Surgical Treatment of Ruptured Aneurysms of the Basilar Artery
Experience with 14 Cases

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In 1961 a discussion of the surgical treatment of 4 ruptured aneurysms of the basilar artery was presented, together with a review of the literature. A fifth case was included as an addendum to the paper and will be described further (Case 5).

At the time, it was concluded that direct surgical attack was feasible and worth while under exceptional circumstances, when life was threatened as after repeated hemorrhages. Since then 7 more ruptured aneurysms of the basilar artery have been operated upon in the same fashion. A review of these 12 cases will form the basis of this paper.

Aneurysms arising from the vertebro-basilar circulation comprise about 15 per cent of the total. They are discovered when this system is outlined with contrast medium in cases of spontaneous intracranial hemorrhage in which bilateral carotid angiography is negative. Previously it was suggested that the site of bleeding will be discovered by vertebro angiography in about 1 of every 4 such cases. Until recently angiography of the posterior circulation has not been pursued vigorously because of the difficulties encountered in direct puncture of the vertebral artery and the feeling that aneurysms of these vessels were not readily amenable to surgical treatment. A number of reports have appeared in which aneurysms arising from the vertebral, and branches of the vertebral and basilar arteries, have been obliterated safely. Logue has recently reported on 10 such cases with 3 deaths. In addition, he explored 2 aneurysms arising from the basilar bifurcation but was unable to occlude the sacs. Höök et al. have described in some detail 28 cases of aneurysms of the vertebral-basilar system. Of the 12 which were operated upon, 4 arose from the basilar bifurcation. One of these was successfully clipped. The 2nd presented as a 3rd ventricle tumor and was not discovered by a transcallosal approach. The remaining 2 patients died from brain stem softening, one after unsuccessful attempts at clipping (Bohm) and the other in spite of successful occlusion (Norlén). Jamieson has operated on 10 basilar aneurysms with only 2 long term survivors, both severely disabled.

For completeness it can be recorded that in addition to the 7 basilar aneurysms from this unit (5 were operated upon elsewhere), 7 other aneurysms of the vertebral basilar system have been discovered. Three arose from the vertebral artery and 4 from the posterior cerebral artery. Two of the vertebral aneurysms were fatal before an operation could be done, but the 3rd, arising at the origin of the posterior inferior cerebellar artery was ligated without sequelae. One patient with a posterior cerebral aneurysm refused operation and remains disabled with a hemiplegia and 3rd nerve palsy. The other 3 were operated upon and ligated. One of these patients with intra-cerebral and intra-ventricular hemorrhage died, but the 2 survivors are well.

In our unit, vertebro-basilar angiography has been carried out by direct puncture in the neck. The advent of the indirect methods by retrograde filling from the brachial or subclavian arteries has made the procedure more routine on most neurosurgical services. "Four vessel" angiography is a term now used to denote the ideal investigation of these patients. In Logue's view the majority of aneurysms arising from the vertebral artery or its branches are on the left side.

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437
The operative approach originally described was used in the succeeding 8 cases. In 2 patients a left subtemporal route was chosen because of the eccentric origin of the aneurysm. Three patients were operated upon under deep hypothermia (12–14°C.) using cardiopulmonary by-pass and exsanguination as part of a project to determine the usefulness of this method.

Case Reports

In follow up of our first 4 cases it may be said that the 2 survivors (Cases 1 and 2) remain well and active. Case 1 is leading a normal life on his farm and has no neurological deficit. The sole residuum of the stormy postoperative course in Case 2 is in relation to her vision. There is a complete right homonymous hemianopsia and, although the left field is full, visual acuity is reduced to counting fingers and reading newspaper headlines. She does the housework and remains the delight of her large family who say that aside from being slightly forgetful "Mother is as good as she ever was."

Case 5, H.C., may be summarized again in view of the final result.

On December 18, 1960, a 48-year-old man suffered his first hemorrhage and was admitted in a drowsy state with bilateral extensor planter responses and bloody spinal fluid. Bilateral carotid angiography was negative but a vertebral arteriogram demonstrated a small saccular aneurysm arising and projecting forwards and upwards from the bifurcation of the basilar artery (see Fig. 9). He recovered quickly and it was decided to delay operation for 7 days.

Operation. Unfortunately, on December 26th, right hemiparesis and dysphasia developed gradually without marked change in consciousness. Left carotid angiography again was normal and in view of the presumed recurrent bleeding, operation was carried out on December 27th under hypothermia (28°C.) with urea. Three periods (3, 5 and 1½ min.) of complete occlusion of the vertebral and carotid arteries were used to complete the dissection of the aneurysm and occlusion of its neck with a McKenzie clip. There was little evidence of bleeding to account for his sudden deterioration the day before.

Postoperative course. The postoperative angiogram showed the aneurysm to be obliterated and no other abnormality. The postoperative course was encouraging. The 3rd nerve palsy improved as well as the hemiparesis and dysphasia. However, after 3 weeks he was not so responsive and had a high spinal fluid pressure. Ventriculography showed a moderate communicating hydrocephalus and a lumbo-peritoneal shunt done on February 4th was followed by marked improvement. Three weeks later he was up and about on the ward talking and understanding quite well. Then he again deteriorated with ventricular and spinal fluid pressures of 200 mm. of water. With the thought that the shunt was not functioning, external ventricular drainage was established to no avail. He died on March 7, 1961, in coma with acute suppurative bronchopneumonia.

Comment. The brain weighed 1600 gm. and had the flattened gyri and narrowed sulci of chronic high pressure. The vessels of the base were intact and the aneurysm was occluded by the clip (Fig. 1). There was a moderate internal hydrocephalus but brain sections did not reveal the cause of the defective CSF absorption or solve the puzzle of the peculiar course of events, viz. the pre-

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FIG. 1. Case 5. Post-mortem specimen. The neck of the aneurysm has been occluded by a clip. The patient died 2½ months later from communicating hydrocephalus and malfunctioning lumbo-peritoneal shunt.
operative right hemiplegia and aphasia and the absence of blood clot in the interpeduncular space at operation.

Three Cases Operated upon under Deep Hypothermia. Early in 1962 a program was initiated in our unit in which a series of ruptured aneurysms, deemed to be particularly hazardous because of size or position, were operated upon under deep hypothermia (9–15°C.) using cardiopulmonary by-pass, exsanguination and circulatory arrest. In addition, 8 of the 10 cases were operated upon within the first week after the last hemorrhage in order to determine whether this method avoided the hazards of early surgical treatment. Three aneurysms of this group were on the basilar artery.

Case 6, J.E., a 23-year-old man, had 2 mild subarachnoid hemorrhages 4 days apart in March, 1962. He was never unconscious but complained bitterly of severe headache. A bruit was evident over both orbits and the cerebrospinal fluid was bloody. There was fleeting clumsiness of the left arm and a few beats of nystagmus on right lateral gaze. The source of bleeding was shown to be a small saccular aneurysm arising from the basilar artery at the origin of the superior cerebellar artery and projecting to the right (see Fig. 8).

Operation. Craniotomy was carried out on March 26, 1962, 6 days after the last hemorrhage, under deep hypothermia (12°C.) instituted with cardiopulmonary by-pass through a sternal split. The tentorium was divided and during 6 minutes under low flow (500 cc./min.) the aneurysm was exposed but in dissecting the sac free from the cerebral peduncle it ruptured. Then, while the circulation was completely arrested for 15 minutes, the dissection was completed and a McKenzie clip applied across the neck. The clip was oblique and, to make sure the aneurysm was obliterated, a 3-0 silk ligature was tied down snugly proximal to the clip and flush with the basilar artery.

Postoperative course. A 3rd nerve palsy was present but aside from 3 or 4 days of confusion and restlessness the postoperative course was uneventful. The postoperative angiogram showed the aneurysm to have been obliterated. When seen 1 year later there was no evidence of the oculomotor palsy and he was actively engaged in farming.

The next patient was operated upon at the University Hospital, Edmonton, Alberta, in conjunction with Dr. Thomas Speakman. The pump run was carried out under Dr. John Callaghan.

Case 7, H.R., a 63-year-old man, was found to be ill in bed on the morning of July 9, 1962. He was difficult to arouse, confused and restless. The spinal fluid was bloody but there was no localizing signs. He remained restless and irrational. Carotid angiography demonstrated an aneurysm arising from the left side of the basilar bifurcations (Fig. 2a).

Operation. A left temporal approach was used because of the eccentric origin. On July 11, cardiopulmonary by-pass was instituted through a sternal split and the body temperature was reduced to 12.5°C. The brain did not slacken off well in spite of the administration of urea. The tentorium was divided just behind the entrance of the 4th nerve. The aneurysm was large and bulbous and partially hidden behind the large posterior communicating artery and a leash of small perforating vessels arising from it (Fig. 2b). After exsanguination of 2500 cc. the circulation was arrested for 18 minutes. Great care was taken in brushing the perforating vessels from the wall of the aneurysm but an attempt to pass a ligature around the neck was not successful. However, the aneurysm was oozing even with the pump off and could be collapsed. With the neck held in forceps the sac was tilted forward under the posterior cerebral artery and a long Mayfield clip accurately applied. The sac remained empty but there was oozing from the region of the perforators which required a gelfoam pack. The bone flap was replaced although the brain was moderately tight.

Postoperatively, the patient was stuporous with bilateral fixed and dilated pupils and a moderate right hemiparesis. Postoperative angiography the following day showed the aneurysm no longer filled but there was a shift and evidence of a left temporal mass (Fig. 2c). The bone flap was removed together with small extradural collections of clot. The temporal lobe was swollen and soft. Following this decompression the patient gradually improved and 2½ months later when the bone flap was replaced he was self-sufficient and had recovered all his faculties except memory and speech.

Comment. In spite of his age the patient made surprising progress over the following year. The left 3rd nerve palsy did not recover completely. The expressive dysphasia has lingered and marred the final result although his mental faculties appear to be otherwise intact. Undoubtedly the major part of the neurological deficit was a sequel of the left subtemporal approach which seemed necessary in view of the position of the aneurysm.
Case 8. J.S., a 66-year-old mildly hypertensive man, was admitted in a drowsy and confused state on June 22, 1963, 4 days after the first hemorrhage. The vertebral angiogram demonstrated a small aneurysm arising from the left side of the basilar artery at the origin of the superior cerebellar artery (see Fig. 8). In addition there was a small angioma fed by the left superior cerebellar artery lying lateral to the aneurysm in the angle. He remained confused and on July 6th had a second hemorrhage which made his state of consciousness worse.

Operation. Left temporal craniotomy under deep hypothermia (14.0°C.) was carried out 6 days later. The angioma was seen embedded in the pons and its surface was packed with ham-
mered muscle. The aneurysm was freed from firm clot and a McKenzie clip applied across the neck flush with the basilar artery. Low flow rates were used for 9 minutes of dissection and total arrest for 2 minutes while the clip was placed. The patient had been doing well for 5 hours, without paresis or 3rd nerve palsy, when rapid deterioration occurred. He became unresponsive, with labored breathing and pinpoint pupils, and died 30 minutes later.

At autopsy there was a massive pontine hemorrhage which was considered to have arisen from the angioma, possibly related to the use of heparin. The aneurysm was securely clipped (Fig. 3).

Comment. Although craniotomy under deep hypothermia is a considerable undertaking involving 2 surgical teams and a maze of equipment and technical help, the slack brain and completely dry field allow superb exposure of the aneurysm and its connections and accurate placement of a clip or ligature. Bleeding during the rewarming phase is troublesome and exasperating, but with patience and restraint it comes under control after titration with polybrene. There has been no difficulty starting the hearts and maintaining the temperature above 32°C.

However, our conclusion was that the use of cardiopulmonary by-pass and deep hypothermia in the early treatment of ruptured aneurysms creates enough additional hazard so that it is probably not warranted when the aneurysm can be obliterated by more conventional means. We question whether basilar aneurysms require this considerable addition to the procedure, but the only death among these 3 cases was probably due to the administration of heparin.

Four Cases Operated upon under Moderate Hypothermia and Artificial Hypotension. Four more patients with ruptured basilar aneurysms have been operated upon since Case 8 under moderate hypothermia and artificial hypotension.

Case 9. E.S., a 30-year-old housewife, was operated upon in conjunction with Dr. Joseph Cluff at the Vancouver General Hospital. The only hemorrhage from the bifurcation aneurysm (Fig. 4a) had occurred 9 days previously on February 2,
1963, with transient numbness of the left side. She had recovered completely.

Operation was carried out under moderate hypothermia (30°C.) and from the right side. Two ligatures placed one above the other were used to occlude the broad neck of the sac. Slight bleeding occurred as the ligature carrier was passed behind the aneurysm. During this period both vertebrais and the left carotid were occluded 5 times for intervals varying between 3 and 5 minutes.

Postoperative Course. The patient never roused after the operation. She remained stuporous with bilateral fixed and dilated pupils and a spastic quadriplegia. Postoperative angiography 6 weeks later showed the aneurysm to be obliterated and there was no other vessel occluded (Fig. 4b). She was transferred to the Provincial Mental Hospital after 6 months. The 3rd nerve palsy recovered partially on the right and she would eat if fed. The four-limbed spasticity persisted and she did not recover the ability to speak.

Case 10. G.Me., a 52-year-old man, had been stuporous and opisthotonic for several hours following his first hemorrhage. He had 2 further hemorrhages on the day of admission 2½ weeks later (July 22, 1963). Although the second attack was mild, the third was severe and he remained drowsy and confused until operation 24 hours later. There was a congenital divergent squint and the right plantar response was extensor. The aneurysm (Fig. 5a) was large, elongated, and projected upwards from its broad origin in the angle formed by the union of the left vertebral with the basilar artery. A smaller artery, deemed to be the anterior inferior cerebellar, arose from the base of the sac. Even so, a ligature placed above it would probably obliterate 4/5ths of the aneurysm. His future seemed bleak and the family and his physician were in favour of an operation.

Operation. Preliminary isolation of the carotid and vertebral arteries in the neck was done although no circulatory arrest was used. Under hypothermia (28°C.) a left temporal bone flap was turned down and the brain made slack with urea and lumbar cerebrospinal fluid drainage. The tentorium was divided along its attachment to the petrous apex (Fig. 5b). The rest of the dissection was done under artificial hypotension (80 mm. of Hg) lasting 1½ hours. The 4th nerve arched over the fundus and the 3rd nerve and posterior cerebral artery were dissected free to expose the apex of the sac and a layer of thickened clot anteromedially over the site of the rupture. The aneurysm was gently freed from the pedunule but sharp dissection had to be used to free its rather dense attachment to the dura over the posterior clinoid. It was not necessary to divide the trigeminal nerve as had been anticipated. After opening Meckel’s cave and retracting the nerve
laterally, the base of the aneurysm and the artery arising from it could be seen clearly. A 2-0 silk ligature was passed around the aneurysm and worked down over the fundus and tied firmly just above the branch anterio-inferiorly (Fig. 5b). The only mishap was that in retracting the anterior cut edge of the tentorium the 4th nerve was partially torn.

Postoperative course. The patient came around well after the procedure with no further neurological deficit. His squint appeared unchanged. Twelve days later he deteriorated again and had bloody xanthochromic cerebrospinal fluid. The source of this apparent recurrent hemorrhage remained obscure, for the repeat vertebral angiogram showed the aneurysm to be obliterated as planned (Fig. 5c). Thereafter he remained mentally sluggish and incontinent for several weeks and then gradually became well enough to be discharged home 2½ months after admission.

He was re-admitted 3 weeks later because of further deterioration at home. He now showed evidence of marked mental change, lying quietly in bed, incontinent, confused and disoriented. The small subtemporal opening was bulging and an air encephalogram showed the presence of a marked degree of communicating hydrocephalus. After lumboperitoneal shunt improvement was dramatic. He was discharged in 2 weeks, active, alert, but with some impairment of memory and initiative. He remained well when seen 3 months later with the subtle mental changes slowly improving.

Case 11. R.E., an obese, hypertensive, 48-year-old woman, was unconscious for a short time following a subarachnoid hemorrhage on August 6, 1963. The globular aneurysm arose from the basilar bifurcation and projected upwards and
slightly posteriorly (Fig. 6a). Operation was delayed because of what finally proved to be a falsely positive cerebrospinal fluid Wasserman test. On August 23rd she probably had another mild hemorrhage manifested by sudden headache and numbness down her left side.

Operation was carried out on September 16, 1963, using moderate hypothermia (28.5°C.), artificial hypotension and urea. A neck dissection was not done (her neck was short and thick). It was not necessary to retract the 3rd nerve or divide the tentorium but the mammillary body hugged the anterior aspect of the aneurysm. The posterior communicating artery was small and was not sacrificed. It was possible to work the ligature carrier through behind the aneurysm just above the posterior cerebral arteries while the blood pressure was reduced to 70 mm. Hg. The 2-0 silk ligature was tied down firmly.

Postoperatively, the patient remained semicomatose and quadriplegic with bilateral fixed and dilated pupils although immediate vertebral angiography showed that the aneurysm was obliterated and there was no evident vessel occlusion (Fig. 6b). Following tracheostomy she was fed by tube for 3 months. She gradually recovered to the point where she could be placed in a chair and fed. She would open her left eye and obey simple commands such as feeble grasping. The quadriplegia remained flaccid. The left oculomotor palsy showed partial recovery but the right remained complete. She died on March 9, 1964, 7 months after operation from an acute bronchopneumonia. Permission for autopsy could not be obtained.

Case 12. J.R., a 54-year-old housewife, was operated upon in conjunction with Dr. John Raaf at the Good Samaritan Hospital, Portland, Oregon.

This patient had had a subarachnoid hemorrhage verified by lumbar puncture 5 years previously. A second unverified hemorrhage occurred in late November, 1963. She had awakened with

FIG. 5(b). Case 10. The ligature can be seen tied tightly just above the origin of the anterior inferior cerebellar artery.
severe headache and a stiff, sore neck which lasted for a week. The third hemorrhage apparently occurred following an alteration in which an attempt was made to choke her on New Year’s Eve. Drooping of the left eyelid appeared the following day and ptosis was complete after a week.

On admission to hospital 3 days later the cerebrospinal fluid was clear but contained 13 red blood cells. Vertebral angiography by brachial injection demonstrated a large bilocular aneurysm arising from the left side of a tortuous basilar artery below the origin of the anterior superior cerebellar artery (Fig. 7a). She complained constantly of left fronto-temporal headache and had a complete left 3rd nerve palsy. There was questionable hypoesthesia over the left forehead. In view of the repeated hemorrhages from the enlarging aneurysm both she and her husband were prepared to accept the risks of operation.

Operation. This procedure was carried out on March 16, 1964, 10 weeks after the last hemorrhage, under moderate hypothermia (99.8°F.) and artificial hypotension. On the previous day both vertebral and carotid arteries were isolated under tapes in the neck. The brain was very slack for the left subtemporal approach after urea and lumbar drainage of cerebrospinal fluid. The dome of the larger antero-superior loculus projected upwards through the incisura and was densely adherent to the tentorial edge, posterior clinoid and the diaphragma sellae. It appeared to be the site of hemorrhage for the wall was thin and the overlying meninges were stained, adherent and thickened. The dissection of the aneurysm was done under hypotension with deepened anesthesia at 80 mm. Hg which lasted 2 hours except for a 20-minute period when the pressure fluctuated between 70–80 mm. Hg.

The tentorium was divided behind the large sac to a point halfway along the petrous ridge (Fig. 7b). The lower posterior bilocular sacculus was thick-walled and partially embedded in the crus cerebri. It was possible to expose this portion including its attachment to the basilar artery although no attempt was made to free the tip from its bed in the peduncle. The fibres of the 5th nerve were brushed from its lower aspect along with a large vein. It was necessary to use sharp dissection to free the larger thin-walled sac from the tentorium, posterior clinoid process and diaphragma sellae. The 3rd nerve was splayed out in the fibrous tissue over the supero-medial portion and the carotid and posterior communicating arteries were lightly adherent to the anterior aspect. With the aneurysm now in full view its bilocular kidney shape was apparent. It was decided to obliterate

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**Fig. 6. Case 11. (a) The sac is globular and angled. (b) Postoperative angiogram. The aneurysm has been obliterated without injury or spasm of major vessels.**
each loculus of the sac separately. A 2-0 silk liga-
ture was placed around the more fragile upper
portion but as soon as tension was applied the sac
tore mesially at or near its attachment to the
basilar artery. The hemorrhage was stopped by
tamponade with a patty. Two long silver clips
were applied to obliterate this portion of the
aneurysm (Fig. 7b). Slight arterial ooze from
the mesial corner was stopped with hammered
muscle. During this phase 2 periods of vertebral
artery occlusion were used for 1½ and 2 minutes,
respectively. The 4th nerve had been preserved
until rupture occurred but was torn when a large
sucker was used to clear the field of blood. The

Fig. 7(a). Case 12. Basilar view of
bilocular aneurysm.

Fig. 7(b). Case 12. Operative details demonstrating exposure after division of tentorium.

Fig. 7(c). Case 12. Postoperative arteriogram
showing the degree of occlusion of the sac.
Aneurysms of trunk of basilar artery

**Fig. 8.** Aneurysms of the trunk of the basilar artery. Case 14 is described in the addendum.

Plan to obliterate the lower saccule was now abandoned in view of the unknown effect of the operative hemorrhage and the additional manipulation for it was rather densely embedded in the peduncle. The thick wall of this portion made a subsequent hemorrhage seem unlikely. The dura was closed and the bone flap replaced.

Postoperative course was uneventful and the patient remains well. The 3rd nerve palsy remains complete and the trochlear paralysis is evident in that the eye no longer rotates downwards on lateral movement. The postoperative angiogram (Fig. 7c) shows the degree of obliteration of the aneurysm.

**Symptoms and Signs**

There was no constellation of symptoms or signs in this group of 12 cases that could be ascribed to the location of aneurysm (Table 1). The stupor, drowsiness and confusion with bilateral extensor plantar responses was in no way different from that seen with subarachnoid bleeding from other sources. One field defect occurred from optic tract involvement by a large bifurcation aneurysm. Two patients had a 3rd nerve palsy as the only sign. Hemiparesis or hypoesthesia were not felt to be specific. It was of some interest that 2 patients (Cases 1 and 2) appeared to have paresis of upward gaze. This was felt to be significant and probably related to the quadrigeminal plate being jammed against the tentorial edge by the clot expanding in the interpeduncular and pontine cisterns.

**Discussion**

Following review of these 12 cases it is my feeling that from an anatomical and surgical point of view basilar aneurysms should be divided into 2 groups, those arising from the basilar bifurcation and those having their origin along the trunk of the artery.

There were 5 cases in the latter group (Fig. 8), 4 of whom did well while 1 died from the misadventure with heparin (Case 8). The approach in these cases is simpler, through the tentorial opening with less tem-
### TABLE 1

Treatment of 12 patients with ruptured aneurysms of the basilar artery

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>No. Bleeds</th>
<th>Interval†</th>
<th>Focal Signs and Symptoms</th>
<th>Grade</th>
<th>Size and Site</th>
<th>Hypothermia</th>
<th>Hypotension</th>
<th>Circulatory Arrest (Minutes)</th>
<th>Method of Occlusion</th>
<th>Course</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A.N.</td>
<td>50</td>
<td>M</td>
<td>3</td>
<td>24 hrs.</td>
<td>Divergent squint</td>
<td>3</td>
<td>Small, origin of superior cerebellar</td>
<td>36.5°C.</td>
<td>5, 3, 6</td>
<td>Olivecrona clip</td>
<td>Confused &amp; weeks Temporary C3 palsy</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>2. M.K.</td>
<td>45</td>
<td>F</td>
<td>4</td>
<td>20 hrs.</td>
<td>Pinpoint pupils</td>
<td>3</td>
<td>Small, bifurcation</td>
<td>28°C.</td>
<td>5, 8</td>
<td>Mayfield clip</td>
<td>Stupor 1 week then Korsakoff 4 weeks Cortical blindness</td>
<td>Good R. field defect Poor visual acuity</td>
<td></td>
</tr>
<tr>
<td>3. D.C.</td>
<td>45</td>
<td>F</td>
<td>2</td>
<td>12 hrs.</td>
<td>L. field defect</td>
<td>4</td>
<td>Large, bifurcation</td>
<td>28°C.</td>
<td>7</td>
<td>Mayfield clip</td>
<td>Continuing coma Died after 3 days</td>
<td>Died</td>
<td></td>
</tr>
<tr>
<td>4. P.P.§</td>
<td>52</td>
<td>F</td>
<td>2</td>
<td>36 hrs.</td>
<td>Extensor plantar</td>
<td>1</td>
<td>Large, bifurcation</td>
<td>25°C.</td>
<td>3, 5</td>
<td>Mayfield clip</td>
<td>Cardiac arrest (Hypothermic ventricular fibrillation)</td>
<td>Died</td>
<td></td>
</tr>
<tr>
<td>5. H.C.§</td>
<td>45</td>
<td>M</td>
<td>2</td>
<td>24 hrs.</td>
<td>R. hemiparesis</td>
<td>3</td>
<td>Small, bifurcation</td>
<td>28°C.</td>
<td>3, 5, 14</td>
<td>McKenzie clip</td>
<td>Improved, C3 palsy Communicating hydrocephalus L.P shunt—improved Death after 24 months</td>
<td>Died</td>
<td></td>
</tr>
<tr>
<td>6. J.E.</td>
<td>23</td>
<td>M</td>
<td>2</td>
<td>6 days</td>
<td>Clumsy L. arm Nystagmus</td>
<td>1</td>
<td>Small, origin of superior cerebellar</td>
<td>18°C.</td>
<td>Low flow 0°</td>
<td>McKenzie clip and ligature</td>
<td>Confused 4 days Temporary C3 palsy</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>7. H.R.§</td>
<td>65</td>
<td>M</td>
<td>1</td>
<td>48 hrs.</td>
<td>Confused Irrational</td>
<td>3</td>
<td>Large, bifurcation</td>
<td>12.8°C.</td>
<td>15</td>
<td>Mayfield clip</td>
<td>Stupor, fixed pupils Removal bone flap Dysepsis and poor memory Slow improvement C3 palsy</td>
<td>Fair</td>
<td>(Expressive dysphasia)</td>
</tr>
<tr>
<td>8. J.S.</td>
<td>66</td>
<td>M</td>
<td>2</td>
<td>6 days</td>
<td>Drowsy Confused</td>
<td>2</td>
<td>Small, at superior cerebellar-angina angina</td>
<td>14°C.</td>
<td>Low flow 0°</td>
<td>McKenzie clip</td>
<td>Good for 3 hours then death from pontine hemorrhage</td>
<td>Died</td>
<td></td>
</tr>
<tr>
<td>9. E.S.§</td>
<td>50</td>
<td>F</td>
<td>1</td>
<td>7 days</td>
<td>Transient numbness L. side</td>
<td>1</td>
<td>Large, bifurcation</td>
<td>30°C.</td>
<td>3, 3, 5</td>
<td>2 ligatures</td>
<td>Stupor Bilateral C3 palsies Quadriaparesis</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>10. G.Mc.</td>
<td>52</td>
<td>M</td>
<td>3</td>
<td>24 hrs.</td>
<td>Drowsy Confused Extensor plantar</td>
<td>3</td>
<td>Large, vertebral-basilar junction</td>
<td>28°C.</td>
<td>1 hr 15’ 80 mm. IIg</td>
<td>Ligature</td>
<td>Slow recovery Communicating hydrocephalus L.P shunt at 3 months T4 palsy</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>11. R.F.</td>
<td>48</td>
<td>F</td>
<td>2</td>
<td>24 days</td>
<td>Transient numbness L. side</td>
<td>1</td>
<td>Large, bifurcation</td>
<td>28.5°C.</td>
<td>1 hr 70 mm. IIg</td>
<td>Ligature</td>
<td>Stupor Bilateral C3 palsies Quadriaparesis Death 6 months Pneumonia</td>
<td>Died</td>
<td></td>
</tr>
<tr>
<td>12. J.R.§</td>
<td>54</td>
<td>F</td>
<td>3</td>
<td>10 wks.</td>
<td>Oculomotor palsy</td>
<td>1</td>
<td>Large, bilocular midbasilar</td>
<td>29.8°C.</td>
<td>80 mm. IIg</td>
<td>2 Mason clips</td>
<td>C4 palsy</td>
<td>Excellent</td>
<td></td>
</tr>
</tbody>
</table>

* Cases 1 to 4 reported previously.
† Interval = Time between operation and last hemorrhage.
§ Operated upon elsewhere.
poral lobe retraction. It may be necessary to divide the tentorium to enlarge the exposure and this requires care to preserve the trochlear nerve. Although this thin strand does not cross the field, retraction of the anterior corner of the divided tentorium puts traction on the nerve where it penetrates the dura nearby. In 2 of our cases the nerve was injured in this fashion (Cases 10 and 12) although the palsy proved not to be important in view of the existing 3rd nerve palsies. Where the 3rd nerve is intact even gentle retraction of this large trunk may produce a postoperative oculomotor palsy but all of these except one have recovered after several weeks or months.

Cases 10 and 12 show that even large aneurysms from the basilar artery at its origin from the vertebral or from its midportion can be ligated or clipped by this route. It is important that in this group all of the aneurysms projected laterally or forward but not behind the basilar artery so that it was not necessary to disturb the tiny perforating branches to the brain stem.

These results are in some contrast to those of Jamieson, whose 3 trunked aneurysms did poorly (2 died, 1 poor). However, 1 was huge and thought to be a tumor in front of the medulla while that in the patient who survived was a fusiform aneurysm and only a large clot could be removed from the temporal lobe.

On the other hand it will be seen that only 2 of the bifurcation aneurysms (Fig. 9) did well, 1 remaining poor and 4 died. Three of the deaths were only indirectly related to operation on the aneurysm per se; the first from cardiac arrest with poorly managed hypothermia (Case 3), the 2nd in extremis before operation with intracranial clot (Case 4). The 3rd death was due to communicating

![Aneurysms of basilar bifurcation](image)

*Fig. 9. Aneurysms of the basilar bifurcation. Case 13 is described in the addendum*
hydrocephalus (Case 5), a late complication that occurred in 2 cases perhaps related to the fact that the postoperative arachnoid reaction at the incisura may be severe.

Of more concern are the “poor” case (Case 9) and the 4th death (Case 11). These were women, aged 30 and 48, who had come around well after mild hemorrhages. The aneurysms were large and globular with rather wide bases at the crotch of the basilar artery. In each case the operative procedure seemed straightforward and particularly uneventful, yet neither patient regained consciousness. Both remained in continuing light stupor with quadriplegia and bilateral fixed and dilated pupils, the picture of midbrain infarction. What happened?

The aneurysm lies tucked in the interpeduncular space against the posterior perforated substance and behind the mammillary bodies. Exposure of the region requires a slack brain and firm retraction and the mammillary bodies sit at the end of the retractor (Fig. 10). Of more importance is the anatomy of the vessels for there are myriads of tiny perforating arteries arising from the basilar bifurcation and the posterior cerebral arteries which irrigate the base of the forebrain and core of the midbrain (Fig. 11). A ligature was used to occlude the necks and almost unnoticed at the time there was slight brief arterial bleeding as the ligature carrier was passed behind the base of the aneurysm. The dome of the aneurysm was not disturbed and no difficulty was encountered in tying the ligatures tightly. The postoperative angiograms showed the aneurysm to have been obliterated and there was no arterial spasm or visible occlusion.

In view of these factors we feel that the ligature carrier injured or tore tiny unseen perforating twigs producing catastrophic midbrain infarction. The stormy postoperative course in Case 7 who had temporary bilateral 3rd nerve palsy as well as temporal lobe swelling was probably on the same basis although his subsequent recovery has been gratifying.

Jamieson also had discouraging results with bifurcation aneurysms. Only 1 of his 7 cases survived and that one is unemployable, with a 3rd nerve palsy and amnesia. In addition he showed that clipping the posterior cerebral or communicating arteries for exposure or bleeding is to be avoided. In the light of this experience an operation on a bifurcation aneurysm of the basilar artery can only be considered as an extremely hazardous venture. The results in our 7 cases may be unduly gloomy in view of the unfortunate complicating factors in Cases 3, 4 and 5. However, the calamity of midbrain infarction which occurred in 2 women (Cases 9 and 11) who were well when they submitted
to operation is sobering. Only after careful consideration of all the factors should an operation be offered to these patients and their families.

Future attacks on bifurcation aneurysms must be made with extreme care to avoid injury to the important tiny perforating vessels which form a leash over the hidden portion of the aneurysm. In cases with small bifurcation aneurysms projecting upwards and forwards it should not be difficult to avoid this hazard. The concern will be with the larger globular sacs. It is dangerous to dissect or pass a ligature blindly behind the base of such a sac and the basilar bifurcation. However, if the aneurysm were made soft by artificial hypotension or temporary great vessel occlusion in the neck, it should be possible to dissect free this portion under direct vision. The sac can be indented or grasped with forceps and tilted forward so that a plane can be developed between the wall of the aneurysm and this cluster of vessels. Undue traction might avulse these penetrators or put them into spasm. Due consideration must be given to the traction effect of a ligature drawn up tightly. A clip might be safer in this regard yet a ligature is more readily applied to a neck that is just too wide or awkwardly placed. Certainly, the smaller the sac, the easier will be the job. Occasionally resection of the anterior temporal lobe may be necessary particularly where the middle fossa is deep or difficulty is encountered in making the brain slack. This has not seemed necessary in this series, yet left temporal contusion and swelling undoubtedly accounted for the persistent disturbing dysphasia in Case 7. Undoubtedly, some large aneurysms will prove to be inoperable and tactful withdrawal will be the wisest decision. Wrapping a large sac in this location with the plastics presently in use, would be even more hazardous in view of the more extensive dissection required to expose the whole of the lesion.

In the event that midbrain injury remains a consistent hazard, more thought might be given to the method of Mount and Taveras using the Hunterian principle. In one case

Fig. 11. A drawing to demonstrate the leash of vital perforating arteries in the bed of the aneurysm.
with adequate posterior communicating vessels they were able to place a clip across the basilar artery just below the bifurcation and above the origin of the superior cerebellar arteries. The patient survived the procedure without serious sequelae.

The obliteration of large aneurysms by the production of thrombosis within the aneurysmal sac by mammalian bristle and electrical potential difference is still at a stage of preliminary investigation. Knighton has been able to induce thrombosis throughout a large (3 cm.) aneurysm arising from the basilar-superior cerebellar arterial junction by the injection of horse hairs. Repeat angiography 1 month later showed that the distal three quarters of the aneurysm was still obliterated. However, in a second similar case no thrombosis occurred within the sac.

**Conclusion**

The natural life history of a once-ruptured aneurysm is bleak enough that surgical efforts to obliterate these lesions safely should continue. There is no reason not to apply this principle to ruptured basilar aneurysms and although it is not possible to draw definite conclusions from a series of 12 cases it seems reasonable to state that an operation is warranted in certain carefully selected cases.

The brain must be slack for the approach and this can usually be accomplished by urea or mannitol and lumbar drainage of cerebrospinal fluid. Deep hypothermia with the cardiopulmonary by-pass does not seem warranted in view of the additional hazards but conventional hypothermia may provide extra protection in the event of inadvertent rupture of the sac, or other operative complications.

Aneurysms of the trunk of the basilar artery appear to be most amenable to safe surgical treatment probably because of easier access and avoidance of injury to perforating vessels. In a sense these aneurysms, lying free in the subarachnoid space, are as accessible as those in the anterior communicating region or middle cerebral bifurcation which are buried in eloquent brain regions. All have originated and projected from the side of the basilar artery away from the origin and penetration of the perforating vessels into the brain stem, so that injury to these important structures can be avoided. Temporary (and rarely permanent) oculomotor palsy will be a consequence of retraction of this nerve. Trochlear nerve injury may be a problem with the large sacs. Small saccular aneurysms of the trunk might therefore be considered for operation in most cases and even large sacs can be obliterated safely.

On the other hand, aneurysms of the bifurcation constitute a special surgical problem. Although it is possible to shut off the neck of the sac with clip or ligature there is extreme danger to the patient from heavier retraction on the temporal lobe and injury to the group of important tiny perforating vessels which are hidden behind the aneurysm. At the present time it is my feeling that these aneurysms should be operated on only after careful consideration of the risk to the patient. Until more is known it might be wise to restrict operation to those bifurcation aneurysms where the sac is small, projects forward and has a good neck.

**References**


6. Knighton, R. S. Personal communication.


Addendum

Since this paper was submitted for publication 2 more basilar aneurysms have been operated upon under hypotension (70–80 mm. Hg) at normal temperature. The tracings of the angiograms are included in Figs. 8 and 9.

Case 13. M.S., a 51-year-old nurse, had had a single subarachnoid hemorrhage 13 days before operation after wrestling with a heavy, delirious patient. The aneurysm projected upwards and forwards and seemed suitable for a clip (Fig. 9).

However at operation under hypotension the dissection proved to be difficult because of a dense adherent arachnoiditis possibly from a previous unrecognized hemorrhage. When the aneurysm was exposed, a looping branch of the posterior cerebral artery, which seemed to irritate the mammillary region, was adherent to both the base and fundus of the sac and could not be freed easily. As any attempt to place a clip would have obliterated this important vessel, the aneurysm was packed in hammered muscle except for the lower anterior aspect which was adherent to the arachnoid and clivus. Recovery from a 3rd nerve palsy was complete after 6 weeks and there have been no other sequelae.

Case 14. J.H., a 65-year-old lawyer, was admitted after one hemorrhage from which he quickly recovered. The aneurysm was large, bulbous and arose from the origin of the basilar artery at the union of the vertebrals (Fig. 8).

Thirty-one days later the aneurysm was exposed by a left subtemporal approach and division of the tentorium just behind the length of the petrous ridge. Retraction of the cerebellum gave an excellent view of the posterior slope of the petrous bone, the clivus and the aneurysm. Under hypotension, by working between the 7th and 8th nerves above and the 9th and 10th below, the arachnoid was dissected free from the sac but the union of the vertebral arteries was hidden beneath. Because of his age the aneurysm was reinforced with a coat of plastic (Selverstone) which seemed to flow nicely over the whole surface. He was well for 24 hours but then became drowsy and aphasic with a postoperative extradural clot. Recovery of consciousness was prompt after evacuation of the clot but after 3 weeks there was still some persisting receptive dysphasia.