Clip-Grafts for Aneurysm and Small Vessel Surgery*

Part 3: Clinical Experience in Intracranial Internal Carotid Artery Aneurysms

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A progress report on the use of the clip-graft for intracranial internal carotid artery aneurysms is now indicated. Experience with the clip-graft for anterior communicating aneurysms will be considered separately in a future communication.

This report considers technical and anatomical details important to the selection and use of the various sizes of clip-grafts for carotid artery aneurysms. Errors and complications are discussed in some detail so that hopefully they may be avoided in the future. Since this has not been designed as a treatise on aneurysms in general, the problems of “spasm,” selection of cases, and timing of surgery are not dealt with separately but only as they apply to the subject matter presented.

General Technical Considerations

Position of the Patient. The patient is placed in a supine position with one shoulder elevated on a roll. The neck is slightly extended and turned 45° away from the side of the aneurysm. When spinal fluid drainage is instituted, in this position the brain naturally falls away from the optic nerve and carotid artery on the side of the surgery. This facilitates the operative exposure to be described below, and holds brain retraction to a minimum. This position also allows free venous drainage from the head if the shoulder has been properly elevated. Furthermore, slight extension of the patient’s head allows exposure of the ipsilateral common carotid artery in the neck if this be part of the planned procedure.

Operative Exposure of Sphenoid Wing

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and Dura. The procedure is essentially as described previously, but for completeness will be summarized here.12 The internal carotid artery is approached through a small frontotemporal bone flap hinged on the temporalis muscle and down the sphenoid wing, a portion of which is resected. The dura is opened in a semi-lunar fashion, allowing equal exposure of frontal and temporal lobes for their symmetrical retraction.

Spinal Fluid Drainage. We usually place an ordinary lumbar puncture needle in the patient’s lumbar region for spinal fluid drainage. After removal of the stylet, with the aid of a hemostat the needle is bent at right angles a short distance from the skin and then connected to a sterile IV administration unit which in turn is connected to an empty IV bottle. A standard lumbar puncture needle has functioned better than a malleable needle. The flow is checked after the patient has been repositioned for surgery following lumbar puncture. However, no more fluid is drained at this point than will fill the tube of the intravenous administration set.

It is strongly recommended that spinal fluid drainage not be instituted until the dura has been opened because of the increase in epidural bleeding and the possibility of premature rupture of the aneurysm. The latter occurred in one patient when the dura was being tacked to the galea along the edges of the craniotomy. Spinal fluid drainage had changed the size and shape of brain structures adjacent to the aneurysm, thus causing premature rupture.

Visualization of Internal Carotid Artery and Application of Clip Graft. The operating microscope is utilized after spinal fluid drainage has been instituted and the bridging veins severed. Initially the optic nerve is identified and then the arachnoid incised with the tip of a No. 11 blade. The dissec-
tion of the arachnoid is always on the surface of the artery away from the projection of the aneurysm. The initial area of dissection is therefore dictated by the arteriographic picture.

We recommend that the internal carotid artery be visualized to its bifurcation before application of the clip-graft. In cases where the aneurysm ruptures prematurely this has not always been possible. The clip-graft can be correctly applied in spite of bleeding if one is able to visualize the carotid artery. It is important to see that the clip completely surrounds the vessel by noting that a full vessel enters one end of the clip and leaves the other. One must be sure that the clip has not been applied obliquely thus occluding the lumen of the vessel or impairing blood flow. One must also be careful not to apply the clip-graft too far distally lest the origin of the A-1 segment of the anterior cerebral artery from the internal carotid artery be compromised, or the middle cerebral and anterior cerebral arteries be compressed together in the distal end of the clip, thus causing embarrassment to the circulation through both vessels.

_Hypotension._ Following the method of Drake, surgery of these aneurysms has been performed under moderate and at times rather marked hypotension.\(^4\) It has been our practice to lower the blood pressure as the major structures at the base of the brain are approached. Blood pressure has been controlled by the depth of anesthesia rather than by blocking agents. As the optic nerve and carotid artery are approached and the arachnoid surrounding these structures dissected free, we usually maintain the blood pressure in the neighborhood of 60 to 80 systolic and on special occasions lower it to 50.

After clipping of the aneurysm, blood pressure is restored to normotensive levels. Closure of the dura should not be started until the blood pressure is normal. In one case a postoperative subdural hematoma was felt to be directly related to failure to note this precaution; a small arterial bleeder developed on the tip of the retracted temporal lobe when the blood pressure returned to hypertensive levels.

_Hyperoncotic Agents._ If spinal fluid drainage does not provide adequate room, urea has been used; however this or any other hyperoncotic agent transiently increases the blood volume making it much more difficult to control the patient's blood pressure. An additional consideration is the marked diuresis following surgery and the possibility of the so-called "rebound phenomenon." The immediate postoperative electrolyte and fluid balance as well as accurate determination of the patient's true blood volume are complicated by the use of this agent.

_Exposure of Common Carotid Artery in the Neck._ Exposure of the common carotid artery in the neck prior to the intracranial approach has not been a uniform practice but has been used in selected cases. This surgical exposure has been timed in a number of cases, and it has been found to take only 10 minutes. The additional dissection necessary to expose the internal carotid artery has added too much time to the surgical procedure to justify its routine use. Also, significant atherosclerosis is not common below the bifurcation, and the chance of damage to the vessel wall from temporary occlusion is not as great. The precautionary placement of umbilical tape around the common carotid artery has proved to be of immense help in controlling bleeding from the ipsilateral carotid artery in three cases of operative rupture.

_External Hypothermia._ Early in the series moderate external hypothermia was used routinely. Although it was never proven, an impression developed that hypothermia might add to the development of "vasospasm." We have now abandoned its routine use for carotid artery aneurysms because it creates unjustified delay in the procedure as well as complications of its own. An additional consideration has been that aneurysms in this location have been repaired with the clip-graft without the use of temporary clips on the internal carotid artery or its major branches.

_Circulatory Considerations._ The anatomical configuration of the circle of Willis is of utmost importance in planning the surgery.\(^7\) Particular attention should be directed to the origin of the posterior cerebral artery. It is necessary to know if this artery fills only from the posterior communicating artery, as is the case in a fetal circula-
Clip-Grafts for Carotid Aneurysms

The 4 mm Diameter Series. The 4 mm diameter clip-graft was developed for especially large aneurysms or aneurysms arising from large carotid arteries as in older patients with atherosclerotic vessels and fusiform dilatations of the artery. These vessels not infrequently also have atherosclerotic plaques projecting into the lumen and it becomes desirable to compromise the vessel lumen as little as possible.

This clip is supplied with two types of handles, one fitting a normal Mayfield clip holder, the other a miniaturized Mayfield clip holder. The one with the large handle is designed to have as much spring tension as possible to close on the base of those very large aneurysms with thick walls that are sometimes difficult to occlude. The smaller handled clip is applicable, however, in most instances. The clips are provided in lengths of 5 and 7 mm.

The 3 mm Diameter Series. The 3 mm diameter clip-graft is recommended for those vessels which appear especially small in the arteriogram. This is sometimes the case in small patients but more often in vessels which appear to be in "spasm." However, it should be noted that in cases of "spasm," the size of the vessel as seen in the arteriogram is not necessarily the true size of the external caliber of the vessel when viewed through the operating microscope. Therefore, preoperatively it has not always been possible to know for certain the true size of the vessel. The discrepancy between the intraluminal size and the exterior diameter has at times appeared to be due to relative swelling of the vessel wall. In these cases the vessel wall appears to be white and thickened. It may be that in some cases "cerebral vasospasm" is actually edema of the vessel wall.

Another use of this size clip-graft is for the aneurysm which ruptures prematurely. On such occasions it is difficult to locate the site of bleeding, and since it may be from the vessel wall itself rather than from the tip of the aneurysmal sac, it is necessary to have the graft fit the vessel wall rather snugly. This allows the vectors of intraluminal pressure to seal the parent arterial wall against the clip-graft as it surrounds the vessel.

Selection of Clip Size

The 3.5 mm Diameter Series. For most aneurysms arising from the internal carotid artery a clip-graft 3.5 mm in internal diameter and 5 mm in length will be appropriate.

In a number of cases, by using the clip-graft 5 mm long, it has been possible to avoid unnecessary occlusion of both the anterior choroidal and posterior communicating arteries. In particularly large aneurysms or in those with long bases, the 7 mm clip may be necessary.

tion, if it fills from both the posterior communicating artery and basilar artery, or if it fills from the basilar artery alone. In instances where the posterior cerebral artery fills from the basilar artery either alone or in part, occlusion of the posterior communicating artery can be accomplished with minimal risk. In those cases in which the posterior cerebral artery fills only from the involved posterior communicating artery, occlusion of the latter artery is hazardous. Each case, however, must be evaluated on its own merits, and if the aneurysm is far enough removed from the origin of the posterior communicating artery, it is possible to place a clip-graft properly around the involved carotid artery without encroachment on the origin of the posterior communicating artery. In one patient with a persistent "fetal" circulation, the resident staff chose an intracranial approach because the opposite common carotid artery had been ligated for an aneurysm on that artery some years previously. It was hoped preoperatively to spare the posterior communicating artery. At surgery it was found that the aneurysm was quite large and involved both the posterior communicating and to a lesser extent the anterior choroidal artery. Surgery was completed without difficulty, and the aneurysm was occluded at its origin from the carotid artery with a 3.5 × 5 mm clip-graft. The patient awoke with a hemiparesis which progressed to a hemiplegia and then regressed to a severe hemiparesis. The postoperative angiograms demonstrated patency of the clip-graft without "spasm." However, the anterior choroidal and the posterior cerebral arteries no longer filled. We concluded that this neurological deficit was secondary to a capsular infarct resulting from simultaneous occlusion of these vessels in this particular configuration of the circle of Willis.
Also, in this situation one has a better chance of sealing the vessel if the longest available clip is used, namely, one 7 mm in length.

The 2.5 mm Diameter Series. This size of clip-graft was designed for middle cerebral artery surgery, but could be used for the occasional carotid artery in severe "spasm" and in which the aneurysm ruptured prematurely. We used it in only one case of carotid artery surgery in which a 3 mm diameter clip fitted too loosely to seal the vessel; the postoperative arteriogram demonstrated patency of the vessel, and the patient had no complication from use of this clip-graft.

Construction and Care of Clips

The clip-grafts are prepared so that they can be autoclaved repeatedly. They are constructed of a single unit to avoid the inclusion of a spring or other parts which might be subject to corrosion.9

It is of some importance to consider that the clip is constructed of 301 stainless steel which, in order to more closely satisfy the requirements of an implant, has sacrificed some of the elements of spring. It can be opened and closed as is necessary at surgery, but needless and repeated maneuvers of this nature can result in deformation of the handle of the clip and loss of spring tension. Also, if one opens and closes these with the fingers, there will be deformation of the clip handle and as a result the clip will not close as tightly as it should.

These same hazards apply to the standard Mayfield clip and are not unique to the clip-graft.

Special Surgical Considerations

Aneurysm Projecting Laterally Under the Edge of the Tentorium. In our series this has been the most common type of aneurysm arising from the carotid artery. An operative sketch of such an aneurysm and its repair is shown in Fig. 1 and the pre- and the postoperative arteriograms of such a lesion in Fig. 2.

The clip is applied at an angle to the aneurysm of approximately 120°. With the angled clip holder the angle of application of the clip-graft to the aneurysm can be 180° away from the primary direction of projection of the aneurysm. It is, of course, preferable to place the clip-graft on the vessel from the normal side and away from the projection of the

![Fig. 1](image-url)

A. ANTERIOR CEREBRAL ARTERY
B. OPTIC NERVE
C. CAROTID ARTERY
D. ANTERIOR CHOROIDAL ARTERY
E. POSTERIOR COMMUNICATING ARTERY
F. EDGE OF TENTORIUM
G. MIDDLE CEREBRAL ARTERY

Fig. 1. Application of a 3.5 × 5 mm clip-graft to an aneurysm projecting laterally under the edge of the tentorium. The clip-graft is demonstrated being applied at an angle to the aneurysm of approximately 120°, with the miniaturized clip holder. Carotid aneurysms in this location with this projection have been the most common in this series.
Fig. 2. Typical pre- and postoperative arteriograms of a carotid artery aneurysm projecting laterally under the edge of the tentorium. Note the contrast medium can be visualized through the lumen of the clip-graft in the postoperative film.

aneurysm. This avoids dislodging a clot from the aneurysm itself into the lumen of the vessel.

Aneurysms Projecting Laterally Above the Tentorium. An operative sketch of this type of aneurysm is shown in Fig. 3, with pre- and postoperative arteriograms shown in Fig. 4. The angle of application in these cases should be from the superior and medial aspects of the carotid artery. These aneurysms are more difficult to approach than those projecting more inferiorly. The approach is such that the surgeon may be confronted by the aneurysm prior to identifi-

Fig. 3. Application of a 3.5 × 5 mm clip-graft to an aneurysm projecting laterally above the edge of the tentorium. The clip-graft is illustrated being applied with an angled clip holder to allow the angle of application to the aneurysm to be as great as possible.
cation of the artery and normal adjacent structures. In such instances retraction of the temporal lobe is particularly hazardous and is likely to initiate severe bleeding from the aneurysm.

We have seen four aneurysms in this location, and of these, three have ruptured prematurely. One patient made an uneventful postoperative recovery, but only after severe bleeding at surgery necessitated rapid application of a clip-graft to the artery prior to identification of adjacent structures and small branches of that vessel.

In another patient the aneurysm burst as the surgeon came near the vessel. The common carotid artery in the neck had not been isolated, identification of the internal carotid artery intracranially had not been obtained prior to the uncontrolled bleeding, blood pressure control was difficult because of premature administration of urea, and a catastrophic series of events resulted in death of this good (grade II) candidate for surgery 2 days postoperatively. The clip-graft was never placed because by the time the vessel could be identified it had been torn in two, and it was necessary to sacrifice the parent vessel.

The third patient was a grade IV candidate with an intracranial clot. There was a very large aneurysm on an internal carotid artery which served as the sole source of blood to both anterior cerebral arteries. In this instance, there was immediate furious bleeding as the temporal lobe was gently retracted for division of bridging veins. It was, however, possible to place two clip-grafts on the lengthy and tortuous carotid artery. These clips were proven patent postoperatively, but the patient continued a gradual course of deterioration and died approximately 2 weeks following surgery.

In the fourth patient (grade IV), the surgery went without complication (Fig. 4). After placement of a clip-graft on the internal carotid artery a moderate amount of bleeding developed. This proved to be back-bleeding from the posterior communicating artery, promptly controlled by application of a straight Mayfield clip to the distal portion of this artery. The patient died several weeks postoperatively from asthmatic and cardiac complications. She had also experienced an anaphylactic reaction to a postoperative arteriogram. At the time of death she appeared on the way to recovery neurologically, having passed through a period of "spasm."

Aneurysms Projecting Medially from the Carotid Artery. The operative sketch of such an aneurysm is illustrated in Fig. 5, and the pre- and postoperative arteriograms in Fig.

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**Fig. 4.** Typical pre- and postoperative arteriograms of aneurysm projecting laterally above the tentorium. The Mayfield clip was applied in this case to the posterior communicating artery to control a minimal amount of back-bleeding from this vessel. This is seldom necessary.
6. These aneurysms are perhaps ideal for the clip-graft in that the normal side of the vessel presents itself to the surgeon, with the major portion of the aneurysm under the optic nerve. There are three such patients in the series; all have done well and are working full time.

Aneurysms Projecting Superiorly from the Carotid Artery. Aneurysms in this location are illustrated in the operative sketch in Fig. 7 and in the pre- and postoperative arteriograms in Fig. 8. The clip-graft is not very useful for those aneurysms located on the most proximal portion of the carotid artery, as is quite common. Since development of the clip-graft we have encountered nine aneurysms in this location, an unusually high incidence. Four of these cases were treated

Fig. 5. Application of a 3.5 × 5 mm clip-graft to an aneurysm projecting medially from the carotid artery under the optic nerve. These aneurysms are easily treated with the clip-graft.

Fig. 6. Typical pre- and postoperative arteriograms of an aneurysm projecting medially from the carotid artery under the optic nerve. Note the contrast medium is visualized through the clip on the postoperative study.
FIG. 7. Application of a 4.0 × 5 mm clip-graft to an aneurysm projecting superiorly from the carotid artery. This aneurysm was far enough distal on the carotid artery so that it could be treated with the clip-graft, but many aneurysms in this location are too far proximal on the carotid artery to be successfully treated with this type of clip.

by techniques other than the clip-graft and are not included in this series.

In the remaining five patients the aneurysm was located more distally on the internal carotid artery and therefore could be treated alone or in part with a clip-graft. On

FIG. 8. Typical pre- and postoperative arteriograms of an aneurysm projecting superiorly from the carotid artery. This is an arteriogram of a so-called "blister" which arose from the dorsal aspect of a fusiform dilatation of the carotid artery. At surgery there was fresh clot around the vessel and fibrinous material over the dome of the blister so that there was no question that this was the aneurysm which had bled. The patient made an excellent recovery. The clip-graft is somewhat hidden from view behind the sphenoid wing on the postoperative study.
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The beveled clip-graft is used to avoid encroachment on the carotid artery as the clip-graft is placed to reinforce the bifurcation site.

one occasion it was used after the aneurysm tore at its base following application of a Mayfield clip. In another case, operated on by Dr. James Robertson, the true site of bleeding proved to be from a small sessile aneurysm (blister) on the dorsal aspect of a carotid artery which also had an aneurysm at its bifurcation and one projecting laterally under the tentorium. In this case the blister and aneurysm projecting laterally under the tentorium were incorporated in one clip-graft; the aneurysm at the bifurcation was treated with a Scoville clip. This was of particular interest under the operating microscope as one could visualize the point area of weakness in the blister as well as the definite defect in the vessel wall which gave rise to this aneurysm. A third patient, illustrated in Fig. 8, represented a similar lesion but here it was located on an atherosclerotic fusiform dilatation of the carotid artery proximal to the origin of the posterior communicating artery. The fourth and fifth cases were treated with a combination of the clip-graft and a spring clip, since the aneurysms were too far proximal on the vessel to accept a clip-graft alone.

Aneurysms Arising at or near the Bifurcation of the Carotid Artery. In aneurysms at or near the bifurcation, or arising from the middle cerebral artery just distal to the bifurcation of the carotid artery, it is sometimes difficult to determine by arteriography whether they arise from the carotid artery or from the middle cerebral artery. An operative sketch of an aneurysm in this location is shown in Fig. 9 and the pre- and postoperative arteriograms in Fig. 10.

In this group of four cases most aneurysms have projected inferiorly or posteriorly from their origin and have actually arisen from the proximal portion of the middle cerebral artery rather than from the carotid artery itself. The clip-graft has been applied around the middle cerebral artery in each case, care being taken to avoid encroachment on the parent carotid artery. By using the beveled clip illustrated in Fig. 9, it has been possible to reinforce this bifurcation site without deformation of its normal configuration or impairment of the blood flow.

Aneurysms that Rupture Prior to Operative Identification. In cases of premature rupture it is often possible to tease the end of the aneurysm sac into the suction tip.
This, of course, facilitates application of the clip-graft. If this is not possible, one must visualize the parent artery and place the clip-graft around it circumferentially. As stated previously, we have preferred to use a 3-mm-diameter × 7-mm-long clip-graft in such instances. If there is complete cessation of bleeding when the clip is placed around the artery, one needs only to inspect the clip to be sure it is completely around the vessel and not obliquely placed. If there is only moderate bleeding from the ends of the graft, this can readily be arrested by the temporary applications of small pieces of gel-foam as indicated above. It should be re-emphasized that continuous or furious bleeding implies that either the clip-graft has not been placed over the vessel wall defect, that the graft is too large for the vessel, or that there is back-bleeding from the posterior communicating artery. The pre- and postoperative arteriograms of an aneurysm that ruptured prior to its identification and in which a defect in the vessel was repaired are shown in Fig. 11.

In two patients, hemorrhage from premature rupture was so severe that the carotid artery could not be visualized until damage to the brain and artery was irreparable.

**Results**

In the last 27 months we have used the clip-graft on 45 cases of aneurysms arising from the internal carotid artery. Of the 45 cases, 26 were operated by one of us (T.M.S.), 9 by other members of the staff, and 10 by the resident staff. Results in these cases have varied with the class of the patient and experience of the surgeon. They are presented by dividing them according to projection (Table 1) and the classification of Botterell, et al. (Table 2).²,³

**Grade I Candidates.** There were 18 grade I candidates operated on, 15 of whom had an excellent result and have returned to full employment with no neurological deficit. One patient had a good result but did not return to full employment, and another developed a hemiplegia from thrombosis of the artery. One patient died from a recurrent subarachnoid hemorrhage 4 months postoperatively. The site of recurrent bleeding in this case was never identified, but lateralizing symptomatology suggested it was from the opposite side of the brain from that of the aneurysm repaired. Interestingly enough, at the time the aneurysm was repaired, the surgeon had noted that he doubted that the aneurysm he had visualized and repaired was the one which had bled. However, complete four-vessel arteriography pre- and postoperatively failed to demonstrate another site of bleeding.

In this group both the over-all mortality and morbidity were approximately 6%.

**Grade II Candidates.** There were 14
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FIG. 11. Typical pre- and postoperative arteriograms of an aneurysm which ruptured prior to its identification. A. 3.0 × 7 mm clip-graft was placed circumferentially around the carotid artery sealing the defect in the vessel wall which gave rise to the aneurysm. This patient, a grade I candidate, made an excellent recovery. Note the contrast medium through the clip on the postoperative film.

grade II candidates operated on. Seven had excellent results, with full employment and no neurological deficit; two had a good result but did not return to full employment; and one had a poor result with a severe right hemiparesis and aphasia. There were four deaths in this group; three of these were considered preventable technical errors and the fourth was the result of severe "vasospasm" in a patient with marked hypertension.

In this group the over-all mortality was 28%, and the morbidity was 7%.

Grade III Candidates. Eight grade III candidates were operated on. In four there was an excellent result with no neurological deficit and full employment. There were three deaths in this group, one from a pulmonary embolism, one from a complication after discharge from the hospital most likely related to hemiplegia, and one from severe and progressive "vasospasm."

The mortality in this group was approximately 38%.

Grade IV Candidates. There were five grade IV cases operated on, with one excellent result, one good result, and three deaths. The cause of death in two patients

<p>| TABLE 1 |
| Results in carotid artery aneurysms related to projection of aneurysm |</p>
<table>
<thead>
<tr>
<th>Projection</th>
<th>No. of Cases</th>
<th>Excellent</th>
<th>Good</th>
<th>Poor</th>
<th>Death</th>
<th>Morbidity (%)</th>
<th>Mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laterally, under tentorium</td>
<td>29</td>
<td>17</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>Laterally, above tentorium</td>
<td>4</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>3</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>Medially, under optic nerve</td>
<td>3</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Superiorly</td>
<td>5*</td>
<td>4</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>At bifurcation, posteriorly</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>—</td>
<td>1</td>
<td>0</td>
<td>25</td>
</tr>
</tbody>
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* In an additional 4 cases no attempt was made to use a clip-graft.
was a myocardial infarction, and in the third, progressive and severe "vasospasm." In the two patients who suffered myocardial infarction, it was felt the underlying cause for their lingering illness and ultimate death was related to "vasospasm."

The mortality in this group was therefore 60%.

**Grade V Candidates.** No grade V candidates were operated on.

**Graft Patency.** The radiopaque column of Hypaque can be visualized on postoperative arteriograms through the clip-graft's stainless steel cylinder (Figs. 2, 4, 6, 8, 10, and 11). Graft patency as determined by postoperative arteriograms or unquestioned clinical status has been 97%. All but two patients actually had postoperative arteriograms.

The case in which the artery thrombosed deserves further consideration. In this case, a grade I candidate, the surgery went without complication, and the patient made an uneventful postoperative recovery for 5 days. At the time of surgery it was felt that the clip-graft had been applied slightly obliquely on the vessel, but both ends of the vessel appeared patent and the aneurysm was definitely occluded. There was, nevertheless, the suggestion that the course of the vessel had been altered by the application of the clip-graft. An immediate postoperative arteriogram demonstrated good patency of the vessel, but there was some deformation of the vessel as it curved through the clip-graft. A small portion of the base of the aneurysm was still visible as it arose from the parent artery, so that it appeared the clip-graft had occluded the aneurysm approximately 1 or 2 cm from its origin rather than at its proximal base. This was the only case in which any portion of the aneurysm was visualized postoperatively. Seven days following surgery this patient developed a hemiparesis on the left side; arteriography demonstrated stenosis at the site of the graft. The patient improved on hemodilution and hypertensive therapy, and we felt that she was over this critical stage.

In retrospect, she probably should have received anticoagulation therapy. Five days following the development of the hemiparesis, or 12 days after surgery, she developed a complete hemiplegia, and repeat arteriography at this time demonstrated arterial occlusion. Obviously, one cannot be certain of the cause of thrombosis in this case, but it was our impression that it was either related to the slightly oblique placement of the clip or to the developing thrombus in the outpocketing of the base of the aneurysm.

**Discussion**

The clip-graft does more than merely occlude an aneurysmal sac; it patches and reinforces the basic etiological defect in the media of the vessel wall. This reinforcement is not provided by a conventional spring clip, which also at times fails to occlude the entire aneurysm. The formation of a new aneurysm at the site of occlusion by a spring clip has been reported; this would be unlikely with the clip-graft. It is not possible for a clip-graft to "milk-off an aneurysm," a complication which is not rare with conventional spring clips.

As has been suggested by Hunt, we have operated on grade I candidates as soon as it was feasible. Grade II and grade III candidates have also been operated on rather early, our reason being that early rebleeding
has been more frequent than is generally accepted, particularly if the patient has had more than one previous subarachnoid hemorrhage.

There is no evidence that the use of the clip-graft has any beneficial or detrimental effect on the progress and course of “vasospasm.” It might be noted that the chief cause of death or morbidity in this group of cases was “vasospasm” or complications arising from prolonged “vasospasm.”

This series of 45 patients with carotid artery aneurysms is not large enough to represent a highly significant group statistically, but some comparisons can be made with other series. Morbidity is certainly as great a consideration as mortality, and accordingly functional survival is perhaps the most significant figure. The over-all functional survival for single aneurysms arising from the internal carotid artery was 49% in the Cooperative Study. In our group of cases this functional survival figure is 66%. In both series, these figures consider all grades of patients as a unit; it appears that our cases had a slightly higher proportion of good candidates for surgery. As has been the experience of others, the lowest mortality (6%) has been in the grade I candidates.

The above mortality and morbidity figures are not acceptable. With further refinements in technique and greater individual surgical experience the mortality and morbidity should be reduced significantly. However, the greatest reduction in these figures will await the solution to the problem of “vasospasm.”

Summary

The selection and appropriate application of clip-grafts to carotid artery aneurysms have been discussed. The 4.0 × 5 mm, or 3.5 × 5 mm, clip-graft is applicable to most aneurysms arising from the internal carotid artery; its use commonly spares the origin of the anterior choroidal artery and, depending on the location of the aneurysm and length of the internal carotid, not uncommonly also spares the origin of the posterior communicating artery. Other clip-graft sizes are available for selected cases.

The postoperative patency of clip-grafts applied to carotid arteries for the repair of these aneurysms has been 97%.

The surgical approach in this series has been frontotemporal, down the superior margin of the sphenoid wing; this provides a better angle for application of the clip-graft than the subtemporal approach, and permits the majority of the dissection to be completed on the normal side of the vessel, away from the common projection of these aneurysms. Surgery has been performed under the operating microscope.

We believe the clip-graft has made aneurysm surgery easier for the surgeon and safer for the patient.

References


9. McFadden, J. T. Metallurgical principles in neurosurgery. (Submitted for publication.)

10. Murphy, F., Garcia, J., Hudgins, R., and Sundt, T. "Spasm" of vessel wall edema. (Submitted for publication.)
