Acrylic Investment of Intracranial Aneurysms
A Report of 12 Years’ Experience

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Twelve years have now passed since the first cases of intracranial aneurysms treated by acrylic investment were reported, and it would seem timely to report the results and follow-up on a series of 106 cases. As first suggested, this method is only practiced in those cases where the more usual method of clipping is not possible. The original aim was to secure a simple but effective method of permanent non-disruptable investment of the aneurysmal sac and its parent vessels with a substance both acceptable to the tissues and easily handled intracranially in the presence of cerebrospinal fluid and saline. Self-curing methyl-methacrylate appeared to fulfill these prerequisites, and further investigations of alternative preparations have failed to disclose any better substance.

Method

The method has been outlined in the original papers. Little needs to be added, but it must be stressed that it is important that total investment be achieved (Figs. 1 and 2). Incomplete investment means no investment and the aneurysm is then more liable to rupture than if it had not been dissected. Even minimal “surgical trauma” provokes a cellular reaction in all layers, resulting in further weakening of the aneurysm and increased liability to rupture within a few days.

Basically the powder is the polymeric, and the liquid, the monomeric methyl ester of methacrylic acid. The powder, as well as the hardened material, is chemically akin to perspex and is fully compatible with living tissue.* The liquid, however, prior to hardening by polymerization is a powerful lipoid solvent and should therefore not be allowed to be absorbed by the body or to come into contact with the tissues until polymerization is about to commence. The powder is provided in gamma-irradiated bags, a method of sterilization that does not interfere with a peroxide present in the powder as a catalyst for the polymerizing process. The fluid is easily sterilized by pressure bacterial filtration.

Results

This report concerns 106 cases of proven subarachnoid hemorrhage due to ruptured intracranial aneurysms subsequently treated by acrylic investment. The series includes 37 personal cases and 69 cases treated by neurosurgical colleagues at the Department of Neurological Surgery, Frenchay Hospital, Bristol, who kindly made their results available for inclusion in this survey. The 106 cases comprise 41 aneurysms of the right middle cerebral, 38 aneurysms of the left middle cerebral, 26 aneurysms of the anterior communicating artery complex, and one of the left posterior inferior cerebellar artery. There were nine deaths, three in the personal series and six among those treated in Bristol.

The age distribution is shown in Table 1. The intervals between last-hemorrhage and surgery are shown in Table 2. Multiple hemorrhages prior to surgery occurred in eight cases of the anterior communicating artery series, and 18 cases of the middle cerebral artery series.

The nine postoperative deaths included three anterior communicating and six middle cerebral aneurysms. One patient died 3 years later from another aneurysm; the other eight patients died within 14 days of the operation, at ages varying from the third to the sixth decade. Three cases showed widespread cerebral edema at autopsy; one had signs of basilar artery thrombosis unasso-
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No case of postoperative death was due to rebleeding. Two thirds of the anterior communicating and five out of six of the middle cerebral fatalities were in cases with multiple hemorrhages and operated on within 7 days of the last hemorrhage.

Follow-up of the cases, varying from 1 to 10 years, has revealed no evidence to suggest recurrent hemorrhage after investment.

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TABLE 1

<table>
<thead>
<tr>
<th>Decade</th>
<th>Middle Cerebral Arteries</th>
<th>Anterior Communicating Arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>4th</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>5th</td>
<td>26</td>
<td>9</td>
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<tr>
<td>6th</td>
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<td>3</td>
</tr>
<tr>
<td>7th</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8th</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td>26</td>
</tr>
</tbody>
</table>

TABLE 2

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Anterior Communicating Aneurysms</th>
<th>Middle Cerebral Aneurysms</th>
<th>Posterior Inferior Cerebellar Artery Aneurysm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 or less</td>
<td>7 (2 deaths)</td>
<td>19 (5 deaths)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>5 (1 death)</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>20 (1 death)</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>7</td>
<td>—</td>
</tr>
<tr>
<td>over 4</td>
<td>4</td>
<td>8</td>
<td>—</td>
</tr>
</tbody>
</table>
We have followed 22 cases for more than 5 years.

A review of the incidence of postoperative epilepsy reveals that two of the 26 patients with anterior communicating artery aneurysms suffered from postoperative epilepsy; in one patient this started 4 years after surgery, while the other had a single attack 5 days after operation. Of the 79 cases of middle cerebral aneurysm, 13 suffered postoperative epilepsy; it is interesting to note that in eight of these there was preoperative evidence of a hemiparesis or hemiplegia. In all cases anticonvulsants were purposely withheld postoperatively in an endeavor to ascertain what the true incidence of postoperative epilepsy would be. Once epilepsy developed, anticonvulsants in appropriate dosage were prescribed.

There is some difficulty in stating the exact percentage of all aneurysm cases treated by investment, but the following facts throw some light upon this. The 37 personal cases included 24 middle cerebral aneurysms out of 100 such cases that came to surgery; there were 10 out of an operative total of 103 aneurysms of the anterior communicating complex. The case of posterior inferior cerebellar artery aneurysm was the only one seen during this 12-year period.

Of the cases dealt with by my colleagues at Bristol up to 1965, 30 middle cerebral investments were performed out of a total of 95 cases, and 13 investments of anterior communicating artery aneurysms out of a total of 105. Thus, acrylic investment was practiced in approximately 30% of middle cerebral aneurysms and 11% of anterior communicating aneurysms. The size of the aneurysmal sac in this series varied from 3 to 15 mm. Figures 3 and 4 show original operative sketches of illustrative cases.

Discussion

Carotid angiography was performed as soon as possible unless there were specific contraindications. All types of subarachnoid hemorrhage have been encountered, some patients admitted directly, some transferred from other hospitals, and the remainder referred from hospital colleagues. Some cases were referred when fully recovered, others because of deterioration or recurrent hemorrhage. There can be no division into "medical" and "surgical" management, for all cases were initially managed "medically," and when the opportunity appeared correct, surgical intervention was undertaken. Postoperatively the conservative line of treatment was continued. Some cases came to surgery early, whereas others waited days or even weeks until the appropriate conditions were obtained. This must be a matter for surgical judgment, obviously improved by experience, although occasionally proving fallacious. Craniotomy may be commenced only to find as the operation proceeds that further surgical intervention should be postponed until conditions are more favorable. Adverse factors may be a full or "tight" brain and observable vessel spasm.

Although no endeavor has been made in this paper to classify the cases preoperatively, nor to describe the postoperative state in detail, it suffices to say that no great difference has been noted in the results of various methods of treatment used and it is not thought that this factor plays any great part in the ultimate history. It can be said, however, that spasm or thrombosis of the vessels related to the aneurysms has not been seen after investment, a factor sometimes noted in aneurysms secured by a clip. For this reason there has been a tendency, if dissection has been long and tedious, to consider investment rather than clipping even where clipping might appear possible.

The operations in this series were conducted under moderate hypothermia, and during much of the final dissection period the systolic blood pressure was reduced to about 50 mm of mercury. This degree of hypotension for periods up to 1 hour was not followed by any obvious detrimental effect, although usually the attempt was made to keep the period of hypotension as short as possible. It cannot be too strongly emphasized, however, that hypotension during the actual period of work on the aneurysmal sac itself greatly reduces the danger of rupture, and has not been associated with any increased spasm or subsequent disability. Hypotension allows one to dissect the structures with much greater equanimity.

There can be no doubt that with increasing experience one finds fewer cases where investment appears necessary, and it is noteworthy that during the past 6 years only six
cases have been invested while the incidence of appropriately applied clips has steadily increased. However, the absence of a definable neck (Figs. 3 and 4) or the loss of compliability due to contained solid or organized blood clot would preclude the application of a clip, for this might cause disruption of the sac. In general, I do not practice proximal temporary clipping because it tends to encourage a more traumatic type of dissection. In the event of rupture, it is a very simple matter to achieve hemostasis by application of a small plaque of muscle followed either by clipping the sac appropriately or investing the aneurysm, parent vessels, and muscle graft in toto. The possibility of bleeding between the investment and the sac or vessels, a form of "tamponade" queried by Selverstone and Ronis in 1958, has not been found either in my own cases or those con-

Fig. 3. Schematic diagrams of middle cerebral artery aneurysms.
ducted at Bristol. It may be mentioned that to achieve maximal flow prior to investment the vessels were treated by local Papaverine.

In an endeavor to surmount the theoretical disadvantage of tamponade, investigation of the properties of methyl 2-cyanoacrylate monomer was undertaken, but it appears that it is more liable to cause harm than good when treating muscular walls already diseased. My opinion is that it should not be
used in the treatment of intracranial aneurysms. To date there has been no evidence of any further hemorrhage after an aneurysm has been invested by methyl methacrylate. It is clear that the dissection required to achieve total investment is locally more traumatic than the simple application of a clip about the neck of a sac. However, in those cases where clipping requires the inclusion of some vessels with the sac, the result is clearly more disastrous although it may not be immediately so apparent. The figures on epilepsy suggest that investment is no more liable to be associated with epilepsy than alternative methods of treatment, and it would appear that many cases that ultimately become epileptic are associated with preoperative neurological deficits.

Summary
I have presented a study of 106 cases of subarachnoid hemorrhage, comprising 79 aneurysms of the middle cerebral artery, 26 of the anterior communicating complex, and one of the left posterior inferior cerebellar artery, all invested with methyl methacrylate. Direct intervention at the appropriate time determined the choice of investment. There were nine postoperative mortalities, six with middle cerebral aneurysms and three with anterior communicating artery aneurysms. No invested aneurysm caused a death within the follow-up period of from 1 to 10 years, nor was there any evidence to suggest recurrent hemorrhage. In many cases the outcome was decided by the severity of the initial hemorrhage, which may have been fatal although this was not immediately apparent. The mortality rate for surgical treatment of aneurysms is known to vary. The mortality of favorable cases is low, from 5% to 1% in selective series, whereas surgery undertaken in the acute phase of subarachnoid hemorrhage has been reported by Pool and Potts as 40% for “all risk” cases. This series had an over-all mortality of just under 9%.

Approximately one in five middle cerebral aneurysms and one in 12 anterior communicating artery aneurysms seemed more suitable for investment than clipping. I have stressed that, with increasing experience, more and more aneurysms appear to allow the application of a clip about the neck, but it may require careful and perhaps “courageous” sharp dissection. There can be no doubt, however, that when this is possible and uncomplicated by long dissection, a suitably placed clip about the neck of the sac is the most appropriate treatment.

Acknowledgment
I am indebted to my neurosurgical colleagues at the Bristol Regional Neurosurgical Centre for permission to study their notes and include their case results in this paper. I also wish to thank the Department of Medical Illustration and the University Department of Medical Art, Manchester Royal Infirmary, for their technical help.

References