Surgical treatment of basilar artery aneurysms

Elective circulatory arrest with thoracotomy in 12 cases

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The authors report a technique to aid in the surgical treatment of patients with basilar artery aneurysms. Under moderate hypothermia a nondominant temporal craniotomy and small anterior temporal lobectomy are performed. After median sternotomy is done and ventricular fibrillation is induced, microscopic dissection around the aneurysm proceeds for 4 minutes. If more time is needed, manual cardiac systole is performed for 60 seconds. This has been repeated for as long as 28 minutes, with an average of 9 minutes of arrest. After the aneurysm has been treated, normal sinus rhythm is restored in the heart. The operative technique and 12 case histories are presented. There were two deaths among the early cases. All others have done well.

KEY WORDS • aneurysm • basilar artery • elective circulatory arrest

SINCE our initial reports of the successful treatment of an aneurysm of the basilar artery using elective circulatory arrest via thoracotomy, we have operated on 12 additional cases. Changes in the technique, indications for its use, and a review of the cases are presented.

Technique

The patients are premedicated with combinations of secobarbital, 100 mg; meperidine hydrochloride, 50 mg; scopolamine, 0.4 to 0.6 mg; or atropine, 0.5 to 0.6 mg.

The patients are placed in the supine position with the nondominant side of the head up and a small sandbag under the shoulder. General anesthesia is induced with intravenous thiopental sodium (180 to 400 mg), and maintained with halothane, 0.5% to 2%, in either oxygen (6 l/min), or in nitrous oxide (3 l/min) and oxygen (2 l/min). Curare and moderate hyperventilation are used. At 6:30 a.m. the patients are taken to the anesthesia room where hypothermia is induced by surface cooling to 82.4°F to 84.2°F (28°C to 29°C) facilitated by chlorpromazine. Blood pressures are

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monitored by an intraarterial (radial or brachial) cannula. In most cases, after approximately 3½ hours, the core temperature has reached 32°C and active cooling is continuing. At this time, the upper cooling blanket is lowered to the level of the umbilicus and the patient is transferred to the operating room.

The head, neck, and chest are prepped and draped. Two separate nursing teams are used. The neurosurgical nurse works from a Mayo stand at the head and the thoracic nurse from a Mayo stand across the legs of the patient. The neurosurgical team performs a routine temporal craniotomy. This is now always on the nondominant side to avoid any possibility of injury to the vein of Labbé. The squamous temporal bone is removed to the floor of the middle fossa. No urea, mannitol, or spinal drainage is used, and there is no retraction under the intact temporal lobe. Instead, a small subpial anterior temporal lobectomy is done, using the Greenwood suction cautery (including the new small tips used with the microscope).* Great care is taken not to pull on the pia arachnoid of the lobe and thus transmit traction effects to the incisura and aneurysm. The vein of Labbé is carefully preserved. After the lobectomy and exposure of the incisura, malleable copper retractors are placed without tension, as if they were bookmarks. The operating dissecting microscope is brought into place, and the thoracic surgery team enters. A median sternotomy and pericardotomy are done, and moist gauzes are placed over the exposed heart.

Using the microscopic instruments, the surgeon cuts the tentorium and carefully protects the fourth cranial nerve. The arachnoid over all structures is removed with sharp dissection. During this procedure perforating vessels are carefully preserved. Gently curved microdissectors are used when needed for retraction of the third and fourth cranial nerves and the posterior cerebral and superior cerebellar arteries. No cottonoids are placed over the cranial nerves. In basilar tip aneurysms, after complete removal of the arachnoid, it is rarely necessary to exert much retraction on the cerebral peduncles. Only the neck of the aneurysm is dissected, unless a wrapping or coating procedure is to be done.

At this time, the core temperature has usually reached a minimum of 82.4° to 84.2°F (28° to 29°C), and rewarming has begun. If premature rupture occurs or if aneurysm obliteration is imminent, ventricular fibrillation is instituted by applying electric shock directly to the heart (0–8 V alternating current). If treatment of the aneurysm has not been completed in 4 minutes of circulatory arrest, the intracranial procedure is stopped while the heart is manually massaged for 1 to 2 minutes; this produces a peripheral pressure of 60 mm of mercury. Another 4-minute period of arrest may then be entered. The shortest period of arrest was 1 minute and the longest was 28 minutes, with an average of 9 minutes. After aneurysmal treatment, the heart is massaged until myocardial tone returns. The NaHCO₃ solution, 250 mg 5%, is administered intravenously. When myocardial tone has returned, the heart is converted to normal sinus rhythm with a single direct current (dc) shock. Effective pressures are rapidly achieved with only a rare ventricular extrasystole. In no case has there been any difficulty in reinstituting a normal or adequate circulation.

We have used a variety of clips including Mayfield, Olivecrona, Housepian, Scoville, and Heifetz. In all recent cases involving the basilar tip, a medium straight Heifetz clip has been adequate. Of course, the usual precautions of visualizing the proximal and contralateral vessels prior to clipping are observed. No temporary clips are used on the basilar artery, and no vessels (posterior communicating or branches) or cranial nerves are sacrificed. After a clip has been placed, bits of crushed muscle are wrapped around it, between the metal edges and the cranial nerves. If coating is necessary (two cases), bits of muslin gauze are placed. Selverstone spray* is then used, and finally, bits of muscle are placed over the area.

Steroids are given during the procedure. After aneurysm treatment, 250 cc of low

*Greenwood suction cautery (bipolar coagulation forceps with suction) manufactured by Codman and Shurtleff, Inc., Randolph, Massachusetts.
molecular weight dextran (Rheomacrodex)† are given over a 2-hour period. Another 250 cc dose is given over 4 hours and then 500 cc every 24 hours for a total of about 3 days. Tracheotomy, which was elective during the early cases, has not been needed in recent cases. Chest drains are removed after 24 hours, and the patient is allowed to walk within 48 hours.

**Analysis of Cases**

Using elective circulatory arrest, since 1967 we have performed craniotomies and thoracotomies on 12 patients with basilar artery aneurysms (twice in one patient), for a total of 13 operations (Table 1). The last 10 operations were performed by the senior author. There were six men and six women, with an average age of 52; the youngest was 28 years old and the oldest 62. Five were hypertensive but none had serious cardiovascular difficulties. One had had more than one episode of subarachnoid hemorrhage. All were in Grades 1 to 3 (according to Botterell’s classification) when considered for operation. Four had extraocular muscle palsies and four papilledema. Ten had aneurysms of the basilar tip, two of the basilar stem, with one of these being a giant aneurysm (Fig. 1). Three of the group had multiple aneurysms, and two of these had a total of seven aneurysms. One had an associated arteriovenous malformation. None had arteriographic evidence of significant vascular spasm when admitted, but eight had angiographic evidence of hydrocephalus. Operation was delayed in eight until they were awake and alert at the time of operation. Parenteral steroids were used in all cases throughout hospitalization, and low molecular weight dextran was used in the immediate postoperative period. In one patient (Table 1, Case 7), the clip fractured and slipped; successful reoperation with arrest was accomplished 32 days after the first attempt. During the same period, four other patients with basilar tip aneurysms were admitted in Grade 4 or 5 status. All died of recurrent subarachnoid hemorrhage before clinical improvement.

**Operative Results**

There were two operative deaths in the 12 patients, both in early cases. One was thought to be related to inadvertent sacrifice of the vein of Labbé on the dominant side. The other was felt to be related to prolonged retraction of the cerebral peduncles for exposure of the aneurysm and multiple clip placements to repair a tear. In addition, one patient with a giant aneurysm could not be helped by surgery and later died of the effects of the aneurysm. Three early patients had mild paresis and slow initial recovery probably related to retraction during surgery. These three, and later cases, have made a satisfactory recovery and have been able to lead a normal life without neurological deficit. The patients in the later group have had a shorter hospital stay and a more favorable postoperative course. Postoperative angiograms have been done in two early cases, and in those cases treated since we discovered a slipped clip in one patient.

**Characteristic Case Summaries**

**Case 8.** This 49-year-old hypertensive man had a subarachnoid hemorrhage 18 days prior to admission. When examined he was awake and alert and complained of headache and double vision. Blood pressure was 150/100. Examination revealed only a mild left third nerve paresis. Angiography showed a large aneurysm of the basilar artery tip and mild ventricular enlargement. Five days after admission, craniotomy and thoracotomy were done. The aneurysm had a rather broad neck, closely applied to the basilar artery and involving part of the ipsilateral posterior cerebral artery. Multiple 4-minute periods of cardiac arrest with collapse of the aneurysm were made in the attempt to get a clip or ligature about the neck. Straight and angled Heifetz and Mayfield clips were used initially, and Housepian, Olivecrona, and Scoville clips were tried in subsequent 4-minute arrest periods. Finally a ligature was placed which kinked and largely occluded the basilar artery. After 28 minutes of arrest we

*Selverstone spray supplied by courtesy of Bertram Selverstone, M.D., Providence, Rhode Island.
†Rheomacrodex manufactured by Pharmacia Laboratories, Inc., Piscataway, New Jersey.
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Fig. 1. Tracings of x-rays of individual basilar artery aneurysms in 12 cases. The numbers refer to Cases 1 to 12 cited in Table 1.
McMurtry, Housepian, Bowman and Matteo

TABLE 1

Summary of results in 12 patients with basilar artery aneurysms

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age, Sex</th>
<th>X-ray Determination*</th>
<th>Aneurysm Location</th>
<th>Enlarged Ventricles</th>
<th>B.P.</th>
<th>Preoperative Symptoms†</th>
<th>Preoperative Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57 F</td>
<td>basilar tip, lt occipital AVM</td>
<td>no</td>
<td>110/80</td>
<td>SAH 7 wks PTA</td>
<td>awake, alert, rt field defect</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>45 M</td>
<td>basilar tip</td>
<td>yes</td>
<td>190/100</td>
<td>SAH 7 days PTA</td>
<td>confused, disoriented, lethargic, bilat. 6th n. palsies, rt Babinski, hemorrhages rt fundus</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>53 M</td>
<td>basilar tip</td>
<td>no</td>
<td>180/100</td>
<td>SAH 5 days PTA, severe headache</td>
<td>early papilledema</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>52 F</td>
<td>basilar tip</td>
<td>yes</td>
<td>180/90</td>
<td>SAH 11 days PTA</td>
<td>dull, confused, diplopia, lt central 7th n. weakness</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>62 F</td>
<td>basilar tip</td>
<td>yes</td>
<td>120/70</td>
<td>SAH 4 days PTA</td>
<td>dull, disoriented</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>50 M</td>
<td>giant, calcified</td>
<td>yes</td>
<td>140/70</td>
<td>progressive rt-sided weakness, diplopia, confusion, poor memory, incontinence</td>
<td>rt hemiparesis, diplopia, lt 3rd &amp; rt 7th n. paresis</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>28 F</td>
<td>basilar tip</td>
<td>yes</td>
<td>175/130</td>
<td>SAH 6 hrs PTA, repeat SAH 28 days postop</td>
<td>lethargic on both occasions</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>49 M</td>
<td>basilar tip</td>
<td>yes</td>
<td>150/100</td>
<td>SAH 18 days PTA</td>
<td>mild lt 3rd n. paresis</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>59 M</td>
<td>basilar tip</td>
<td>yes</td>
<td>130/70</td>
<td>SAH 3 wks PTA</td>
<td>vitreous hemorrhages</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>54 F</td>
<td>basilar tip</td>
<td>no</td>
<td>120/80</td>
<td>SAH 2 wks PTA</td>
<td>mild rt 7th n. weakness</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>45 M</td>
<td>basilar tip &amp; anterior communicating</td>
<td>yes</td>
<td>114/72</td>
<td>SAH 22 days PTA</td>
<td>dull</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>45 F</td>
<td>basilar tip &amp; bilateral middle cerebals</td>
<td>no</td>
<td>180/70</td>
<td>SAH 13 days PTA</td>
<td>awake, alert, mild aphasia</td>
<td></td>
</tr>
</tbody>
</table>

* X-ray films showed no evidence of spasm in any of the 12 cases. AVM = arteriovenous malformation. † SAH = subarachnoid hemorrhage; PTA = prior to admission.

succeeded in wrapping the aneurysm with muslin gauze and muscle. Recovery was very slow because of depressed sensorium but there were no focal neurological findings. Pneumonia was successfully treated and the patient eventually recovered and was discharged 51 days after craniotomy. He continued to improve and returned to work. However, gait difficulties and an organic mental syndrome developed, and he was hospitalized for a pneumoencephalogram and an intrathecal RISA scan 1 year after operation. This showed large ventricles and an incisural block; a ventricular
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### TABLE 1 (continued)

| Days After Admission | Operation                                                                 | Cardiac Arrest (min) | Postoperative Course$  
|----------------------|---------------------------------------------------------------------------|----------------------|----------------------
| 7                    | 2 Olivecrona clips                                                        | 14                   | mild Lt 3rd n. palsy & hemiparesis, cleared in several months; embolization of AVM 4 yrs later, well |
| 11                   | Scoville clip to arteriosclerotic neck                                    | 1                    | alert, slightly disoriented, mental deterioration; VA shunt 42 days postop, dramatic improvement, well |
| 8                    | neck tear, angled Olivecrona clip                                         | 23                   | hemiparesis, aphasia, stupor; re-angio, severe spasm, rt VP shunt, died 1 yr later |
| 11                   | dominant vein of Labbé torn inadvertently, straight Mayfield clip          | 3.75                 | awake with mild paresis postop; hydrocephalus 28 days later, VA shunt, pneumonia, GU infection, septicemia, death |
| 32                   | straight Mayfield clip                                                    | 12                   | awake, dull; hydrocephalus 28 days postop, no shunt, improved, well |
| 30                   | VP shunt, two shunt revisions, craniotomy (symptoms felt now due to mass effect), wrapped | 9                    | improvement after VP shunt and 1st revision, no improvement after 2nd; as pre-op after craniotomy; died several years later of pneumonia |
| 11                   | medium Housepian clip; re-op in 32 days, clip fractured & slipped, new clip applied | 6 & 12               | well after re-operation |
| 5                    | broad neck aneurysm; clipping & ligation unsuccessful, wrapped & sprayed | 28                   | slow initial recovery, shunt for hydrocephalus 1 yr later, well |
| 10                   | large aneurysm wrapped & sprayed                                          | 9                    | awake, alert, full recovery |
| 10                   | med straight Heifetz clip                                                 | 2                    | awake, alert, no deficit |
| 15                   | med straight Heifetz clip on ant. com. artery aneurysm; 42 days later, same clip on basilar artery aneurysm | 1 for second operation | full recovery from both operations, no deficit |
| 4                    | Lt middle cerebral aneurysm sprayed & wrapped; 2 mos later, med straight Heifetz clip to basilar aneurysm; rt middle cerebral artery aneurysm sprayed & wrapped 18 days after 2nd operation | 1 for second operation | full recovery after 3 operations, no deficit |

$\dagger$ VP = ventriculoperitoneal shunt.

$\S$ VA = ventriculoatrial shunt; GU = genitourinary.

Auricular shunt was performed following which he showed marked improvement and was discharged.

Case 11. This 45-year-old man had had three subarachnoid hemorrhages. The first, which occurred in 1958, was caused by an aneurysm of the right internal carotid artery at the junction of the posterior communicating artery, and was treated with internal carotid occlusion in the neck. After a second hemorrhage in 1962, a left third nerve palsy developed, and a craniotomy was done with successful clipping of an aneurysm of the right internal carotid at the posterior
communicating artery. In 1967, repeat angiography showed complete obliteration of both aneurysms but suggested the presence of an anterior communicating artery aneurysm. Large polycystic kidneys were also found. The third hemorrhage occurred on October 22, 1972, and the patient was admitted 22 days later. On examination he was awake and alert with mild headache and slight paresis on the right as a result of the previous left third nerve palsy. Blood pressure was 114/72. Complete angiography showed a large aneurysm of the anterior communicating artery and a basilar tip aneurysm. The anterior communicating artery aneurysm was clipped successfully 15 days after admission. He had a benign postoperative course. Forty-two days later he had a craniotomy and thoracotomy with a small anterior temporal lobectomy. A medium Heifetz clip was used on the neck of the basilar tip aneurysm. Total arrest was 1 minute. He was fully awake postoperatively but had some atelectasis. He recovered quickly and has returned to work.

Discussion

Early literature is replete with accounts of morbidity and mortality related to aneurysms. However, there are relatively few articles related to basilar artery aneurysm surgery, and in most of the cases the results were discouraging with significant mortality. In the Cooperative Study, although a "meaningful tabulation of results of surgery" could not be stated, eight of the 11 patients with basilar tip aneurysms died and two did poorly.

The prognosis for patients with surgically treated basilar artery aneurysms has changed dramatically in the past 5 years, largely due to the superb work of Drake. A few other surgeons have recently reported improved results, often using magnified vision and induced hypotension. We recognized that premature rupture was one of the greatest causes of poor results and death in patients with basilar artery aneurysms. Premature rupture was at times related to retraction on the intact temporal lobe with traction transmitted to the arachnoid around the incisura and the aneurysm, or to dissection of the aneurysm itself, or to placement of a clip across the aneurysm with subsequent tearing and hemorrhage. Attempts at isolating the four vessels in the neck and occluding them under deep hypothermia at the appropriate moment were often met with torrents of blood from collateral feeders. Likewise, in several cases we observed that the flow of blood resulting from tears while the patient was under moderate induced hypotension was too great to provide for rapid and accurate movements in this small and vital field. Therefore, we devised a method that provides for constant complete control of the causes of premature rupture or leakage after a clip has been placed.

The small temporal lobectomy is done in a subpial manner so that no traction is transmitted from the temporal lobe or pia arachnoid to the incisura. Mannitol and urea are not used as they too may cause rapid relaxation with pulling on the incisural arachnoid and premature rupture. With dissection, if rupture occurs there will be a "controllable flow" for 30 seconds to 1 minute, and then a "cadaver-like" state in which one can actually pick up the aneurysm, manipulate it, see points of tear together with perforators and contralateral vessels, and plan for repair. If tears occur during ligation or clipping, the point of weakness may be promptly visualized, allowing the surgeon time to plan for repair. The direction in which the tip of the aneurysm points does not matter when one is using this technique since the whole aneurysm collapses and can be moved about freely. Aneurysm necks felt to be too large to clip or containing arteriosclerotic plaques may be ligated or clipped and carefully repaired if leakage occurs on re-instituting manual cardiac systole.

We prefer this method to the closed chest technique. We have had no serious pulmonary or cardiac difficulties postoperatively. With the open technique there is a longer time available for safe arrest. The associated complications of clamping a major cardiac vessel, such as thromboembolism, loss of control of cardiac rhythm, and post-arrest hypertension, are obviated by the open method.

There is no question that in our series other factors have been of vital importance.

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in the results. The use of the dissecting microscope, the timing of the operation, the use of steroids and most important, experience, have been essential. We feel that if the tentorium is cut and all of the arachnoid carefully dissected from all visible structures, there is less retraction needed on vital structures, such as the cerebral peduncles, vessels, and cranial nerves, and less chance of tear during retraction. Because of the complete collapse upon arrest, the vessels can be moved about at will, and we feel that there is no need to always approach the aneurysm from the side of its neck if it is directed laterally. In fact, we believe it should not be approached from the dominant side. Only the aneurysm neck and not the body or dome are dissected out. With the tentorium cut, we have not found it necessary in this series to place temporary clips on the distal basilar artery.

We have been impressed with the low incidence of vasospasm and the high incidence of hydrocephalus and the need for shunting procedures. The hydrocephalus has been well recognized by others, and its adequate treatment has certainly contributed to a good result in at least two cases.

Perhaps with additional experience we may find the benefits of elective arrest insufficient to account for its continued use. However, we believe that it does offer an additional safety factor and perhaps a better chance of success.

Acknowledgment

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