IMMEDIATE AND LATE RESULTS OF SURGERY IN CASES OF SACCULAR INTRACRANIAL ANEURYSMS

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There is an increasing interest in the surgical treatment of spontaneous subarachnoid haemorrhage, and hence a study of the results in a personal series between 1947 and 1955 may be of value, particularly in view of the frequency and gravity of the condition. With conservative management the mortality rate in hospital cases of subarachnoid haemorrhage ranges between 50 and 60 per cent during the first 6 to 8 weeks, while half the survivors are left with an appreciable disability. If the patients who leave hospital alive are followed up for an average period of 5 years, about 20 per cent of them will be found to have died of recurrent bleeding, usually within the first year. Ask-Upmark and Ingvar put the natural prognosis of subarachnoid haemorrhage succinctly when they stated that out of every 5 patients 3 would die of the disease sooner or later, 1 would be left disabled, and only 1 would make a good recovery.

As the commonest cause of subarachnoid haemorrhage is bleeding from a saccular intracranial aneurysm, considerations of its surgical treatment are largely those of the management of aneurysms. Thus autopsy studies in patients who have died in hospital while under a conservative regime have disclosed these lesions in approximately 75 per cent of cases. A similar proportion of cases of aneurysm is probably present in patients admitted to hospital with subarachnoid haemorrhage. Among the other remaining causes are bleeding arteriovenous malformations (5 to 10 per cent) and bleeding from an atheromatous cerebral artery, a telangiectasis, or a vascular cerebral tumour.

By means of cerebral angiography, it is readily possible to visualise most aneurysms. In recent years, therefore, several different neurosurgical centres have attempted to show that the immediate prognosis for a patient with subarachnoid haemorrhage from an aneurysm can be improved by surgical treatment. All these centres, however, have had difficulty in securing control material from a comparable series of patients treated conservatively, but the general consensus of opinion among them is that the immediate prognosis can be improved materially.

CASE MATERIAL

We have therefore analysed the results achieved in 112 consecutive patients treated surgically by one of us (M.A.F.) and his associates, and now followed up for from 2 to 10 years (Table 1). The first 50 patients were all
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operated on in New Zealand between 1946 and 1950 and have already been reported. Of these patients, 33 made good recoveries, 8 were left with an appreciable disability and 9 died (mortality rate 18 per cent). The remaining 62 patients were all operated on in the Guy’s-Maudsley Neurosurgical Unit between December 1950 and July 1955, and the last 50 of these patients operated upon after December 1951 have also been reviewed recently. Of these 50 patients, 38 made a good recovery, 9 were left with a disability,

\[ \text{TABLE 1} \]

\[ \text{Distribution of aneurysms in 112 patients} \]

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal carotid artery (at posterior communicating artery)</td>
<td>41</td>
<td>37 per cent</td>
</tr>
<tr>
<td>Carotid bifurcation</td>
<td>7</td>
<td>6 per cent</td>
</tr>
<tr>
<td>Anterior cerebral artery</td>
<td>34</td>
<td>30 per cent</td>
</tr>
<tr>
<td>(a) First part</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(b) At anterior communicating artery</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>(c) Distal part</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Middle cerebral artery</td>
<td>17</td>
<td>15 per cent</td>
</tr>
<tr>
<td>Vertebral-basilar system</td>
<td>3</td>
<td>3 per cent</td>
</tr>
<tr>
<td>Patients with multiple aneurysms</td>
<td>10</td>
<td>9 per cent</td>
</tr>
</tbody>
</table>

and 3 died. In the intermediate group of 13 cases not yet reported there were 4 deaths. Recently all but 2 of the survivors of both series have been followed up by letter or personal interview, the follow-up periods ranging from 2 to 10 years. It is particularly on these late follow-ups that this present report is based. Throughout this decade the actual surgical techniques used have been slowly evolving and improving. Emphasis will therefore be placed on the fatal cases and those with poor results in an endeavour to see how they can be avoided.

The basis of selection in these three groups of patients differs. In early cases the patients were usually admitted and treated within 2 weeks of their last haemorrhage, but in some of the later cases the patients came to us after the aneurysm had already been demonstrated radiologically elsewhere. Similarly the surgical policy has not been uniform. Until the end of 1951 patients with subarachnoid haemorrhages were regarded as emergencies to be investigated and operated on as soon as possible after admission. Since 1952, however, with increasing experience with these cases, and encouraged by reports from other countries, we have waited, whenever possible, for about a week before commencing investigation and treatment. Occasional exceptions to this rule were made in patients who sustained a recurrent bleeding while in the Unit during the waiting period. Also in a few of the recent cases the patients had never had spontaneous bleeding but were exhibiting signs of local compression.

This lack of uniformity in the selection and handling of patients, however, is helpful in assessing the variations of treatment. In the following review the aneurysms will be considered in groups according to their situation.
Attention will be paid to the length of time intervening between the last haemorrhage and the day of operation. Further for those patients who survived with a disability, an attempt has been made to ascertain whether this disability preceded operation or was caused by it.

ANEURYSMS OF INTERNAL CAROTID ARTERY AT POSTERIOR COMMUNICATING ARTERY

There were 41 patients in this group, of whom 39 were referred because of subarachnoid haemorrhage. One of these, however, collapsed during arteriography performed 5 days after a haemorrhage, and died within a few hours. Two patients never had frank subarachnoid bleeding, but presented dysphasia of sudden onset and a third nerve palsy respectively.

The 38 patients operated on after subarachnoid haemorrhage will now be discussed particularly. They were treated by one of two main methods—either carotid ligation (common and/or internal carotid ligation) performed under local analgesia, or direct attack by craniotomy under general anaesthesia—or by a combination of these. Twenty-three of these patients exhibited a third nerve palsy, and this always recovered or improved greatly after operation, generally with disappearance of the diplopia at rest. A slight persisting weakness of the external ocular movements has not therefore been assessed.

CAROTID ARTERY LIGATION (Fig. 1)

Before this was carried out, the adequacy of the collateral circulation through the circle of Willis was tested by the Matas digital compression test. Often this was supplemented by the arteriographic demonstration of cross filling of the cerebral vessels from the opposite carotid artery while the ipsilateral carotid was temporarily compressed in the neck. If there was no adequate cross circulation a direct attack was performed. In the earlier cases, if the collateral circulation seemed free, ligation of the internal carotid artery was carried out forthwith. In later cases, however, common carotid ligation was first performed, usually in two or three stages, followed sometimes by internal carotid ligation. Even with all these precautions experience has shown that hemiplegia may ensue.

A. Primary Internal Carotid Artery Ligation: 6 Cases (Fig. 1a). The 3 successful cases (ages 28, 40, 52 years) need no special comment. The patients remain well after 8 to 9 years. Hemiplegias were, however, produced in 2 patients operated on 2½ weeks after the last bleeding, and in a third patient operated on after 9 weeks. The first of these patients, a woman aged 19 years, had another haemorrhage during the course of open arteriography. The ligation was performed immediately, but subsequently she exhibited severe dysphasia and hemiplegia which slowly improved, until now, 8 years later, she does her full housework, although her speech is still faulty. The second patient, aged 47 years, had only a partial narrowing of the artery with a ligature. A few hours later a left hemiparesis developed. The ligature was promptly removed and the artery in the neck seemed to be patent.
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There was no immediate improvement, but gradually the hemiparesis has lessened and now 7 years later she does all her housework. In this patient, therefore, the vessel has not been permanently ligated. In the third patient, a man aged 67 years, a left hemiparesis developed 2 days after ligation. He was given anticoagulants, and now 8\(\frac{1}{4}\) years later he has only slight residual weakness. These last 2 cases presumably were complicated by thrombosis or embolism occluding the carotid bifurcation.

B. Common Carotid Ligation: 9 Cases (Fig. 1b). Again the 5 successful cases (ages ranging from 20 to 68 years) need no comment. There were in the group, however, 1 death, 2 cases of recurrent haemorrhage, and 1 case of persisting preoperative disability. The death occurred in a man aged 24 years and was the result of thrombosis developing in both common carotid arteries. This presumably was caused by arteriography although atheromatous changes were also present. Another patient, aged 37 years, operated on 2 days after her third bleeding, had a recurrent haemorrhage 2 weeks later. An intracranial operation followed with recovery (see later). The other recurrence was in a woman of 68 years admitted in a drowsy state. She had only a partial ligation and seemed to make a good recovery, but her death nearly

Fig. 1. Results in 18 cases of internal carotid aneurysm treated by carotid ligation. The charts show on the left side the bleeding-operation time interval, and on the right side the duration of follow-up.
3 years later was ascribed to a further haemorrhage; there was no autopsy. The patient with a persisting preoperative hemiparesis dating from her bleeding 8 weeks before still showed this disability 3 years later.

C. Common Carotid Ligation Followed by Internal Carotid Ligation: 3 Cases (Fig. 1c). A man of 65 years, 3 months after his subarachnoid haemorrhage, had this series of ligations with a good result and he remains well 6 years later. The other 2 patients, aged 42 and 58 years, were both operated on 6 weeks after their bleeding, and aphasia and hemiplegia developed within a day of the tying of the internal carotid artery. In the first patient, the ligature was promptly removed, but without benefit. Both patients remain severely disabled 3 and 4½ years later respectively.

Comment. On comparing the results in patients who had only the common carotid artery tied with those who had the internal carotid artery tied, whether immediately or after ligation of the common carotid, two striking facts emerge (Fig. 2). Firstly, no patient who had only a common carotid ligation had any disability as a result of this (apart from 1 death caused by bilateral carotid thrombosis secondary to arteriography performed on a patient with very arteriosclerotic carotid arteries). On the other hand, in 5 of the 9 patients who had the internal carotid artery tied there developed hemiplegia, with or without aphasia, and no improvement occurred in the 2 patients who had the ligature removed. Admittedly, 1 patient had bled during arteriography just before the ligation, but even excluding this case, there were 4 patients out of 8 who were disabled by the operative procedure. Thus when cross-circulation tests are satisfactory, ligation of the common carotid artery is generally well tolerated, but ligation of the internal carotid artery still carries a considerable risk of hemiparesis and of aphasia, presumably because of formation of spreading thrombus. Therefore we now hesitate to perform internal carotid ligation, particularly on the left side, even though the cross-circulation arteriographic test seems satisfactory.

Secondly, while no patient has had any recurrence of haemorrhage after internal carotid ligation, this occurred in 2 patients out of 8 after common
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carotid ligation. Admittedly 1 of these occurred after only a partial narrowing of the artery, but the other occurred 2 weeks after complete ligation. However, our experience with the trapping operation (see later) shows that even ligation of the internal carotid artery may not prevent further trouble, as seen in 2 patients to be described who had the trapping operation. Our experiences are paralleled by those of Black and German\(^4\) who reported 5 late deaths in 25 patients with internal carotid aneurysm treated by carotid ligation; 2 of the deaths were certainly caused by recurrent haemorrhage.

INTRACRANIAL OPERATIONS (Fig. 3)

A. **Primary Intracranial Attack** (Fig. 3a). There were only 2 patients in this group, and both did well. The first was a man of 43 years who was still having frequent headaches 3 months after two mild subarachnoid haemorrhages. His aneurysm was wrapped round with muscle and he remains well 4 years later. The second patient, a woman aged 49 years, had had

![Fig. 3. Results in 21 cases of internal carotid aneurysm treated by an intracranial operation with or without preliminary carotid ligation.](image)
four severe subarachnoid haemorrhages in 3 weeks. She could not tolerate compression of either carotid artery for more than a few seconds, as there was no cross circulation between the two sides of the circle of Willis. Six days after her last haemorrhage the aneurysm was exposed and its neck was clipped. She remains well 2 years later. Recent experience has suggested that these aneurysms should be approached through a large frontotemporal craniotomy. Generally they are best visualised by elevating the temporal lobe from the floor of the middle fossa, but sometimes an anterior approach beneath the frontal lobe is required.

B. Combined Carotid Ligation and Intracranial Attack (Dandy's Trapping Operation): 15 Cases (Fig. 3b). In the earlier cases the usual sequence was first to ligate the internal carotid artery in the neck, often preceded a few days before by ligation of the common carotid artery. Within 2 or 3 days, through a frontal craniotomy, the internal carotid artery was then clipped above the level of the aneurysm but below its bifurcation into anterior and middle cerebral arteries—the so-called "trapping" operation of Dandy.6 In this operation the intracranial approach to the artery is from in front while the aneurysm generally lies posterolaterally.

On two occasions the surgeon modified the sequence of events and learnt a salutary lesson. In both cases the common carotid artery was first ligated in the neck, and then a few days later the intracranial internal carotid was clipped above the aneurysm. In both instances the aneurysm immediately swelled and burst, bleeding not being controlled until the internal carotid artery had been clamped below the aneurysm and then tied in the neck. Both patients recovered satisfactorily. On later occasions therefore, whenever a trapping operation was undertaken after only a common carotid ligation, the intracranial internal carotid artery has always been clipped below the aneurysm before occluding it above the lesion.

The original trapping operation theoretically imperils the main blood supply to the retina via the ophthalmic artery from the internal carotid. The only vessel still capable of filling the aneurysm is the posterior communicating artery.14 This we have tried to obviate by obliterating the internal carotid artery with clips opposite the neck of the aneurysm. In our experience of "trapping" operations there has been no case of ipsilateral blindness from occlusion of the retinal artery, although such a complication has been described.18

Again the 7 successful cases (ages ranged from 27 to 46 years) will be passed over and emphasis placed on those cases in which disability, recurrence or death ensued (Fig. 3b). It may be mentioned, however, that 2 female patients have since had babies, one by natural delivery and the other by Caesarian section, without trouble from the aneurysms.

In this subgroup there were 1 death, 3 instances of recurrence, and 4 of recovery with disability. A 48-year-old man, operated on 3 weeks after his fourth haemorrhage, had hemiplegia 16 hours after completion of the trap-
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ping. He died 3 days later of cerebral infarction, but at autopsy the vessels of the circle of Willis and the middle cerebral artery appeared patent. The cause of the infarction was therefore presumed to be arterial spasm. Two patients still show some persisting preoperative disability, but 2 others have disabilities attributable to operation. In the first of these latter cases, a man of 43 years, the trapping operation was followed by right hemiplegia with aphasia. Now, 5½ years later, he remains disabled, although he does simple clerical work. The other patient, a man aged 52 years, made an uneventful recovery from his trapping operation on the right side. Seventeen days later percutaneous carotid arteriography was performed on the left side to demonstrate the adequacy of the trapping. The right middle and anterior cerebral arteries were filled well from the left side, but unfortunately during the next 3 days severe left hemiplegia developed from which he gradually recovered almost completely in the course of a year. We have since been very chary of performing postoperative arteriograms unless necessary, a point of view on which we diverge from Mount and Taveras.20

The 3 cases of recurrence are instructive. The first, a man of 30 years, complained of left-sided headache during his second attack of subarachnoid haemorrhage. The left carotid arteriogram, however, seemed normal, but on the right side an aneurysm of the internal carotid artery was shown. This was trapped. Two and a half years later he suddenly died and at autopsy (Dr. Denis Stewart) he was found to have bled from an aneurysm on the left internal carotid artery. It therefore seems likely that it was the left-sided aneurysm that had bled on both occasions, but had not been shown on the arteriograms. The second patient, a man of 49 years, presented a left third nerve palsy as well as a subarachnoid haemorrhage. Only left carotid arteriography was performed, and the aneurysm so found was treated by a trapping operation. He remained well for 2½ years and then had two recurrent haemorrhages, the second of which was fatal. At autopsy he too was found to have a second aneurysm on the other internal carotid artery, which was responsible for his fatal haemorrhage. These patients emphasise the importance of performing bilateral carotid arteriography in every case. Even so aneurysms may be missed.

The third case was even more instructive, for there was a late recurrence of bleeding from an aneurysm trapped according to Dandy’s original method. The patient, a woman aged 44 years, made a good recovery from a trapping operation for a right carotid aneurysm. Two and a quarter years later she had recurrent bleeding with left hemiparesis. Left carotid arteriography showed the anterior and middle cerebral arteries on both sides, but did not fill the aneurysm. A vertebral arteriogram, however, showed the original aneurysm filling through an anastomotic circulation over the occipital, external carotid, and ophthalmic arteries. It had increased slightly in size (Fig. 4). Mr. Anthony James, to whom we are indebted for the further history, then exposed the lesion again and found an enlarged ophthalmic artery
entering the aneurysm. He clipped this vessel, and the patient remains well 3½ years after this second operation. Had the intracranial internal carotid artery been clipped below as well as above the aneurysm at the first operation, this complication would probably have been avoided.

C. Other Combined Operations: 4 Cases (Fig. 3c). There were 4 patients, 1 of whom died. A man of 40 years, operated on early in the series, was explored intracranially 2 days after his second subarachnoid haemorrhage. The aneurysm burst and it was therefore packed with muscle, after which the internal carotid artery was ligated in the neck. The patient died 8 days later,

![Image](http://example.com/fig4.png)

**Fig. 4.** Tracing of a vertebral arteriogram showing a "trapped" aneurysm of the internal carotid artery filling through an anastomotic circulation via the external carotid and ophthalmic arteries.

and at autopsy the carotid bifurcation on that side was found to be thrombosed, with extensive cerebral infarction. Another patient, a man of 32 years, had the usual sequence of common and internal carotid ligations, followed in this instance by a muscle-wrapping operation. He remains well 7½ years later. The third patient, a boy aged 16 years, had common and internal carotid ligations performed in the neck, followed by intracranial clipping of the neck of the aneurysm. He remains well 4 years later. The last patient, a woman of 59 years, had the common carotid artery tied in stages 2 weeks after her second subarachnoid haemorrhage. She had hemiplegia before operation. Subsequently the neck of the aneurysm was clipped to avoid diminishing the cerebral blood supply any further. She made a good recovery and remains well 2½ years later.

**Comment.** Excluding the 2 patients who died of haemorrhage from a second and unsuspected aneurysm, it may be noted that in 3 out of 13 patients treated by trapping, serious cerebral infarction (1 fatal) developed while only 1 patient had recurrent bleeding from the treated aneurysm. This bleeding could probably have been avoided by the method of obliterating the
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parent artery opposite the aneurysm. The proportion of disabilities in this group is lower than in the group treated by ligation of the internal carotid artery in the neck. Furthermore, the patient who bled via an ophthalmic-artery anastomosis, suggests that these aneurysms cannot be regarded as really safe until they are entirely isolated from the circulation. Our present view is that, if the neck of the aneurysm is narrow, this is best done by clipping or tying the neck, perhaps after preliminary ligation of the common carotid artery. If on exposure the aneurysmal neck is unsuitable for occlusion the trapping can be carried out.

PATIENTS WITHOUT SUBARACHNOID HAEMORRHAGE

There were 2 cases. The first, a man aged 51 years, presented persisting dysphasia of sudden onset after premonitory attacks, and was treated by ligation of the left common carotid artery in stages, followed by ligation of the external carotid artery. His dysphasia improved, but unfortunately he had a retinal embolism in the left eye 3 months later. Apart from persisting visual loss caused by this, he remains well 3 years later. The other patient, a woman of 47 years, presented right frontal headache and third nerve palsy; she had the right common carotid artery tied in stages, followed by ligation of the external carotid artery. Her oculomotor paralysis recovered and she remains well 2 years later, but is under treatment for a carcinoma of the corpus uteri. Both of these patients have had the equivalent of ligation of the internal carotid artery, and both have made good recoveries.

ANEURYSMS AT CAROTID BIFURCATION

There were 7 patients with this lesion, all of whom had had subarachnoid haemorrhage (Fig. 5). Two patients had common carotid ligations as their only treatment. One of these, a man of 49 years, who had a very large aneurysm and was still drowsy 4 days after his haemorrhage, died suddenly of a massive pulmonary embolism 8 days later. The other patient was a man aged

![Fig. 5. Results in 7 cases of carotid bifurcation aneurysm treated (a) by carotid ligation, and (b) by direct attack.](image-url)
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67 years who complained of frequent severe headaches since his haemorrhage 8 months previously. Since operation he has been free of headaches, and is well 5 years later.

Five patients have had craniotomies (including 2 after ligation of the common carotid artery). The procedures included 2 muscle wrappings, 1 muscle wrapping with clipping of the intracranial internal carotid artery, 1 ligation of the neck of the sac, and 1 clipping of the neck of the sac. All these patients, whose ages at the time of operation ranged from 31 to 53 years, have made good recoveries and remain well after periods of from 3 to 9 years, although in 1 patient a mild hemiparesis persists from before operation. An additional patient, treated successfully for bilateral aneurysms at this site by clipping of their necks, is reported among the cases of multiple aneurysms."

Comment. The number of cases is too small to evaluate different methods of treatment. The only death in the group was caused by pulmonary embolism, and thus is not related directly to the operation.

ANEURYSMS OF ANTERIOR CEREBRAL ARTERY

These can be divided according to their situations into three groups, one large and two small, as follows:

1. Aneurysms of the first part of the artery proximal to the communicating artery—4 cases.
2. Aneurysms of the artery in relation to the communicating artery—24 cases.
3. Aneurysms of the supracallosal part of the artery distal to the communicating artery—6 cases.

These aneurysms have been treated in a variety of ways. Some were treated by carotid ligation, but in general the results were unsatisfactory. Most, therefore, were approached intracranially with either clipping of the neck of the aneurysm (if accessible) or wrapping with muscle.

1. Aneurysms of proximal anterior cerebral artery: 4 cases (Fig. 6)

There were only 4 patients, all of whom had had subarachnoid haemorrhage. In addition 1 had chiasmal compression with bitemporal hemianopia. All were treated by direct attack, but in 2 of them, who were treated by clipping the commencement of the anterior cerebral artery, cerebral infarction

Fig. 6. Results in 4 cases of proximal anterior cerebral aneurysm all treated by a direct attack.
developed. The other 2 (ages 42 and 16 years), treated by muscle wrapping and by clipping of the neck of the aneurysm, respectively, have made good recoveries, and remain well 7 years and 3½ years later.

The first of the 2 complicated cases has already been reported.\(^5\) This was a man of 33 years with a small aneurysm on the first part of the left anterior cerebral artery, and an anomalous arrangement of the circle of Willis, such that both anterior cerebral arteries distal to the communicating artery were supplied mainly from the right carotid artery. He was treated by clipping the small left anterior cerebral artery proximal to the aneurysm, but a right hemiplegia developed, affecting particularly the face and arm, and also dysphasia which persists 7½ years later. The second patient, a man aged 53 years, had an aneurysm on the first part of the right anterior cerebral artery compressing the chiasm. This aneurysm was isolated between clips placed on the parent artery. A left hemiplegia developed and he died 10 days later with extensive infarction of the right frontal lobe.

Comment. Although the cases are few, they do suggest that clipping the anterior cerebral artery proximal to the aneurysm is liable to be followed by a hemiplegia. It has been suggested that this complication may be caused by occlusion of Heubner’s artery, which is often a small branch of the main artery that enters the basal ganglia.\(^8\) Our experience thus differs from that of Logue\(^15\) and of Baumann and Bucy\(^2\) who reported having frequently clipped with impunity the first part of the anterior cerebral artery for aneurysms affecting the communicating artery. The site of their clipping may, however, have been a little more distal on the artery than that performed in our 2 cases, in which the clipping necessarily was performed just adjacent to the carotid bifurcation. Clipping the neck of the aneurysm or wrapping it with muscle have proved to be safer procedures for lesions in this situation.

2. ANEURYSMS AT ANTERIOR COMMUNICATING ARTERY: 23 CASES (Fig. 7)

There were 24 patients with this lesion and 23 of these had had spontaneous subarachnoid haemorrhage, whereas in the remaining case the aneurysm was unexpectedly encountered at operation, and then bled. In the early stages of our experience, a few of them were treated by carotid ligation. The results, however, were so poor that the later patients were all treated by a direct attack.

A. Patients Treated by Carotid Ligation: 5 Cases (Fig. 7a). Only 1 patient (a woman aged 54 years) has had a good result. She was in good condition 4 days after her haemorrhage and had one common carotid artery tied in stages. She remains well 8 years later. Two other patients, women of 44 and 46 years, both still semicomatose 2 and 4 days after their bleedings, deteriorated and died after carotid ligations (internal and common carotid artery respectively). Another patient, a man of 52 years, also still semicomatose 12 days after his haemorrhage, had a partial common carotid ligation. He lingered on for a fortnight having frequent attacks of paroxysmal tachycardia, and then died of heart failure. The fifth patient, a man of 30, had a partial common carotid ligation 2 weeks after his third bleeding. Eight days
FIG. 7. Results in 23 cases of anterior communicating aneurysm treated by (a) carotid ligation and (b) by a direct attack.

later he bled again, and subsequently had a craniotomy. He still survives, 5½ years later, though somewhat disabled by mental changes.

B. Patients Treated by Direct Attack: 19 Cases (Fig. 7b). Including the patient (Fig. 7a) who had a recurrent haemorrhage after a partial ligation of one common carotid artery, there were 19 patients in this subgroup. Three of them had one common carotid artery tied before the intracranial attack, while in 4 cases large clots were also removed from the frontal lobe. In all but 1 instance the operation performed was wrapping the aneurysm with hammered muscle. Altogether 12 of the 18 patients so treated, whose ages ranged from 19 to 63 years, had good results, and remain well after periods of from 2 to 7 years. The nineteenth patient was a 51-year-old woman who had had subarachnoid haemorrhages 2½ and 1½ years previously, and had a very large aneurysm, too big for muscle wrapping. Her aneurysm had been shown
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by repeated arteriography to be enlarging. It was treated by proximal clipping of one anterior cerebral artery. She remains well 2 years later.

There were 2 deaths, 1 case of fatal recurrent haemorrhage, and 3 cases of recovery with disability. The first death was that of a fit young man, aged 25 years, who had a muscle-wrapping operation 6 days after his subarachnoid haemorrhage. The aneurysm bled at operation, and he died the following day. The second fatal case was that of a woman, aged 52 years, who had had four subarachnoid haemorrhages in 3 1/2 months, with a left hemiparesis persisting after the last of them. She was operated on 4 days later. The aneurysm bled at operation, and was wrapped with muscle. She subsequently remained in a state of akinetic mutism with hemiplegia and died 9 months later. At autopsy there was infarction in the territory of the middle cerebral artery on the side opposite to the operative approach. The cause of this is obscure, as the artery was not thrombosed. Presumably vasospasm may have been responsible. The patient with recurrent haemorrhage was a woman of 43 years who had her first operation 10 days after haemorrhage. She bled at this operation, and the wrapping was therefore more in the nature of an emergency packing of the lesion. However, she made a good recovery, but had a recurrent haemorrhage 4 weeks later. Five days after this second bleeding one anterior cerebral artery was clipped and divided proximal to the lesion, but she went into a state of mutism and died 2 1/2 months later. Autopsy showed infarcts in both frontal lobes caused by thrombosis of both anterior cerebral arteries.

Three patients remain disabled, but in 1 the disability was present before operation. One was the patient who had a recurrent haemorrhage after carotid ligation, and who had a muscle-wrapping operation the following day. He is alive 5 1/2 years later, but is lacking in initiative and able to do only labouring work. The second patient, a man of 28 years, who had had seven subarachnoid haemorrhages in as many years, was operated upon 4 months after the last of them. As well as being wrapped with muscle the aneurysm was clipped and coagulated with the diathermy. He made a poor mental recovery, and still has frequent fits and headaches. Arteriography later showed that both anterior cerebral arteries were occluded. He is still alive 7 1/2 years later, but carries out only simple labouring tasks. The third patient, a man of 50 years with a previous history of frequent headaches, was semicomatose with a left hemiparesis at the time of operation. Physically he is now well after 5 1/2 years, but his headaches persist.

Patient with Accidental Subarachnoid Haemorrhage. A man aged 32 years presented features of hypopituitarism and bitemporal hemianopia. Roentgenograms and air encephalography showed a suprasellar extension of a pituitary tumour, and he was explored for this condition. An unsuspected aneurysm was inadvertently opened and bled profusely at this first operation, a muscle pack being used to control the haemorrhage. Later his vision deteriorated still further, and at a second operation the aneurysm was obliterated with clips and an intracapsular removal of the pituitary adenoma was
carried out. He remains well, with good restoration of vision, 2½ years later, and has recently married.

Comment. From the practical viewpoint it is important to note from the preoperative arteriograms whether the aneurysm projects downwards and forwards from the communicating artery, or upwards and backwards. The former can always be approached from beneath the frontal lobe and usually recovery is satisfactory. The latter, however, have often to be approached from above by detaching one frontal lobe from off the falx and opposite frontal lobe. If the retracted frontal lobe becomes oedematous, it should be resected. Subsequently the patients are apt to show mental and intellectual deterioration which may, however, clear up.

3. ANEURYSMS OF DISTAL ANTERIOR CEREBRAL ARTERY: 6 CASES (Fig. 8)

All the patients had intracranial haemorrhage. These aneurysms tend to bleed into the brain with the production of intracerebral clots, and therefore carry a high incidence of epilepsy and hemiplegia. An aneurysm on the anterior cerebral artery of one side may bleed into the contralateral hemisphere. Not realising this, in the 1 patient treated by carotid ligation the common carotid artery was tied on the wrong side (Fig. 8a). The patient continued to decline and death ensued within 24 hours from the effects of a large intracerebral clot.

The remaining 5 patients have all been treated by a direct attack on the aneurysm, with 1 death (Fig. 8b). Only 1 of the 4 survivors, a woman of 56 years, has a really good result, the other 3 retaining some disability caused by hemiparesis, fits, or mental change which antedated the operation. All, however, are able to work. The operations performed were excision of the aneurysm in 2 cases (including the patient with a good result), isolation of the lesion between clips in 1 case, and clipping of the anterior cerebral artery just proximal to the aneurysm in the fourth case.

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**Fig. 8.** Results in 6 cases of distal anterior cerebral aneurysm treated (a) by carotid ligation, and (b) by a direct attack.
The fifth patient treated by a direct attack died 2 months after operation. She was a woman of 38 years, a known hypertensive (B.P. 220/125) who 6 weeks before operation had had an attack of intracranial haemorrhage which left her weak in both legs and with bilateral extensor plantar responses. She deteriorated rapidly after arteriography, and a right frontal craniotomy was performed with removal of much clot and disrupted brain tissue. The aneurysm was wrapped with muscle. She failed to respond, remaining confused and paraplegic, and died 2 months later. Autopsy showed thrombosis of both anterior cerebral arteries with infarction of the corpus callosum and medial portions of both hemispheres.

Comment. Cases in this subgroup are rare, and are generally associated with intracerebral haemorrhage. These aneurysms, however, can sometimes be excised. The liability to subsequent epileptic attacks is great.

ANEURYSMS OF MIDDLE CEREBRAL ARTERY

All 17 patients in this group had had subarachnoid haemorrhage, and 16 of them were operated on at periods ranging from a few hours to a month after their last bleeding (Fig. 9). The remaining patient, a man of 32 years, had complained of headaches on coitus during the 9 months that had elapsed

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**Fig. 9.** Results in 17 cases of middle cerebral aneurysm treated (a) by carotid ligation, (b) by a direct attack, and (c) by a combination of procedures.
since his bleeding and he was operated on by a direct approach with relief of symptoms. The operative procedures used fall into two categories, carotid ligation and direct approach. Sometimes these were combined. Most of the patients treated by carotid ligation alone were operated on in the earlier stages of our experience, and the poor results so obtained caused this method to be abandoned.

**Carotid Ligation: 5 Cases** (Fig. 9a). The 3 patients who were treated within a week of their bleeding by ligation of the common carotid artery all had poor results. Two of them, females aged 59 and 66 years, had hemiplegia after the ligation, and 1 of these, after initial improvement, died a year later, probably of recurrent bleeding. The other patient is still alive 6½ years after, although disabled by dysphasia and hemiplegia. The third patient, a female of 59 years, died 4 days after carotid ligation with extensive infarction in the territory of the middle cerebral artery. On the other hand, the patients who were treated in the second fortnight after their haemorrhages, are still alive. The first of these, a man aged 28 years, had a one-stage ligation of the internal carotid artery without ill effects. He remains well 8½ years later. The second, a man of the same age, had a common carotid ligation followed by internal carotid ligation. Four days later aphasia and hemiplegia developed, but fortunately, after treatment with anticoagulants, these improved, and he is now well 5½ years later.

The over-all results in this small group of cases are thus poor, and the incidence of complications is high. We feel that carotid ligation has little place in their treatment.

**Primary Intracranial Attack: 9 cases** (Fig. 9b). Generally the aneurysm was exposed by a craniotomy and wrapped with muscle, although in 1 case it was clipped successfully. There have been no deaths or recurrences in any of these patients and 7 (ages from 30 to 59 years) have done well. The remaining 2 patients have recovered with persisting disabilities. One of these, a woman of 47 years, was investigated by arteriography a year after her first attack of subarachnoid haemorrhage, and was shown to have an aneurysm. Operation was advised but refused, and she was discharged. Shortly afterwards she had two more haemorrhages, following the second of which she was in deep coma. An emergency craniotomy was performed, an extensive clot was sucked out, and the aneurysm was wrapped with muscle. She recovered but with severe hemiplegia and dysphasia, and with blindness in the ipsilateral eye. The second patient, a woman aged 40 years, was in the last stages of pregnancy, and was still very stuporous and dysphasic 10 days after her haemorrhage. At operation her aneurysm was clipped and also shrivelled with diathermy. She had a normal delivery 2 days later, the baby being healthy. Six years later she remains alive but severely disabled with aphasia and hemiplegia. A postoperative arteriogram showed that the middle cerebral artery was thrombosed, and this probably occurred because the diathermy current which was used to shrivel the aneurysm spread to the artery itself. This particular method of treatment had previously been mentioned by Dandy.5
RESULTS OF SURGERY IN SACULAR ANEURYSMS

Combined Operations: 3 Cases (Fig. 9c). Two patients (aged 27 and 41 years) had a common carotid ligation followed by an intracranial attack, while in 1 other (aged 31 years) the sequence was reversed to give an additional measure of support. All these patients have done well.

Comment. Carotid ligation, especially in the acute stage, has been shown to carry a considerable risk of hemiplegia (with dysphasia if the dominant hemisphere is involved). One of 4 surviving patients had a probable recurrent haemorrhage and this, in conjunction with its risks, has led to the operation being abandoned.

Craniotomy with muscle wrapping has been the usual operation. Sometimes this has been reinforced by carotid ligation. On the whole very good results have been obtained (10 cases) with no recurrences of bleeding to date. Only 2 patients have been left disabled, and in 1 of these the disability preceded operation. In the other the diathermy current was used on the aneurysm with subsequent thrombosis of a middle cerebral artery.

ANEURYSMS OF BASILAR ARTERY AND ITS BRANCHES

Three patients with aneurysms lying on the right posterior cerebral, at the basilar bifurcation, and at the origin of the right superior cerebellar arteries have been treated by ligation of one vertebral artery in the neck (Fig. 10). The intervals since the last bleeding were 4 weeks, 3 weeks and 1 week respectively.

All did well initially, and the latter 2 patients are still well after 3½ and 4 years. The first patient had a unilateral third nerve palsy before operation, and when last seen 3 years later this had recovered. She died 4½ years after operation, the cause of death being unknown.

MULTIPLE ANEURYSMS

There were 10 patients with multiple aneurysm and 9 of them had subarachnoid haemorrhage. The possible combinations of aneurysms are numerous, but even in this small number a few recurring patterns can be discerned.

BILATERAL SYMMETRICALLY PLACED ANEURYSMS: 4 CASES

Internal Carotid: 2 Cases. A woman aged 61 years had a left third nerve palsy after a subarachnoid haemorrhage. Twelve days later the aneurysm on that side was explored. It burst at operation and the bleeding was controlled by a muscle pack. She recovered with a right hemiplegia and dysphasia and is still severely disabled, physically and mentally, 18 months later. Her second aneurysm has not been explored.
The other patient, a woman aged 71 years, presented right-sided headaches and a right third nerve palsy, but had no bleeding. She had the right common carotid artery tied, and was relieved of her symptoms. She died of a coronary thrombosis a year later.

It is worth remarking that there were 2 other patients with symmetrical internal carotid aneurysms already described among the single cases. This gives an incidence of bilateral aneurysms of this type in 4 of 43 patients. In these last 2 cases, however, the second aneurysm was not revealed by arteriography, but caused a fatal haemorrhage 2\(\frac{1}{4}\) and 2\(\frac{1}{2}\) years after operation on the first side.

**Carotid Bifurcation: 1 Case.** One patient with bilateral aneurysm in this site described previously\(^7\) remains well 8 years later. The neck of each aneurysm was clipped intracranially after tying the common carotid artery on the side of the bleeding 2 days after its occurrence.

**Middle Cerebral: 1 Case.** A woman of 54, deeply comatose and deteriorating after two subarachnoid haemorrhages, had a ligation of the common carotid artery and a craniotomy with evacuation of intracerebral clots on the left side. She died a few hours later. Post mortem, a second and unruptured aneurysm was found on the other side.

**MULTIPLE ANEURYSMS ON ONE SIDE (INCLUDING ANTERIOR COMMUNICATING ARTERY): 4 CASES**

Two patients, men of 36 and 62 years, were treated for relatively recent subarachnoid haemorrhages. The first, with aneurysms on the right carotid bifurcation and middle cerebral artery, had a ligation of the common carotid artery performed in stages commencing 6 days after the haemorrhage. The day after completion of the ligation hemiplegia developed and he went into coma. The ligature was removed and a craniotomy was performed with obliteration of the aneurysms with clips. He died a few hours later. A clot was found in the ventricles, the bleeding having occurred from the aneurysm at the bifurcation.

The second man with aneurysms on the anterior communicating and left internal carotid arteries had two craniotomies. At the first, performed 9 weeks after his haemorrhage, the internal carotid aneurysm was wrapped with muscle. He recovered uneventfully and 4 weeks later a similar operation was carried out on the anterior communicating aneurysm. Postoperatively he collapsed with a period of low blood pressure. Subsequently, he made a slow recovery, but remains disabled by mental changes, spastic weakness of both legs, and occasional fits.

Two patients were admitted to hospital because of persisting headache long after their attacks of subarachnoid haemorrhage; one, a man aged 40 years with aneurysms on the left middle cerebral artery and at the carotid bifurcation, had not bled for 11 years, while the other, a woman aged 21 years with one aneurysm on the left internal carotid artery and two on the middle cerebral artery, had not bled for 7 years. Each had a ligation of their
left common carotid artery and both remain well after 3½ and 1½ years respectively.

**ANEURYSMS ON BOTH SIDES: 2 CASES**

A woman of 55 years, a known hypertensive, had a subarachnoid haemorrhage with a left third nerve palsy. She was shown to have aneurysms on the left internal carotid and right middle cerebral arteries. Ligation of the left common carotid artery was performed in stages 10 days after her haemorrhage. She recovered satisfactorily and remains well 2 years later.

The last patient, a woman of 42 years, had two aneurysms on the left internal carotid artery and one each on the right internal carotid and middle cerebral arteries. She came to this country 5 months after a severe subarachnoid haemorrhage, and had two craniotomies. At the first, the left-sided aneurysms were wrapped with muscle, and later the procedure was repeated on the right side. She made a good recovery and is well 1½ years later.

*Comment.* Eight of these 10 cases were discovered during the examination of the last 62 patients—a period during which bilateral carotid angiography has been the rule, although most of the earlier cases also had both sides examined. The treatment in such cases is, of course, dictated by the situation of the aneurysms and the severity of any symptoms, including the occurrence of repeated haemorrhages. Experience shows, however, that there need be no undue hesitation in attacking lesions on both sides.

**DISCUSSION**

This review of our case material has been made with the object of assessing the various factors that make for success or failure in the surgical treatment of aneurysms, and also to appraise the results of operative treatment both immediate and late. During the period when these cases were being collected, many neurosurgeons, including Mount,19 Poppen,25 Hamby,12 Small et al.,29 Norlén and Olivecrona,28 Logue,15 McKissock and Walsh,16 Botterell et al.,5 as well as one of us (Falconer5,8,19) have all described their results in large groups of cases indicating that benefit can often be conferred by timely operation. The different series, however, do not permit of statistical comparison, because in most of them there have been, during the period of collection, changes both in the selection of cases and in the operative techniques employed. The various series should be regarded as attempts to open up a new field of surgery, the problems and possibilities of which are only gradually being understood.

A pertinent criticism of most published series is that they lack adequate controls of patients not operated upon. The surgeons who have come nearest to meeting this objection are Logue15 and McKissock and Walsh,16 who compared their operative results with the results they had obtained in earlier years by conservative treatment in comparable cases. Most authors have merely compared their results with the numerous published reports of subarachnoid haemorrhage treated conservatively in the days before the advent
of surgical treatment. Such a comparison becomes valid only if the results have been strikingly bettered. This we believe to be the case. The statistical method of establishing superiority of treatment by selecting in random fashion cases for either conservative or operative treatment is now scarcely justifiable.

In assessing the results of surgery one cannot concentrate just on aneurysms of a particular type or at a particular site, but must retain an over-all view of the problem. It is of little value advocating early arteriography to disclose a minority group of aneurysms which are then treated in a particular way without at the same time considering what is going to happen to the other groups of aneurysms, as well as to the other bleeding lesions, such as arteriovenous malformations. It soon becomes obvious that aneurysms vary considerably in the gravity and mode of their presentation, in their sites of origin, in their physical characteristics, and in their association with anomalies of the circle of Willis. Thus aneurysms may vary considerably in size, may have wide or narrow necks, may or may not be associated with intracerebral bleeding, and may be associated with anomalous arrangements of the circle of Willis which preclude a particular form of treatment such as proximal clipping of the parent artery. Again, in more than 10 per cent of cases multiple aneurysms occur.

It is, therefore, not possible to lay down any hard and fast program either for the selection of cases for operation, or for the method of operative treatment of particular aneurysms. There are some trends, however, and these can perhaps be illustrated by our own case material. Several statistical studies\textsuperscript{11,17,27,33} have shown that mortality from subarachnoid haemorrhage is highest immediately after bleeding, and that about 30 per cent of patients treated conservatively in hospital will die within the first 2 or 3 days. Our own experience (Fig. 11) suggests that our operative interventions have done little to improve this, for the mortality rate of patients operated on during the first week is 30 per cent, a figure which approaches the expected natural mortality at this period. Many of our patients operated on at this

![Fig. 11. Over-all results in 109 patients with 118 demonstrated aneurysms. The cases are arranged in four columns according to the bleeding-operation interval.](image)
period were gravely ill, and it is our experience that it is difficult to salvage such cases. Vasospasm probably plays a part in this, and aggravation of vasospasm may well account for the worsening of symptoms that follows either arteriography or operation in some of the more gravely ill patients. For instance, it is difficult to account on any other basis for the infarction without thrombosis or embolism noted post mortem in the territory of the right middle cerebral artery in 1 of our patients operated upon for aneurysm of the left anterior cerebral artery.

TIMING AND MANAGEMENT OF CAROTID ARTERIOGRAPHY

The question therefore arises as to at what stage should operative treatment be considered, for arteriography performed shortly after the onset of bleeding sometimes aggravates symptoms. It is our impression that this procedure is best deferred until a week following the last bleeding. Although it is not often possible to salvage patients who would die within a few hours of their haemorrhage, it is usually possible to prevent death from later recurrence. Again the statistical studies cited show that while a third of patients die shortly after their initial haemorrhage, another third will die of recurrent haemorrhage within the next 6 to 8 weeks. These recurrences reach their peak of incidence between the second and fourth weeks after the initial bleeding. Furthermore, of those patients who survive to leave hospital, 20 per cent will die subsequently of recurrent haemorrhage within the next few years.

If arteriography can be deferred until a week following haemorrhage, and then be followed by prompt operation if a remediable lesion is shown, most of these deaths from subsequent recurrent bleeding can be avoided, few complications occur after arteriography, and the prospects for patients can be greatly improved. Thus in Fig. 11 it can be seen that our over-all operative and follow-up mortality when operation was performed later than a week after the bleeding was only 11 per cent, a figure that is considerably lower than the natural fatality rate that is to be expected in these conditions. Operative figures even lower than these have been reported by Norlén and Olivecrona following operations performed 3 to 4 weeks after a haemorrhage, while recently Botterell et al. reported no deaths in 29 patients operated on under hypothermia more than a week after the last bleeding.

Prior to arteriography the Matas test of digital compression of each common carotid artery in the neck in turn for a period of 10 minutes should be made to test the collateral circulation. Carotid arteriography of course should always be performed on both sides with appropriate compression of the opposite carotid artery in order to demonstrate the cross circulation between the two halves of the circle of Willis. This is because aneurysms are multiple in more than 10 per cent of cases. It is only when bilateral carotid arteriography is negative that vertebral arteriography should be proceeded with. Cases in which arteriographic studies are negative on the whole have a
favourable prognosis with conservative treatment, but follow-up studies show that in some of these cases an unsuspected aneurysm will subsequently bleed again.

METHODS OF OPERATIVE APPROACH—CAROTID LIGATION VERSUS INTRACRANIAL ATTACK

Our findings indicate that while carotid ligation is of value for aneurysms of the internal carotid artery in relation to the posterior communicating artery, its results in general are not so satisfactory for aneurysms higher on the circle of Willis or on its distal branches. Again, while common carotid ligation is safe (there were no cases of hemiplegia secondary to it in this series), internal carotid ligation either in the neck or intracranially is apt to be followed within the next 3 days by hemiplegia.

Before carotid ligation is performed, tests of the efficacy of the collateral circulation should be undertaken. The usual tests are (1) the Matas digital compression test involving the common carotid artery in the neck, (2) the angiographic demonstration of a cross circulation through the circle of Willis from the opposite carotid artery, and (3) a trial period of occlusion of the artery with a clamp applied at operation under local analgesia before the artery is ligated. Other measures include recording the arterial pressures in the artery distal to the occlusion and the use of the electroencephalogram during the period of trial occlusion. Neither of these measures, however, is entirely satisfactory.

The question next arises as to the advisability of releasing the ligature if signs of insufficiency of the cerebral circulation develop. Good recovery has been described by Olivecrona following this manoeuvre in which the ligature on the internal carotid artery was released up to 6 hours after being tied. In our experience in this particular series a carotid ligature has been released six times. Four patients with aneurysms of the internal carotid artery treated by internal carotid ligation had their ligatures released upon the appearance of signs of cerebral vascular insufficiency at periods ranging from 2 to 24 hours after ligation, but without improvement in any case. Two patients, 1 with an anterior cerebral aneurysm and 1 with a middle cerebral aneurysm, each exhibited signs of cerebral insufficiency after only a partial common carotid ligation. Both improved after release of the ligature within 12 hours of the original operation, but recurrent bleeding occurred 6 days later, in the second case necessitating a direct attack, with a good result.

Sweet and Bennett have advocated that in tying the carotid artery one should always apply the ligature in such a way that it can be released promptly in order to restore the circulation, and that the ligature should be released even if such late signs develop abruptly. They do not give any case histories illustrating these points, however, but refer to Schorstein’s view that such signs of circulatory insufficiency are more likely to be caused by vasospasm of the cerebral vessels than to thrombosis or embolism. Our own postmortem evidence supports this view. However, in a case subsequent to this series it appears likely that releasing the ligature from the common ca-
rotid artery precipitated fresh aneurysmal bleeding. It is therefore difficult to know what action to advocate when signs of carotid insufficiency develop some hours after the operation.

The methods of treatment to be applied to aneurysms in different situations will now be elaborated.

A. ANEURYSMS OF INTERNAL CAROTID IN RELATION TO POSTERIOR COMMUNICATING ARTERY

No single standard treatment can be applied to this group of aneurysms, but each case must be judged on its merits. If the aneurysm is single, and if the collateral circulation through the circle of Willis is adequate, common carotid ligation in the neck should be considered, as it is a safe procedure. Our follow-up studies, however, suggest that later recurrence may occur (2 cases out of 8 in our series).

The risks of recurrence are less after internal carotid ligation (none in 9 cases) and after trapping operations (1 instance out of 12 cases)* but the risks of producing hemiplegia and perhaps aphasia after these procedures (5 patients out of 9 following internal carotid ligation) are considerable.

The most suitable alternative to common carotid ligation, and the procedure which offers permanent cure, is a direct attack on the aneurysm with clipping or ligation of its neck. For this operation a combined temporal and frontal approach may be required. The procedure is obligatory when the cross circulation through the circle of Willis is deficient, and with experience carries little risk.

B. ANEURYSMS AT CAROTID BIFURCATION

This is a small group. McKissock and Walsh16 feel that they can be benefitted by carotid ligation, but our figures are too small to establish this. The 1 surviving patient so treated has lived 5 years. Whenever possible we feel that the desirable treatment is a clipping or ligation of the neck of the aneurysm. Common carotid ligation should be reserved for those cases in which this treatment is impracticable.

C. ANEURYSMS IN RELATION TO ANTERIOR COMMUNICATING ARTERY

Carotid ligation is of little value in these cases which admittedly are the most difficult of all the aneurysmal groups to treat. Our policy has been to approach them by a direct attack, clipping or ligating the neck of the aneurysm if it is narrow, but otherwise wrapping the fundus with hammered muscle. We have only once tried Logue's15 method of proximal clipping of the principal parent feeding artery and then with apparent success. Baumann and Bucy2 claimed that in most cases the parent anterior cerebral artery can be successfully clipped on either side of the aneurysm, thus isolating it from the circulation. Our experience of this manoeuvre in the 1 case of proximal anterior cerebral aneurysm in which we tried it indicates that the method has its fatalities.

* In 2 other cases in which there was recurrent haemorrhage, the bleeding was from a second aneurysm.
D. ANEURYSMS OF DISTAL ANTERIOR CEREBRAL ARTERY

Cases in this subgroup are rare, and are generally associated with intracerebral haemorrhage. Epilepsy has been a common postoperative complication. Aneurysms in this situation are amenable to direct surgical attack, and can even be excised.

E. ANEURYSMS OF MIDDLE CEREBRAL ARTERY

Carotid ligation has been of little value in these cases, and indeed in the 2 instances in which it was performed within a week of bleeding, it was followed by a hemiparesis. The treatment of choice has been a direct exposure of the aneurysm with manoeuvres similar to those in treatment of an anterior cerebral aneurysm, viz.: clipping or ligating the neck of the aneurysm if it is narrow, and wrapping with hammered muscle if this is impracticable. On the whole surgery in this group of aneurysms has been followed by good results.

AN APPRECIATION OF DIFFERENT METHODS OF INTRACRANIAL ATTACK

Bleeding from an aneurysm generally occurs from its fundus and probably the ideal method of treatment of aneurysms is clipping or ligation of the neck leaving the parent vessel patent. This was done in 9 cases of this series with good results in all cases.

When this is not possible, as for instance when the neck is broad or inaccessible, then an alternative method of treatment is to pack pieces of hammered muscle around its exterior. The necessary exposure of the aneurysm is facilitated by gently sucking away the cortex and white matter surrounding the aneurysm with a fine-bore sucker. The pieces of muscle can then be placed around the various sides of the fundus of the aneurysm and pressed into position for a few minutes, thus reinforcing the aneurysmal walls. This was the sole method of treatment employed in 29 of the 108 patients who had bled (including 3 who had multiple aneurysms), and only 1 of these has bled again subsequently.

Cauterization of the fundus of the aneurysm with diathermy, which was a method recommended by Dandy, led to occlusion of the parent artery in 2 cases in which it was tried, and was followed by considerable permanent disability.

Hypotensive anaesthesia has been employed routinely in the latter half of our series. When we first tried it we were often disturbed by a precipitous fall in blood pressure, and in 2 or 3 instances wondered whether this could not have led to cerebral infarctive changes, thus adversely affecting the results. Since then we have been careful to lower the blood pressure to only 70 mm. Hg for the actual period during which the aneurysm has been exposed. We have not had experience of hypothermia as employed by Botterell et al. as an alternative to hypotension.

Recently Mount and Tavera have advocated employing postoperative (progress) arteriography to check up on the effects on the aneurysm of operative treatment, either by carotid ligation or by direct attack. We would hesi-
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tate to subscribe to this as a routine postoperative procedure, however, for in our hands it has sometimes been followed by hemiplegia, as in the case of internal carotid aneurysm which was trapped.

LONG-TERM FOLLOW-UP RESULTS—LATE RECURRENCES

The long-term follow-up results in 109 patients with 118 aneurysms who had experienced intracranial bleeding may now be summarised as follows (Fig. 11):

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<th>71 cases</th>
<th>Survivors 85</th>
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<td>Good results</td>
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<tr>
<td>Poor results</td>
<td>14 cases</td>
<td></td>
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<tr>
<td>Deaths</td>
<td>16 cases</td>
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</tr>
<tr>
<td>Later recurrences</td>
<td>8 cases</td>
<td>(4 fatal)</td>
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A review of the 8 cases of recurrent haemorrhage shows that 5 were cases of aneurysm of the internal carotid artery at the level of the posterior communicating artery, 2 were cases of aneurysm of the anterior communicating artery, and 1 was an aneurysm of the middle cerebral artery. Three of the 5 cases of internal carotid aneurysm proved fatal. In 2 instances autopsy showed that the fatal bleeding had come from a second and unsuspected aneurysm on the opposite side of the circle of Willis, but in the third fatal case a postmortem examination was not made. The two patients who survived recurrence were both treated by further surgery—1 of these haemorrhages had recurred following common carotid ligation and the other after Dandy's trapping operation.

One of the 2 instances of recurrence in anterior communicating aneurysm followed common carotid ligation, and subsequently was successfully treated by muscle wrapping. The other case terminated fatally, and was the only instance of aneurysm treated by muscle wrapping to do so—there was, however, no further operation or autopsy. The remaining instance of possible recurrence occurred in a case of middle cerebral artery aneurysm, and again there was no postmortem examination.

CONCLUSIONS

Thus, out of 109 patients with 118 arteriographically demonstrated aneurysms which had been complicated by intracranial haemorrhage, 93 (86 per cent) survived operation and were discharged home. These survivors have since been followed up for periods ranging from 2 to 9 years; 8 have suffered a recurrence of bleeding in that period, but in only 4 has it proved fatal. In at least 2 of the fatal cases, however, the recurrent bleeding came not from the aneurysm operated upon, but from a second and unsuspected aneurysm. These figures relating to surgical treatment should be compared with the expectation of a 20 per cent fatal recurrence rate in cases of conservative treatment followed up for the same period.12,31

This leaves 85 patients who have survived the follow-up period, and of these 71 (65 per cent of original group) have made excellent recoveries, re-
suming all their former activities with little or no disability or inconvenience. Fourteen other patients are disabled although some of these live reasonably active lives.

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