THE RESULTS OF SURGICAL TREATMENT OF INTRACRANIAL ANEURYSMS AS DEMONSTRATED BY PROGRESS ARTERIOGRAPHY*

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In order to determine the results of surgical therapy for intracranial aneurysms, postoperative arteriography has been done as a routine procedure in patients having ligation of the carotid arteries in the neck and more recently in patients who have had a direct surgical attack on the aneurysm intracranially. The main purpose was to determine whether the artery was actually occluded and whether the aneurysmal sac was or was not visible. The means of establishment of collateral circulation is an interesting side-light which is being published in another paper.

The procedure followed in progress arteriography is to inject the artery proximal to the site of ligation whenever this is possible. This is not possible when the common carotid artery is ligated, as this artery is most often thrombosed proximal to the site of ligation and actually distal to the ligation as far superiorly as its bifurcation into the external and internal carotid arteries, and no pulsation of the common carotid artery is felt. If pulsation of the common carotid artery is palpable the artery is likely not completely ligated. In 2 cases of common carotid artery ligation the internal carotid artery was injected: in 1 case, by the percutaneous method and in 1, by the open method. When the internal carotid artery has been ligated or the intracranial approach has been used, the common carotid artery is injected, and the status of the aneurysm and of the clamp may be determined in some cases with a single injection. In the case of internal carotid ligation, the carotid syphon and the middle cerebral artery may be well shown by back-flow through the ophthalmic artery. If the artery at the site of the aneurysm is not shown, another arteriogram is done by injection of the opposite carotid. If still the site of the aneurysm is not shown, a vertebral arteriogram is done. In some cases it was not possible to demonstrate the site of the aneurysm.

Fifty-four progress arteriograms were performed in 51 cases at an average time of 10 months postoperatively, the shortest period being 10 days and the longest being 7 years and 10 months. Actually, a greater number of progress arteriograms were done, but only the latest postoperative angiograms were included in this study.

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RESULTS OF SURGICAL TREATMENT OF ANEURYSMS

TABLE 1

Case material and therapy

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ligation Internal Carotid</td>
</tr>
<tr>
<td>Internal carotid</td>
<td>22</td>
</tr>
<tr>
<td>Middle cerebral</td>
<td>6</td>
</tr>
<tr>
<td>Anterior communicating</td>
<td>1</td>
</tr>
<tr>
<td>Anterior cerebral</td>
<td></td>
</tr>
<tr>
<td>Posterior cerebral</td>
<td></td>
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</tbody>
</table>

Of these 51 patients, 35 had aneurysms on the internal carotid artery; 6, on the middle cerebral, 1 of whom also had an internal carotid aneurysm on the same side; 7, on the anterior communicating; 1, on the anterior cerebral; and 1, on the posterior cerebral (Table 1). There were 4 patients who had multiple aneurysms: in 1 case both aneurysms were on one side of the brain, and in 3 cases they were on both sides. The 3 patients in whom the aneurysms were located bilaterally had no therapy directed to the aneurysms on the second side. Thirty-three patients had had subarachnoid hemorrhage. Ligation of the internal carotid artery in the neck was performed in 30 cases. Eleven patients had common carotid ligation, 3 of whom previously had had unsuccessful ligation of the internal carotid, using a tantalum clip. Thirteen had intracranial surgical therapy for the aneurysm. Some of the patients had more than one surgical procedure when the first operation was found to be ineffective, and progress arteriography was done after each procedure.

There were 43 progress arteriograms in which the artery was demonstrated at the site where the aneurysm arose. This, of course, was not possible in the 5 cases in which trapping was done by ligation of the internal carotid artery in the neck and intracranially, and in most of the cases in which ligation of the common carotid was performed. Of these 43 cases the aneurysm was not seen on the angiogram in 24, although its site was well demonstrated; it was smaller in 9; unchanged in 8; and larger in 2. Further explanation, however, is necessary since included in the 43 cases are those in which the clamp or clip was found to be open and also those in which the clamp had to be released because of insufficient collateral circulation; in other words, those cases in which surgical therapy was incomplete.

The most significant cases are those in which progress arteriography showed both the site of the aneurysm and the clip or clamp to be closed (Table 2). There were 10 such patients who had an aneurysm of the internal carotid artery and ligation of the internal carotid artery. In 8 of these 10, the aneurysm was no longer visualized and in 2 it was the same size. In 4 such patients who had an aneurysm of the middle cerebral artery and who were shown to have complete ligation of the internal carotid artery, the aneurysm was not shown in 1 and was smaller in 3.
TABLE 2
Cases in which progress arteriogram showed site of aneurysm and showed that the clamp or clip on internal carotid artery remained closed

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>Aneurysm not Shown</th>
<th>Aneurysm Smaller</th>
<th>Aneurysm Same</th>
<th>Aneurysm Larger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal carotid</td>
<td>8</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Middle cerebral</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3
Cases in which progress arteriogram showed site of aneurysm and showed that the clamp or clip on internal carotid artery was open

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>Aneurysm not Shown</th>
<th>Aneurysm Smaller</th>
<th>Aneurysm Same</th>
<th>Aneurysm Larger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal carotid</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Middle cerebral</td>
<td></td>
<td></td>
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</tbody>
</table>

The progress arteriogram showed the aneurysmal site and showed the clamp or clip to be open on the internal carotid artery in 9 cases (Table 3). In 8 of these cases the aneurysm was on the internal carotid artery. It was not seen in 2 cases, it was smaller in 4, larger in 1, and the same size in 1 case. There was 1 case in which the aneurysm was on the middle cerebral artery and in this case the aneurysm was the same size.

There were 5 cases in which the aneurysmal site was shown and the clamp or clip on the internal carotid artery had been released because of insufficient collateral circulation (Table 4). In 4 of these cases, the aneurysm was on the internal carotid artery; in 2 of these, the aneurysm was not visualized and in the other 2 it was the same size. In 1 case the aneurysm was on the middle cerebral artery and the size of the aneurysm was unchanged.

The aneurysmal site was shown in the progress arteriogram of 9 patients who had had common carotid artery ligation. In only 1 case could we demonstrate that the clip was closed. In this patient, the aneurysm on the internal carotid artery was not seen. In 2 cases the clamp had to be released;

TABLE 4
Cases in which progress arteriogram showed site of aneurysm in patients whose clamp or clip on internal carotid had to be released because of insufficient collateral circulation

<table>
<thead>
<tr>
<th>Location of Aneurysm</th>
<th>Aneurysm not Shown</th>
<th>Aneurysm Smaller</th>
<th>Aneurysm Same</th>
<th>Aneurysm Larger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal carotid</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle cerebral</td>
<td></td>
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</tbody>
</table>
in 1, the aneurysm, on the internal carotid artery, was found to be smaller, and in the other, the aneurysm, on the anterior communicating artery, was found to be the same. In 6 cases the status of the clamp could not be determined; in 2 of these the aneurysm on the internal carotid artery was not seen. in 1 case the aneurysm on the internal carotid artery was smaller, in 2 others, the aneurysm on the internal carotid artery was the same. In 1 case of middle cerebral aneurysm the sac was the same size in the progress arteriogram.

There were 13 arteriograms performed on patients who had had intracranial therapy for their aneurysms. Five of these had trapping by placing a clamp or clip on the internal carotid artery in the neck and intracranially, and the intracranial clip prevented the aneurysmal site from showing. Four had trapping intracranially by clips on the artery on either side of the site of origin of the aneurysm. In 3 of these, the aneurysm was not shown although the artery filled well up to the clip. In 1, the clips had become loos-

![Arteriogram showing Diodrast passing through internal carotid artery at site of the tantalum clip on the artery, and revealing that the aneurysm is present on the internal carotid artery, although it is smaller than it was before ligation.](image-url)
ened and dislodged, and the aneurysm was the same size it had been before therapy. Two patients had the lumen of the aneurysm packed with muscle and in neither was the aneurysm shown. In the 1 patient who had muscle packed around an anterior communicating aneurysm, the progress arteriogram 3½ months later showed the aneurysm to be the same size but different in shape.

We have a control group of 16 patients who had intracranial aneurysms demonstrated arteriographically and who subsequently, without any surgical therapy, had a second arteriogram. The time between the first and the second arteriogram ranged between 2 weeks and 15 months. The average time was 3 months. In 13, the aneurysm was the same size and in 3, it was larger.

Some of the interesting facts are the following: there were 8 patients who had a tantalum clip used for the ligation. In 6 of these, the clip was open (Fig. 1), in 1 the clip was closed on the common carotid artery, and in the other case, the internal carotid artery was clipped both in the neck and intra-

Fig. 2. Pre-operative arteriogram showing aneurysm of internal carotid artery in a patient who later had the internal carotid artery ligated. Hemiplegia developed, from which the patient did not recover completely when the clamp was opened.
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FIG. 3. Progress arteriogram (same case as in Fig. 2) shows incomplete thrombosis of middle cerebral artery; only two small thread-like arteries remain. There is a small defect in the internal carotid artery which represents the residual neck of the aneurysm.

cranially. In 1 case the artery had recanalized around one side of the clip. In using the Selverstone clamp it is necessary to do a final firm tightening of the clamp before removal of the tools, otherwise the artery will not be occluded. This was found to be true in 5 of our cases. In 1 such patient the progress arteriogram showed the clamp on the internal carotid artery to be open and the aneurysm was smaller. This patient had no complications when the clamp was thought to be closed, but the second time the clamp was closed evidence of insufficient collateral circulation developed 8 hours later. This suggests that the clamp was not closed completely on the first attempt. There were 2 patients who had a hemiplegia after arteriography, from which they did not completely recover upon prompt opening of the clamp. In both of these patients, thrombosis of the middle cerebral artery was found when the progress arteriograms were done (Figs. 2 and 3). In 1 patient who had an aneurysm of the middle cerebral artery and was treated by ligation of the internal carotid artery, the progress arteriogram showed
that the Selverstone clamp was not completely occluding the artery and the aneurysm was the same size. The clamp was closed completely and another arteriogram 2 months later showed the internal carotid artery to be occluded; the aneurysm was smaller. Another patient with an aneurysm of the middle cerebral artery, who had had ligation of the internal carotid artery, had a second hemorrhage and the arteriogram showed the clamp to be incompletely closed. These cases emphasize the importance of complete ligation.

The arteriogram does not tell the whole story, especially in patients with large aneurysms, and the clinical signs and symptoms must be considered. In 1 patient having a large aneurysm of the internal carotid artery, the progress arteriogram showed no aneurysmal lumen. Shortly before the progress arteriogram, the patient had a recurrence of frontoparietal headaches which continued intermittently over a period of 5 months, when they became more severe and more frequent. One month later, the patient had a massive subarachnoid hemorrhage and died within an hour. The rupture was found at the neck of the aneurysm, where a small lumen was also found. Over nine-tenths of the aneurysm was filled by organized thrombus and old clot.

Fig. 4. Arteriogram showing a large aneurysm of internal carotid artery with upward displacement of middle cerebral artery.
Another patient, who had a large aneurysm of the internal carotid artery (Fig. 4), was treated by ligation of the internal carotid artery with a tantalum clip. Seven years later he began to have a recurrence of headaches. A progress arteriogram was done which revealed that the clip was partly open, but the aneurysm did not fill (Fig. 5). In spite of this, it was believed that there was some activity in the aneurysm, and the common and external carotid arteries were ligated with immediate relief of the headaches.

**DISCUSSION**

It is important to state that there were no complications as a result of the progress arteriogram, except in 1 patient who had a temporary paresis of one upper extremity; and further, that the arteriogram shows the status at the time it is done, and shows what has been accomplished. A negative arteriogram does not mean that the patient will have no trouble from the aneurysm in the future. The number of cases reported is not sufficient to draw any statistical conclusions. However, certain inferences are suggested and many interesting facts were found. The results of direct intracranial attack on the aneurysm, as demonstrated arteriographically, were found to be better than any form of ligation of the carotid arteries in the neck, in this small series. However, in 1 case the clips had loosened from the anterior cerebral artery and the aneurysm was the same size. In four-fifths of the patients with aneurysm of the internal carotid artery who were shown to
have complete ligation of the internal carotid artery, the aneurysm no longer filled on arteriography, and in the other one-fifth, the aneurysms were unchanged. The results were less good, as far as non-visualization of the aneurysm is concerned, when the aneurysm was on the middle cerebral artery, but in all the cases of complete ligation of the internal carotid artery the aneurysm was not seen or was smaller. The results were also less good when the clamp on the internal carotid artery was found to be open or when it had to be released. There were 2 patients in the entire group of surgically treated cases in whom the aneurysm was larger, and in both of these the clamp or clips were found to be open. These facts emphasize the importance of complete ligation but it would be valuable to know why the aneurysm did not fill in some cases of temporary or incomplete ligation. One obvious explanation is that it required only a few hours in these patients for the aneurysmal sac to fill with clot. In 1 patient who was operated on intracranially, 5 days after carotid ligation in the neck, the sac was found to be four-fifths filled with clot. It is significant that in the 16 patients who had no surgical therapy, the progress arteriogram showed the aneurysm to be the same size or larger. In not one of these cases did the aneurysm fail to show.

SUMMARY

1. The text describes the results of surgical therapy in 51 patients having intracranial aneurysms as shown by 54 progress arteriograms.

2. Progress arteriography is not a completely definitive method of evaluation of results; the clinical symptoms and signs are important.

3. The series is too small to draw conclusions on a statistical basis; but certain inferences can be made.
   (a) Arteriographically the results of direct surgical attack on the aneurysm are better than those of any form of carotid ligation.
   (b) Arteriographically the results of complete and permanent ligation of internal or common carotid are better than partial or temporary ligation and, of the two, ligation of internal carotid is superior.
   (c) Ligation of the carotid arteries in the neck, using a tantalum clip, is likely not to be a complete and permanent ligation.
   (d) In 16 patients who had demonstrated aneurysms and had no surgical therapy, the progress arteriograms showed the aneurysm in all cases; in 13 it was the same size, in 3 it was larger.

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