. An extreme degree of opisthotonos developed prior to operation. The aneurysm filled only from the right vertebral injection (Figs. 1 and 2 upper left and right). On April 23, a Selverstone occlusion of the right vertebral artery in the neck was done uneventfully. On April 26, 1971, the patient had an episode of headache and numbness in the back of the head, right side
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<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Presenting Symptoms*</th>
<th>Arterial Supply</th>
<th>Aneurysm Thrombosis</th>
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<td>1</td>
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<td>2</td>
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<tr>
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<td>16</td>
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<tr>
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<td>14 M</td>
<td>SAH</td>
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<td>excellent</td>
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* SAH = subarachnoid hemorrhage.

of the face, trunk, and extremities, with weakness of the left leg and hand; this cleared in about 5 hours. On repeat angiography, the aneurysm was seen to have been nearly completely thrombosed. Only a small crescent-shaped area of filling (1.2 x .5 cm) was seen in the extreme left upper superolateral aspect (Fig. 2 lower). On May 3, a posterior fossa craniotomy was done in the hope that some form of end-aneurysmorrhaphy could be accomplished in order to reduce the bulk of the aneurysm. This was found not to be possible since the left vertebral artery was splayed out into the base of the aneurysm for about an inch. The patient was left with a generous suboccipital decompression. Following this, there was gradual improvement although she required a temporary gastrostomy for bulbar paresis. Subsequently, she made a complete recovery from all neurological deficit and has been able to return to all activities and obtain honor grades in school.

**Case 3.** This 52-year-old woman had sudden onset of a left hemiplegia in the middle of the night in December, 1969. She recovered gradually and after several months was able to assume normal activity but "dragged her left foot a bit." Early in 1971, she began to complain of headache and over the next few months became bedridden with dysphagia and a left hemiparesis and required an indwelling catheter.

Examination early in December, 1971, revealed hypalgesia of the left face with nystagmus in all directions, a right sixth and
seventh nerve palsy and right palatal weakness, a mild spastic quadriparesis, more marked on the left, and marked cerebellar incoordination of the left arm and leg. The 2-
cm fusiform aneurysm of the midbasilar artery previously shown was now greatly enlarged but filled only from the left vertebral artery (Fig. 1). There was marked hydrocephalus. On December 14, a ven-
triculoatrial (VA) shunt was done followed by improvement in headache and mentation. On December 22, a Selverstone clamp was placed on what was thought to be the left vertebral artery and closed. However, repeat angiography showed the clamp to be on a deep cervical artery, so it was reapplied properly to the vertebral artery 3 days later. The clamp was closed over 3 days under

Fig. 2. Case 2. Upper: Preoperative subtraction views show the location of the aneurysm. Lower: Postoperative views show the extent of thrombosis of aneurysm following unilateral ligation of right vertebral artery in the neck. Lateral (left) and anteroposterior (right) projections.
Vertebral and basilar artery ligation in aneurysm surgery

FIG. 3. Location of aneurysms treated by extracranial ligation of both vertebral arteries. Left to right: Cases 4, 5, and 6.

Dicumarol to prevent sudden massive thrombosis of the aneurysm and the basilar artery (compare with Case 5, below). Thereafter, the patient improved dramatically and she was able to walk at the time of discharge. The aneurysm filled only faintly from the right vertebral injection in its upper portion by collateral circulation through the PICA. Remarkably, there was no filling of the basilar artery from the vertebral or either carotid injection and it was not possible to explain how her brain stem was being perfused. When last seen in October, 1972, she was alert and active. The only findings were a mild left-sided spasticity and ataxia.

Comment. Each of these aneurysms presented as a mass lesion with signs of severe pontomedullary compression. In Cases 2 and 3, the aneurysm filled only from one vertebral injection, while in Case 1 there was some filling from the opposite side. In each case, ligation of the appropriate vertebral artery in the vertebral triangle in the neck with a Selverstone clamp was uneventful. The syndrome was arrested for 3 years only in Case 1, but recovery from severe brain-stem compression was spectacular in Cases 2 and 3, although the patient in Case 2 had, in addition, a posterior fossa decompression, and the patient in Case 3 a VA shunt. Even so, extensive thrombosis occurred in all three aneurysms and there was evidence of relief of brain-stem compression, paradoxical in view of the unlikely change in the size of the sacs. It is perhaps significant in Case 1, where postoperatively the opposite vertebral artery filled well the partially thrombosed aneurysm, that the relief was short-lived, and the sac again enlarged, ultimately producing a fatal hemorrhage. In retrospect, ligation of the second vertebral artery should have been attempted.

Extracranial Bilateral Vertebral Artery Ligation

In this group, a bilateral ligation of the vertebral artery in the neck was attempted 3 months apart, since injection of either vertebral artery filled the aneurysm.

Case 4. This 14-year-old boy had three subarachnoid hemorrhages in 1 month early in 1970. There were no neurological findings but he had a continuing severe headache. The aneurysm filled from both vertebral arteries (Figs. 3 and 4 upper left). The right vertebral artery was occluded in the neck on February 28, and the left 3 months later without sequelae. The occlusion of each artery was completed in about 15 minutes with Selverstone clamps.

The patient had no recurrent bleeding. Angiography was repeated yearly and showed good postoperative filling of each vertebral artery above the clamp by collateral flow from deep cervical branches; the aneurysm filled with contrast medium but did not show any change in size. The basilar artery filled through the left posterior communicating artery with a left carotid injection.

Repeat studies in January, 1974, showed extensive collateral flow from deep cervical arteries filling the right vertebral artery and also showed that the aneurysm had enlarged significantly. One particularly enlarged deep cervical branch entered the vertebral artery in
Case 4. Upper Left: Initial admission. Vertebral angiogram, anteroposterior view, showing large vertebrobasilar junction aneurysm filling equally well from both vertebral arteries. **Upper Right:** Angiogram, lateral view, done 4 years later, showing huge collateral deep cervical artery which had developed and was now filling the vertebral artery retrogradely, and also showing an enlarged aneurysm (not visible). **Lower:** Left carotid angiograms. The basilar artery is filled only through the large right posterior communicating artery and only the upper cap of the aneurysm fills. The left vertebral artery fills retrogradely from the external carotid artery but it remains occluded above at the atlas. **Left:** Lateral subtraction. **Right:** Subtraction, half-axial view.
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the sulcus arteriosus (Fig. 4 upper right). On the left side, an arteriovenous communication had appeared between the vertebral artery and deep cervical veins at C-6 and there was no longer filling of the left vertebral artery above C-1.

In December, 1974, the studies were repeated showing the remarkable collateral circulation again on the right side with further slight enlargement of the aneurysm. After discussion with the boy, now aged 19 years, and his parents, it was agreed to attempt occlusion with a Selverstone clamp of the right vertebral artery in the sulcus arteriosus of the atlas beyond the large collateral branch and just proximal to its intracranial entry. With the patient in the park bench position, this segment of the artery was exposed after the overlying rim of the atlas had been removed. During dissection of the artery, an attempt to gain room for the clamp further laterally resulted in a small tear just beyond the entry of the large deep cervical branch. There were no alterations in the vital signs, when the bleeding point and presumably the artery were occluded by pressure. The vessel was quickly set up for repair with traction on a ligature underneath laterally just inside the collateral branch and a temporary clip medially. Since there were still no changes in vital signs, it seemed reasonable to wait before doing the repair which would have required one or two tiny sutures in a portion of the artery that would be just at the lateral edge of the clamp for which there was little enough room. When after 1 hour there were still no vital changes, the artery was clipped distally beside the dural sac and just proximal to the rent to include the large collateral branch. The patient was placed on a low dose of heparin for 5 days and he had a postoperative course that was completely uneventful. Postoperative angiography showed no intracranial filling from either subclavian injection. Although both vertebral arteries filled in their cervical portions through collateral flow, the right artery was occluded by the clips in the sulcus arteriosus. The left artery was occluded at the angle where it entered the sulcus, presumably from thrombosis somehow related to the original occlusion in the neck and the arteriovenous (AV) fistula. What is more significant is that while the basilar artery filled well only with left carotid injection through a large posterior communicating artery, the aneurysm seemed to have undergone nearly complete thrombosis, with only the cap of its very upper portion filling (Fig. 4 lower). The intracranial portions of the vertebral arteries did not fill. Neither PICA was seen, but fairly large anterior inferior cerebellar arteries (AICA's) were seen arising from the small part of the aneurysm, and presumably were irrigating the vertebral-PICA territory.

The patient is scheduled to return in a year for repeat studies when, if there are no significant changes, the vertebral AV fistula might be occluded by embolization.

Case 5. This 48-year-old man presented with a 3-year history of right-sided headache, gait disturbance, dysphagia, and decline in mentation with inappropriate emotional responses. His aneurysm was enormous and filled from both vertebral arteries (Figs. 3 and 5 left); examination revealed ataxia. Because of hydrocephalus, a VA shunt was inserted on December 9, 1970. On December 21, a Selverstone clamp occlusion of the left vertebral artery was carried out over a period of 20 minutes in the recovery room.

He was readmitted 3 months later, still ataxic and complaining of more dysphagia and headache. On May 26, 1971, a Selverstone clamp was applied to the right vertebral artery. On the following day, the clamp was closed completely over 30 minutes without sequelae. Three hours later, he suddenly became drowsy with a right hemiplegia. The clamp was opened and his neurological deficit cleared completely in 30 minutes. The following day, 30 hours after the original occlusion of the clamp, there was sudden onset of deep decerebrate coma. Angiography revealed the right vertebral artery to be patent but massive thrombosis had occurred in the aneurysm; this had undoubtedly occluded a significant segment of the basilar artery (Fig. 5 right). He died 2 weeks later, and permission for autopsy was not obtained.

Case 6. This 55-year-old man had three subarachnoid hemorrhages in the first week of December, 1972. He remained very confused but without focal deficit.

On December 27, the aneurysm was explored through a right temporal craniotomy. Only a small portion of the anterolateral
aspect of the aneurysm could be seen; the major part of the neck and waist was buried in the interpeduncular cistern and would have required division of the crus cerebri in order to be seen (Fig. 3). This approach was discussed but abandoned in view of the major deficit it would have produced. Postoperatively, the patient had a mild left hemiparesis for 2 days, along with an incomplete third nerve palsy and persisting confusion. On January 5, 1973, a Selverstone clamp was applied to the left vertebral artery in the neck. Later that day, the clamp was closed completely without incident. Repeat angiography showed no filling of the vertebrobasilar system from either carotid injection.

He was readmitted in April with complete recovery of his mentation and memory and resolution of the third nerve palsy. A Selverstone clamp was applied to the right vertebral artery and on April 19, the clamp was closed in 1½ hours without sequelae. On April 21, 30 hours after occlusion of the second vertebral artery, the patient was sitting and eating dinner, when he suddenly began to sweat, his speech became slurred, and there was conjugate deviation of the eyes to the left. There was gross intention tremor of the left arm, but the legs were not involved and there was no sensory impairment. The clamp was opened within 3 minutes of the onset. The stupor deepened over the next 5 minutes, and he had small fixed pupils, but thereafter he improved rapidly. On the following day, he was alert, well oriented, and cooperative, but his speech was slurred and there was a disinclination to move his eyes. On April 23, ventricular tachycardia occurred suddenly, and would not revert with a Lidocaine drip or two shocks with the converter. The rhythm spontaneously reverted to normal 5 hours later. Following this episode, he was confused, with a mild left hemiparesis. Angiography revealed the right vertebral artery to be intact, and there was no collateral flow into the vertebrobasilar system from carotid or left vertebral artery injection. He was discharged on digitalis, still confused, with ataxia to the left and impaired position sense in the left foot. Ten months later, his physician described him as being perfectly well except that he had had a single convulsive seizure. However, 18 months later, on October 21, 1974, he died within hours after a massive recurrent subarachnoid hemorrhage. There was no postmortem examination.
Comment. Bilateral ligation of the vertebral artery for aneurysm has only been attempted once before, and resulted in Dandy's celebrated experience.  However, Alexander demonstrated its feasibility in 12 cases where bilateral ligation of the vertebral artery was carried out for epilepsy (simultaneously in 5 cases). There was only one death from empyema and the only other complication was that of Horner's syndrome. It would seem that age and collateral flow either to the vertebral arteries or through the carotid system are important. In the first case the bilateral Selverstone occlusions in the lower neck were uneventful but both vertebral arteries subsequently filled from remarkable collateral circulation and there was filling of the basilar artery from the left carotid artery. The aneurysm was at first smaller, but after 4 years, the collateral flow to one vertebral artery was sufficient to cause it gradually to enlarge. There was no major effect on the aneurysm until both vertebral arteries were occluded beyond their collateral flow at the termination of their extracranial courses. It is interesting that the left posterior communicating artery was then sufficient to maintain the vertebrobasilar circulation.

In the last two patients (Cases 5 and 6), the clamp on the second artery had to be reopened after 3 and 30 hours respectively because of deterioration with a hemiplegia. Both patients recovered promptly, but in the second case deep decerebrate coma followed suddenly, 24 hours later, from massive thrombosis in the aneurysmal sac which occluded the basilar artery. It is conceivable that this might have been prevented if an anticoagulant had been used after the clamp had been reopened and he had recovered from the initial hemiplegia.

What is most important, however, is that no collateral flow from the carotid arteries could be demonstrated in the last two cases pre- or postoperatively. Nor was any collateral supply seen to the vertebral arteries from deep cervical branches.

Intracranial Vertebral Artery Ligation

Each of these aneurysms was explored intracranially because of the possibility that the neck of the aneurysm might be ligated, although in Cases 8, 9, and 12 the size of the aneurysm from massive spontaneous mural thrombosis was not realized until the sac was seen. Each aneurysm except that in Case 12 filled from only one vertebral artery; this vessel was clipped just as it entered the aneurysm distal to any significant arterial branch, except in Cases 9 and 11. In Case 7, the aneurysm could be trapped and collapsed.

Case 7. This 45-year-old woman had had a left common carotid artery ligation for a ruptured carotid-communicating aneurysm in May, 1965 (Fig. 6). In May, 1972, a recurrent subarachnoid hemorrhage occurred with left-sided "numbness" which was subsiding gradually by the time of admission. There was no filling of the aneurysm from a right vertebral injection.

On June 5, 9 days after the bleeding, the aneurysm was explored through a left suboccipital craniectomy with the patient in the park bench position. The aneurysm could be seen arising from the left vertebral artery with a neck smaller than had been foreseen. Even so, it was impossible to prevent a clip placed on the neck from slipping down to occlude the artery. However, the aneurysm was trapped with a clip just below the neck, and a ligature was placed above, where the PICA, arising just at the upper aspect of the neck, left no room for a clip.

The patient's postoperative course was uneventful except that she had a partial 10th, 11th, and 12th nerve palsy with a persisting faint left hemispheric hypalgesia with a mild left hemiparesis and ataxia. In January, 1972, the right carotid aneurysm was clipped and a stump left vertebral-superior cerebellar aneurysm was packed with gauze, after which she made an uneventful recovery. Angiography at that time revealed filling of the vertebrobasilar system through the right vertebral artery, which also filled the distal left vertebral artery and PICA. When seen in July, 1973, she had recovered completely except for slight hoarseness of her voice and a droop of the left palate, but there was no dysphagia. The tongue now deviated only slightly.

Case 8. In April, 1970, this 34-year-old woman complained of right earache and blurring of vision. On examination, in September, 1971, she was staggering and had diplopia, and by July, 1972, she was grossly ataxic with right trigeminal hypalgesia and a complete right sixth nerve palsy. The aneurysm filled chiefly from the left vertebral
artery with only a small portion of the upper aspect of the neck filling from the right vertebral injection (Fig. 6).

On July 5, the left vertebral artery was clipped as it entered the aneurysm after temporary occlusion had demonstrated no change in the vital signs. Remarkably, there was early recovery of the sixth nerve palsy to about 75% of normal. The ataxia and fifth nerve signs disappeared completely. Angiography revealed that the lower loculus of the aneurysm had thrombosed although the upper remained largely unchanged. Six months later, further thrombosis had occurred in the upper loculus. The patient was perfectly well except for double vision.

**Case 9.** This 42-year-old woman had a subarachnoid hemorrhage in June, 1963, and thereafter complained of headache and a gradual onset of a spastic tetraparesis more marked on the left side, with nystagmus slower and coarser to the left. The aneurysm filled only from the left side and appeared in the angiogram to have a neck; however, at exploration through the left side with the patient in the park bench position, the aneurysm was much larger and globular with both vertebral arteries entering it at their union (Fig. 6). The left PICA came off just at the neck with no room for a clip beyond it. Trial occlusion of the left vertebral artery was carried out just below the PICA in the hope that the PICA would fill from the right vertebral artery. There were no changes in the vital signs and the PICA seemed to fill just as well, so a permanent clip was applied. The vital signs remained stable throughout the termination of the procedure. Postoperatively, she was well except that there was more weakness proximally in the left arm. Angiography revealed that complete thrombosis of the aneurysm had occurred and that the left PICA filled retrogradely from the right vertebral artery. Within a few months there was complete recovery from the tetraparesis, and the only residual symptom was a mild hyperreflexia.

**Case 10.** On February 6, 1973, this 52-year-old woman suffered a subarachnoid hemorrhage with transient loss of consciousness during a violent argument. She remained neurologically normal. On March 5, 1973, a left subtemporal transtentorial approach was used in order that the basilar artery might be seen without the dome of the aneurysm obscuring the view. The left vertebral artery could be found entering the base of the aneurysm but neither the upper aspect of the neck nor the root of the basilar artery could be seen in spite of a fair amount of retraction of the pons (Fig. 6). The left vertebral artery was held closed with forceps for a minute or two without sequelae, so a Scoville clip was applied flush with the neck. The patient was mildly dysphasic and confused after the operation, and had a partial sixth nerve palsy. Angiography showed an occluded left vertebral artery and no filling of the PICA although there was no sign of an infarct. The right vertebral injection showed that the aneurysm was virtually completely occluded by thrombus. Only slight widening of the artery existed at its connection with the sac. There was now evidence of marked hydrocephalus. The cerebrospinal fluid (CSF) was orange-colored under pressures of 270 to 330 mm H₂O.

After a VA shunt on March 26, her improvement was dramatic. She was discharged perfectly well except for diplopia, and she

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**FIG. 6. Location of aneurysms treated by intracranial ligation of the vertebral artery.** *Left to right: Cases 7, 8, 9, 10, 11, and 12.*
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subsequently recovered completely from the sixth nerve palsy.

Case 11. This 50-year-old obese woman had a brief coma producing subarachnoid hemorrhage on August 16, 1974. Vision was reduced severely in both eyes by retinal hemorrhages but she remained otherwise well. The aneurysm filled only from left vertebral injection but faint reflux could be seen from the right vertebral artery into the very termination of the left (Fig. 6). On September 4, she was operated on in the park bench position through a left suboccipital craniotomy with the head well flexed. The cerebellum did not slacken off well even with drainage of CSF and with mannitol. Exposure of the neck of the bilocular aneurysm was difficult and necessitated heavier retraction on the cerebellum and medulla in order to gain room. The 12th nerve was split by the lateral loculus.

By this time, the cerebellum was becoming quite tight and bulging through the craniotomy although the airway was repeatedly verified to be clear and there was no clot. Although the aneurysm could have been clipped, the cerebellar swelling made this now very dangerous. After holding the vertebral artery closed with forceps for a few minutes without sequelae, this vessel was occluded proximal to the origin of the PICA, since the origin of this branch made it impossible to get a clip between it and the neck. It was felt that the PICA would be irrigated by reflux from the right vertebral artery.

The postoperative course was uneventful except for paresis of the palate and tongue on the left side. The cerebellar swelling was believed due to venous obstruction in the neck from the operative position and neck flexion. Right vertebral angiography revealed that the aneurysm was largely thrombosed and there was retrograde filling of the left PICA.

Case 12. This 31-year-old woman had a subarachnoid hemorrhage in December, 1973, associated with choked discs, right hemiparesis, and left fourth and sixth nerve pareses. The aneurysm was considered to be inoperable but except for diplopia, she recovered completely following a VA shunt for the associated hydrocephalus. Six months later she had mental dulling, paralysis of upward gaze, and return of the cranial nerve pareses. Repeat angiography showed the aneurysm to be greatly enlarged and presumably dangerous (Fig. 6). The posterior cerebral arteries were filled by small posterior communicating arteries from respective carotid injections but there was no filling of the basilar artery. Since the aneurysm was suspected to be huge with mural thrombus, it was agreed to attempt occlusion of the basilar artery just below it, or failing this, to occlude the large right vertebral artery even though injection of the small left vertebral artery filled the aneurysm.

At operation on September 25, 1974, the aneurysm was exposed through a right subtemporal transtentorial opening. The sac was huge and buried in the pons and midbrain; its base was firm and yellow, splaying out from its origin. Since there were a number of perforating vessels just below, a clip was applied across the basilar artery just above its origin. Within a few seconds, respiration became gasping and the blood pressure rose. The clip was removed. However, the large right vertebral artery could be occluded near its termination without any changes in vital signs, so a permanent clip was applied.

Postoperatively the patient was deeply comatose with a left hemiplegia, and the eyes were deviated to the left. However, she recovered rapidly and by the end of 2 weeks was ambulatory with only a mild left hemiparesis and a right sixth nerve palsy from its retraction. Angiography showed that the right vertebral artery was satisfactorily occluded distal to the PICA but the aneurysm still filled well from the left vertebral injection. A week later, injection of the small left vertebral artery showed that the aneurysm had increased moderately in size although the flow in the sac was stagnant suggesting the occurrence of some thrombosis. It was decided not to attempt left vertebral occlusion in the neck at this time.

Comment. The results in this group of cases where the aneurysm filled largely or entirely from one vertebral artery are striking. Major degrees of thrombosis of the sac occurred in Cases 7 to 11 where the aneurysm was seen at angiography by injection of only one vertebral artery. The exception was Case 12 where preoperative studies demonstrated filling by both vertebral arteries although one was large and the other small. When it was not possible to occlude the basilar artery, it
was considered that occlusion of the larger vertebral artery might promote alterations of flow within the sac and cause thrombosis. The stagnant flow within the aneurysm suggests some alteration of hemodynamics within but it is disturbing that the size of the lumen had increased somewhat. An attempt to ligate the smaller vessel in the neck might well have promoted thrombosis of the sac, but the risk factor was considered quite high in view of the effect of even very temporary basilar artery occlusion.

Also of great interest is that the first three patients in this group recovered dramatically from brain-stem compression syndromes with thrombosis of the sac; this would seem paradoxical, since any major change in the size of the mass would be unlikely. In each of these cases, the opposite vertebral artery was sufficient to irrigate the brain stem and in three cases, the opposite PICA.

Inclusion of Vertebral Artery in Clip across Aneurysmal Neck

In Cases 13 and 14, the opposite vertebral artery, which was small and hidden by the neck, had to be included in the clip in order to occlude the neck of the aneurysm satisfactorily.

Case 13. This 36-year-old man had subarachnoid hemorrhages in 1957, 1964, and 1967 without suffering coma. In December, 1968, he was admitted after the gradual onset of a left hemiparesis. A Pantopaque ventriculogram demonstrated a mass anterior to the medulla but it could not be seen at posterior fossa exploration in another institution. By March, 1971, he had a severe spastic left hemiplegia sparing the face with nystagmus on lateral gaze and 11th and 12th nerve palsies on the left. At operation on March 29, it was decided to use a left subtemporal, transtentorial approach in spite of the left hemiparesis in order to be able to see the neck of the aneurysm. After defining the basilar artery emerging from the neck of the aneurysm (Fig. 7), it was necessary to separate the ninth and 10th nerves from the cerebellum and work behind these nerves in order to see the left vertebral artery at the neck. The right vertebral artery could not be seen; since it was known to be small, it was decided that it must be taken in the clip. The longest Heifetz clip had to be reapplied twice before it stayed on, but the aneurysm bled briskly after needle puncture. After several clips were tried, all of which slipped, the aneurysm had to be separated from a dense adherence to the clivus so that the right vertebral artery could be felt with a hook. Then a long clip could be applied across the neck and the right vertebral artery; at this time the aneurysm collapsed. During this procedure, systolic pressures were kept at 50 mm Hg for 1 hour and between 50 and 60 mm Hg for a second hour.

Postoperatively, the patient remained alert and oriented, without increase in deficit. There were no seventh, eighth, ninth, or 10th nerve palsies in spite of the manipulation of these nerves in order to reach the lower clivus. Angiography revealed a portion of the neck still to be filling and the right vertebral artery to be occluded.

Case 14. This 31-year-old woman had a subarachnoid hemorrhage on May 12, 1971, without deficit. On June 7, a right subtemporal, transtentorial approach was used under mean arterial pressures of 40 to 45 mm Hg for 1 hour. The aneurysm was large with mural thrombus and could be dissected free from the clivus. The far side of the neck and larger left vertebral artery could be seen by depressing the basilar artery and neck of the sac (Fig. 7). A Heifetz clip repeatedly slipped down to occlude the small right vertebral artery and the parent left vertebrobasilar junction, and was removed four times. The
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Figs. 8. Location of aneurysms treated by deliberate basilar artery occlusion. Left to right: Cases 15, 16, 17, 18, and 19.

small right vertebral artery was taken in the base of the clip, and the blades slipped down to occlude the neck, but remained just below the left vertebral artery.

Postoperatively the patient remained well. Partial sixth and seventh nerve palsies became nearly complete on the second day but both resolved completely in 2 months. A slight reduction in hearing remained. Angiography revealed the aneurysm and the right vertebral artery to be completely occluded.

Both patients in Cases 13 and 14 had good results. It would appear reasonable to take the opposite vertebral artery whenever it is necessary to occlude the neck of a large aneurysm, particularly when that vessel is small.

Deliberate Occlusion of the Basilar Artery

Experience has been gained with occlusion of the basilar artery in seven cases, in all but two, it was used deliberately. A form of Hunterian ligation of the basilar artery appeared to be the only treatment that could be offered to the next five patients, who harbored giant aneurysms, three of which arose from the trunk of the artery and two at the termination. In Cases 15, 17, and 19, it was known from preoperative angiography that the carotid circulation filled the basilar artery well through the posterior cerebral arteries. In Case 16, in which the situation was desperate, all that was known was that the posterior cerebral artery filled well from a left carotid injection. In Case 18, large posterior communicating arteries were seen during exploration of the aneurysm.

Case 15. This 59-year-old woman had complained of headaches for 18 months and dysphagia with bulbar paresis for 1 year. For several months she had been bedridden with a severe ataxia. The aneurysm filled almost as well by right or left carotid injections through two large posterior communicating arteries (Fig. 8). It was felt that in these circumstances, the aneurysm might be trapped on the basilar artery and collapsed; the perhaps naive view was that no major vessels arose from this short segment of the artery. On January 30, 1970, she was operated on through a right subtemporal transtentorial approach under deep hypothermia (19°C) and cardiopulmonary bypass. This technique was used to open and collapse the sac under circulatory arrest, and expose the proximal basilar artery. The basilar artery involved was longer than anticipated, but only one small branch that could not be spared was seen on the far side of the sac. Clips were placed on the basilar artery as it entered and emerged from the aneurysm. The patient remained in deep unresponsive coma and died on January 31. Examination of the specimen revealed that both AICA's and several smaller branches arose from the sac between the clips and massive pontine infarction had occurred (Fig. 9). In retrospect, this might have been anticipated. In view of subsequent experience she probably would have survived and benefited if only the lower clip had been applied through a posterior fossa approach.

Case 16. This obese 33-year-old woman, 34 weeks pregnant, had a subarachnoid hemorrhage on November 26, 1972, but was discharged 5 days later after recovery from a
FIG. 9. Case 15. Postmortem photograph showing clips trapping huge aneurysm on basilar trunk. Both AICA's can be seen arising just above the lower clip.

partial third nerve palsy. On the same day, another hemorrhage occurring at home left her drowsy and confused; a third nerve paresis again subsided quickly. At the time of transfer, she was obtunded, with a drift of the left arm and a partial right third nerve palsy. The right posterior cerebral artery filled from the right carotid injection, but there was never any filling of the left from the vertebral or carotid injection although, as it turned out, the left posterior communicating artery was present and joined the posterior cerebral artery as it emerged from the aneurysm (Fig. 8).

On December 14, she deteriorated rapidly into an unresponsive state with extreme sunset eyes and hyperventilation, moving only feebly both legs and the right arm. Mild improvement had occurred by the time of operation on December 15. A large temporal bone flap was used on the left side to avoid the bulk of the aneurysm, which projected to the right. The brain remained tight in spite of mannitol and lumbar drainage of CSF. The crus had to be retracted, since it covered the basilar artery and the origin of the superior cerebellar artery, which arose from the sac 3 or 4 mm distal from its inferior margin. The posterior cerebral artery emerged from the aneurysm a full 2 cm away. Since there was no hope of occluding the aneurysm and the patient's situation was desperate, a reasonable alternative was a clip placed on the basilar artery as it entered the aneurysm. A large decompression was left.

Although initially in the same state as before operation, she gradually declined over 3 or 4 days to a decerebrate state. Vertebral angiography on December 19 showed faint filling of the aneurysm from the superior cerebellar artery, which filled retrogradely by collateral flow from the AICA. Thereafter, there was only minor improvement. She had severe bilateral spastic hemiplegias but would move both feet feebly on command. There were no definite oculomotor palsies although there was downward deviation of the eyes.

The baby was born uneventfully on December 31, 1972. Subsequently, there has been no real improvement in this patient. Repeat angiography on January 2, 1973, showed that the aneurysm no longer filled. The small posterior communicating arteries now filled the respective posterior cerebral arteries and the right superior cerebellar artery. The left cerebellar artery still filled retrogradely from the AICA. In view of the filling of the upper vertebral basilar system from the carotid circulation postoperatively, it is possible that she might have done reasonably well had the basilar artery been occluded before her deterioration with the third hemorrhage. However, this must be interpreted cautiously in view of the events occurring in Case 19.

Case 17. This 25-year-old woman had complained of headache for years, and had noticed incoordination of her right arm and hand for 6 months, ataxia to the right and diplopia for about 3 months, and more recent dysphagia. In January, 1973, she had nystagmus in all directions of gaze, right palatal palsy and right hemiparesis and cerebellar incoordination of movement. She
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fell consistently to the right. Her aneurysm was large, but the jet of dye entering the aneurysm seemed narrow enough that the neck might be occluded (Figs. 8 and 10 left). The right carotid artery filled the basilar artery and its branches down to the region of the aneurysm (Fig. 10 right).

On January 8, 1973, through a posterior fossa approach with the patient in the sitting position, the aneurysm was revealed to be huge with mural thrombus. Each vertebral artery, then both, were occluded with forceps as they entered the aneurysm at their union, without alteration of the vital signs. A Scoville clip was left in place across this union, again without effect.

For 24 hours, she had a devastating neurological deficit with paralysis of all eye movement except downward gaze, bilateral facial paralysis, a complete bulbar palsy, and a dense left hemiplegia. However, by the next day, the extraocular palsies had disappeared except for a left sixth nerve paralysis and nystagmus in all directions. Only the left palate and left side of the tongue were weak; left hemiplegia had subsided to a moderate hemiparesis. Vocalization was feeble.

By the end of January, she was walking with help. The sixth nerve paralysis was resolving and the major remaining deficit was the bulbar paresis. She could talk only in a whisper, but swallowed well. Postoperative angiography on February 2 showed no filling of the aneurysm. The basilar artery and its branches filled well nearly down to the clip from a right carotid injection. Subsequently her recovery has been virtually complete for all brain-stem and cranial nerve function. She has been left with a slightly husky voice from a partial left and faint right vagal palsy. She has had another child and carries on with her household work in normal fashion. It is interesting that the intraoperative trial occlusion gave no hint of the initial severe brain-stem ischemia.

Case 18. This mildly hypertensive, 42-year-old man had a brief coma-producing subarachnoid hemorrhage on April 3, 1973. At operation on April 23, with a mean arterial pressure (MAP) of 40 mm Hg for 40 minutes, a clip could be applied to the neck of the aneurysm but would slip down repeatedly to occlude the origins of the posterior cerebral arteries, which peculiarly emerged downward from the ectatic base of the sac (Fig. 8). Trial occlusion of the basilar artery just below the superior cerebellar arteries produced apnea in 10 to 12 seconds at MAP 40 mm Hg and shallow breathing at MAP 60 mm Hg. It was decided, therefore, not to clip the basilar artery, although both posterior communicating arteries were seen to be of fair size in the operative field. The patient had
only a partial third nerve palsy, but was very disappointed in the result. After discussion, he agreed to reoperation under local anesthetic on April 26; it was necessary to use a narcoleptic because of discomfort. Several more attempts to place a clip on the neck of the aneurysm were similarly unsuccessful. After an antinarcotic, he roused sufficiently to be semi-cooperative. Following trial occlusion with forceps, a Scoville clip was placed on the basilar artery just below the superior cerebellar arteries and produced no change except that he would not move the left side until the retractor was removed (Fig. 11 left). His recovery was uneventful and complete. Angiography revealed the aneurysm to fill faintly from the right posterior communicating artery. Six months later, there was increased filling although the aneurysm remained slightly smaller (Fig. 11 right). He has returned to his professional work.

Case 19. A 44-year-old woman with active hyperthyroidism under treatment had a coma-producing subarachnoid hemorrhage on November 29, 1974, from which she recovered completely. She was hypertensive with exophthalmos, tachycardia, and 30 lb weight loss, but there was no neurological deficit. Treatment of the hyperthyroidism and investigation of a pyrexia delayed definitive treatment of the aneurysm for 7 weeks; by the end of this time she was confused and intermittently hallucinated. On repeat angiography, Dr. John Allcock compressed the right carotid artery during the right vertebral artery injection and demonstrated good filling of the right posterior communicating artery and carotid siphon as well as some filling of the left posterior communicating artery, which previously had filled faintly from the left carotid injection (Fig. 8).

Direct attack on the aneurysm, even on bypass, had been considered but was abandoned in view of the patient’s serious systemic illness. It was decided, in view of the reasonable size of the posterior communicating arteries and previous experience with this situation, to occlude the basilar artery under general anesthesia, since her confused state made use of local anesthesia impossible. A small right temporal flap was made on January 9, 1975. The edge of the tentorium was tied down to the floor of the middle fossa to gain more room in the interpeduncular cistern. The basilar artery was temporarily occluded just below the superior cerebellar arteries first with forceps, then with a clip for 30 minutes without any alteration of vital signs. The clip was therefore left in place.

Postoperatively, the patient remained in light stupor with flaccid limbs, but she could be roused and could localize arm movement.
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Fig. 12. Case 19. Postoperative right carotid arteriogram showing excellent filling of basilar artery and all its branches above the clip. This did not, however, prevent upper brain-stem ischemia. Left: Lateral view. Right: Half-axial projection.

to stimulation. There was no spontaneous movement except in the right leg and no response to command. The pupils were large but reacted briskly and aside from a slight downward deviation, there was no extraocular palsy. Angiography on the first postoperative day showed excellent filling of the basilar artery and all its branches above the clip from right carotid injection (Fig. 12). The left posterior cerebral artery filled faintly from a left carotid injection. The aneurysm had thrombosed almost completely except for a thin crescent half way up on the left side.

Comment. That the posterior communicating arteries are present and of reasonable size is evidently not sufficient evidence that the basilar artery can be occluded safely under general anesthesia, even without alteration of vital signs. This catastrophe might well have been avoided had the artery been occluded temporarily under local anesthesia although this did not seem reasonable in view of the confused state of this patient. Changes in pulse, respiration, and blood pressure may well not occur except with temporary occlusion in the lower portion of the basilar or one or both vertebral arteries.

In view of the excellent basilar circulation in the postoperative carotid angiograms another explanation must be considered, namely, ischemia of the brain stem due to injury by the clip to unseen perforating vessels. There were many small vessels, and two had to be separated on the near side of the basilar artery to provide space for the clip, but it was thought that the blades did not encroach on them. Furthermore, there was evidence of thrombosis in the basilar artery for a millimeter or so above the clip such that other perforators might have been occluded. To avoid this possibility, occlusion of the basilar artery should be by the narrowest clip or by a ligature.

Only two of these five cases have benefited from occlusion of the basilar artery, although in Case 17 the circulation must have been at a critical level for the first few hours. In Case 18, it is interesting that occlusion of the basilar artery under local anesthesia failed to reveal any evidence of ischemia to the brain stem although, with the patient under anesthesia 3 days before, alteration of the respiratory pattern had appeared at MAP's of 40 and 60 mm Hg. In retrospect, ligation of the basilar artery in Case 16 in two places an inch apart was an error in surgical judgment; even though they could not be seen, it could hardly be expected that there would be no major branches from this length of the vessel. The situation in Case 16 was desperate, and the patient's husband wished the baby to survive. She survived the clip placed just below the superior cerebellar
arteries, but was worsened by retraction of a brain that was tight and swollen. Postoperative angiography suggests that had it been possible to occlude the basilar artery before development of the severe midbrain compression syndrome, the outcome might have been otherwise. However, the last case serves to demonstrate that good filling of the upper basilar system from the posterior communicating arteries does not mean that brain-stem ischemia will not develop with basilar artery occlusion, although it is possible that local injury by the clip was responsible.

Emergency Occlusion of the Basilar Artery

In Cases 20 and 21, the surgeon was forced to occlude the basilar artery when the aneurysm burst during the dissection.

Case 20. This 40-year-old man developed a third nerve palsy after treatment of subacute bacterial endocarditis for 1 month. The spinal fluid was xanthochromic but no definite ictus had occurred. The aneurysm doubled in size in 10 days. At right subtemporal exploration on April 8, 1973, the aneurysm was larger still with mural thrombus, but could be dissected free down to its rather broad base (Fig. 13). At this point, the transparent dome burst. The aneurysm could be controlled in a sucker but the fragile base parted from its origin. Repair was considered but not felt to be feasible owing to the size of the rent and the infected arterial wall. The basilar and right posterior cerebral arteries were occluded by clips. Remarkably, he responded for several hours, but then deteriorated into deep decerebrate coma and died on April 11.

Case 21. This 14-year-old boy had a single subarachnoid hemorrhage from a large vertebral junction aneurysm (Figs. 13 and 14 upper). The aneurysm burst during suboccipital exploration and it was necessary to clip the basilar artery above and below the neck. There were no sequelae. The basilar artery filled postoperatively down to the upper clip (Fig. 14 center and lower).

Discussion

Unilateral ligation of a vertebral artery for large aneurysms of the vertebral and basilar arteries appears not to be unreasonable providing that the aneurysm fills principally or entirely through one vertebral artery and that the other vertebral artery exists, unites with its fellow, and seems large enough to supply the basilar arterial system. The best result is undoubtedly achieved when ligation is done intracranially just proximal to the aneurysm; in five of six cases so treated, extensive or complete thrombosis of the aneurysm occurred. However, extracranial ligation has also been rewarding. Unilateral ligation in the neck resulted in nearly complete thrombosis in two of three cases, although in another the aneurysm was reduced in size temporarily.

Inexplicably, dramatic recovery from severe brain stem compression occurred even in cases without additional decompression. Bilateral ligation of the vertebral artery was successful in Case 4 (age 14) although the final nearly complete thrombosis of the aneurysm did not occur until both vertebral arteries were occluded just proximal to their intracranial entry beyond the extensive collateral flow that developed. On the left side this occurred fortuitously after the development of an arteriovenous fistula but, even so, the aneurysm gradually enlarged until the artery on the right side was occluded surgically in the sulcus arteriosus 5 years after its occlusion in the vertebral triangle. In the other two patients (Cases 5 and 6), the clamp had to be opened on the second artery. The use of an anticoagulant might have prevented the complete thrombosis of the basilar artery as well as of the aneurysm in the second case. Case 6 probably demonstrates the futility of occlusion of one vertebral artery for an aneurysm at the termination of the basilar artery. Age is probably a factor in regard to collateral circulation, as was demonstrated
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Fig. 14. Case 21. Subtraction angiograms. Upper: Preoperative anteroposterior (left), and lateral (right) angiograms. Center: Postoperative left carotid angiograms, subtraction anteroposterior (left) and lateral (right) views, showing occlusion of basilar artery and retrograde filling through the posterior communicating artery. Lower: Postoperative vertebral angiograms, subtraction half-axial (left) and lateral (right) views also show occlusion and filling.
in Alexander's remarkable series of 12 documented bilateral vertebral artery ligations (done simultaneously in five). The oldest patient was aged 29, the youngest 11. However, Allcock has shown that it is possible to see the size of and deduce the extent to which the posterior communicating arteries might contribute to the vertebrobasilar circulation by manual compression of the carotid arteries during vertebral artery injection.

Occlusion of the basilar artery undoubtedly can be effective in the treatment of large aneurysms that arise from the trunk or at the bifurcation of this artery; thrombosis was complete in two of the four surviving patients and nearly complete in another. In the other patient (Case 17), the aneurysm was significantly smaller 6 months later. Complete thrombosis occurred also in the case reported by Mount and Taveras. However, there can be no question that occlusion of the basilar artery is dangerous, since three of five deliberate occlusions and one of the two forced occlusions were disastrous. Jamieson was also forced to occlude the basilar artery in his Case 13, and his patient also died. Trapping should undoubtedly be avoided except when the segment to be isolated is very short and devoid of perforating vessels. It is probable that when the basilar artery fills spontaneously and well from carotid injection then basilar artery occlusion will be tolerated. However, even when the posterior communicating arteries are seen to be of reasonable size either at angiography or operation, their contribution may not be sufficient to prevent brain stem ischemia, such as occurred in one of two cases in this series. What is needed in these circumstances is a way to be certain of their functional significance. At this time, the only practical way is to occlude the basilar artery under local anesthesia, or perhaps after implantation with an inflatable cuff in the postoperative period. Serbinenko's remarkable catheter technique with a detachable balloon might provide the means to assess the effect of basilar artery occlusion in the alert patient as well as to occlude permanently the artery, even while retaining the means of reopening the vessel if onset of ischemic changes were delayed. However, the length of the balloon is almost certain to occlude some perforating arteries and falsify the test. Furthermore, in cases where occlusion is not tolerated, extracranial-intracranial anastomosis, unilateral or bilateral to a branch of the posterior cerebral artery, may provide the collateral flow that will allow safe occlusion of the basilar artery.

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