Pilojection* for Intracranial Aneurysms

Report of Progress†

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In 1962 the production of thrombosis within an intracranial aneurysm by pilojection was achieved for the first time. Using shafts of hog hair delivered under high velocity into the wall of the sac, a large aneurysm of the anterior cerebral artery was closed by thrombosis. In reporting this case, it was noted that the patient died from carotid thrombosis caused by carotid arteriography. However, the thrombosed aneurysm was recovered at autopsy. In January 1963 the successful treatment of 3 other patients by pilojection was recorded. Up to February 1963, this procedure has been used on 16 patients with aneurysm including 1 patient with an arteriovenous aneurysm of the spinal cord. In 9 patients the aneurysm was treated under personal supervision and in 6 others the technique of pilojection was used by other neurosurgeons with the author as an observer. The purpose of this presentation is to evaluate the successes and failures of this technique up to date and to discuss the theoretical and practical aspects of pilojection in the treatment of intracranial aneurysms.

Technique

Although the technical aspects of pilojection have been described in the earlier papers, a concise review should be useful. After the aneurysm has been partially exposed to direct vision, shafts of stout mammalian hair, either hog hair or horse hair, are propelled into the wall of the sac using a pencil-size pneumatic gun (Fig. 1). This gun was developed in the Naval Research Laboratory by Harrison P. Hagemeyer of Washington, D. C. The internal instrumentation of the pneumatic gun permits it to operate without any dangerous thrust or recoil. It is fired under pressures ranging from 45 to 50 lbs. per sq. in. and the power supply is furnished by a tank of compressed air or any other nonflammable gas such as carbon dioxide or nitrous oxide. The instrument and its connecting plastic hose are sterilized by a standard autoclave. The shafts of hair are one-quarter of an in. long (6 mm.) and are 0.005 in. in diameter (hog hair) or 0.008 in. in diameter (horse hair). The hairs are sterilized by washing them in an ordinary soap or detergent for 30 min. and then soaking them in 70 per cent alcohol for 18 hrs. When more rapid sterilization is needed the hairs can be treated in an ethylene oxide gas chamber which is now available in many clinics. For small berry-like aneurysms, 3 or 4 shafts of hair properly introduced into the sac seem to be sufficient to obliterate the lesion. For giant-sized malformations, 10 to 15 shafts of hair scattered in orderly fashion over the surface will induce thrombosis and closure.

Clinical Material

Up to Feb. 1, 1963, pilojection has been used on 15 patients with intracranial aneurysm and on 1 patient with a giant arteriovenous aneurysm of the spinal cord. There were 10 males and 6 females in the series. The youngest patient was 6 years old and this was the individual with the malformation in the spinal cord. The 15 patients with intracranial aneurysm varied in age from 34 to 71 years. In 2 patients the aneurysm was situated on the left anterior cerebral vessel, in 4 others on the right anterior cerebral, in 1 on the anterior communicating, in 3 on the

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right or left internal carotid arteries and in 5 on the trifurcation complex. The spinal lesion was located at the T5 to T7 level. Estimated measurements from the arteriograms and by direct vision showed that 6 aneurysms were about 1 cm. in size, 4 about 2 cm. in size, 3 more about 3 cm. and 1 about 4 cm. There was 1 other huge aneurysm, measuring approximately 6 cm. in length and 4 cm. in diameter. Although all of these patients were seriously ill, only 2 of them were desperately ill at the time of operation. In 12 cases, leakage from the aneurysm had occurred prior to treatment and in the remaining 4 no preoperative hemorrhage had occurred. In the 9 patients treated by the author, surgical exposure of the lesion was assisted only by continuous spinal-fluid drainage and hyperventilation. In the other 6 patients, treated elsewhere, hypothermia and/or urea and hypotensive drugs were used as surgical adjuncts.

Surgical Results

In most of the cases an arteriogram was performed in the operating room following pilojection and before closing the craniotomy. Complete thrombosis of the aneurysm was known to have occurred in 9 patients. In 4 more patients, the evidence indicates that only incomplete thrombosis occurred. In 2 more patients the procedure did not result in any degree of thrombosis. In the child with the aneurysm of the spinal cord there was no conclusive proof that clotting had occurred.

In 2 patients the lesion had to be re-exposed and re-treated to promote thrombosis. Following the use of this procedure on 16 patients, 6 of them died, a surgical mortality of 38 per cent for the group as a whole. The 10 survivors had no neurologic deficits at the time of discharge from the hospital.

In order to clarify the surgical results the patients were subdivided as follows:

(a) Patients With Evidence of Complete Thrombosis. Among these 9 patients, 2 died after operation. The first patient in the series died 18 hours after operation and at autopsy the aneurysm was found to be diffusely firm and on hemisection the cavity of the aneurysm was found to be filled with clot. Microscopic examination showed that this was an antemortem thrombosis. The autopsy also revealed that there was an antemortem clot plugging the carotid siphon and that this arose from the site of the carotid punctures during arteriography. The second patient, who died even though the aneurysm had been closed by thrombosis, succumbed 8 days after operation. This individual had the largest aneurysm in the series (Fig. 2). He did well for the first 6 days after operation; then signs of increased intracranial pressure developed and the surgeon reopened the bone flap and extirpated the clotted specimen (Figs. 3 and 4). The patient died the next day. No autopsy was performed.

(b) Patients With Evidence of Incomplete Thrombosis. There were 4 patients in whom arteriography immediately after pilojection, or several weeks later, showed evidence of incomplete thrombosis. Three of these died later. One of them died 2 weeks after leaving the hospital apparently from subarachnoid hemorrhage and no autopsy was performed. Another patient had a large aneurysm of the trifurcation. The lesion was treated by pilojection and the arteriogram performed during the operation showed that 50 per cent of the sac was closed off (Figs. 5 and 6). Arteriograms about 2 weeks after operation showed that no progression in the clotting process had occurred (Fig. 7). The patient died 8 weeks after pilojection and, at autopsy, the clotted and unclotted portions
of the aneurysm could be seen (Fig. 8). The third patient who died had an aneurysm of the trifurcation which ruptured during the original surgical exposure and the surgeon closed a large rent in the dome of the lesion with a row of silver clips. The patient re-bleed several weeks later and the lesion was re-exposed and treated by pilojection. The angiogram performed in the operating room showed that all but a minor part of the sac was occluded. The patient seemed well after operation, but had a devastating hemorrhage a week later and died. The specimen recovered at autopsy showed that only a part of the aneurysm had been closed by pilojection.

(c) Patients With No Evidence of Thrombosis. There were 2 patients in whom pilojection resulted in no thrombosis and 1 of these died later from hemorrhage. In the first case, an aneurysm of the middle cerebral artery was exposed and the pilojector gun was used. An arteriogram performed about 7 days later showed no changes in its size or contour. This patient has remained well up to the time of this report. In the second case, an aneurysm about 1 cm. in size and located on the right anterior cerebral artery was exposed. After using the pilojector gun, the surgeon reported that he could see 3 shafts of hair protruding from the aneurysm. The patient died about 10 days after operation from renewed hemorrhage. Autopsy revealed that no shafts of hair had entered the aneurysm and, instead, the wall of the lesion showed the presence of 3 circular score marks. Ap-
parently the tips of the 3 shafts of hair had only partially penetrated the outer layers of the wall and had not entered the interior as the surgeon had thought.

(d) Patients With Presumptive Evidence of Closure. There was only 1 patient in this group, a 6-year-old child with a large spinal arteriovenous aneurysm on the dorsal aspect of the thoracic spinal cord. This lesion was exposed first in 1959 and no definite treatment was rendered except for the limited services of a decompressive laminectomy (Fig. 9). Prior to the operation in 1959 he had only slight weakness in the lower extremities but after that there gradually developed spastic paraplegia. In January 1963, this aneurysm with its dangerously thin wall was re-exposed and about 16 shafts of hair were propelled into its wall. No change in size or color of the lesion was observed after pilojection. However, the child has shown signs of progressive return of function in his legs and his parents seem to be highly gratified with his improvement.

Discussion

When pilojection was first conceived it was anticipated that clotting within an aneurysm would result from a gathering of certain elements of the blood around the shingles on the cortex of the hair. In other words, the shingles would trap fibrin, red blood cells and platelets and would create a mechanical nidus for clotting. Since the shingles on mammalian hair are oriented so that they point toward the tip of the hair, in all these cases the hairs were inserted into the nozzle of the gun tip-end first, so that the shingles would not be stripped off upon emerging from the gun or upon entering the wall of the artery.

Certain evidence has come to light, however, which suggests that the thrombosis could be based on a change in electropotential involving either the shaft of the hair or the wall of the artery. With reference to the former, Hubbard and Lucas1 of the National Bureau of Standards in 1960 found that certain substances in their isolated state possessed a high negative electric charge. Using an electrochemical technique they measured the charges inherent in such materials as strands of cellulose, spider web, glass and a host of other common solid substances. All of them were found to have a high negative

Fig. 7. Arteriogram of same case as in Fig. 6, made 2 weeks after operation, showing no progression in clotting process.

Fig. 8. Autopsy specimen of aneurysm shown in Figs. 5, 6 and 7. The bottom half of the aneurysm is closed with thrombosis.

Fig. 9. Surgical photograph of large arteriovenous aneurysm of thoracic spinal cord.
charge. They speculated that the high negative charge on these substances would act to incite clotting by uniting with the positively charged calcium ions in the blood. Dr. Hubbard, in a personal communication, stated that he had measured also the electric charges on isolated pieces of hair. In common with the other substances measured, hair too was found to have a high negative charge. Unfortunately, Hubbard in his published report failed to mention his observations regarding these electropotential properties of hair.

On the other hand, it is possible that thrombosis by pilojection may depend on changes of electropotential in the wall of the artery when the intima is wounded. It has been known for a long time that the circulating elements in the blood such as white and red blood cells, fibrinogen and other protein factors have a high negative electric charge. In 1959, Sawyer and Pate found that under normal conditions the intima of an artery has a negative electric charge while the adventitia is positively charged. When the vessel is injured, the polarity is reversed and the intima becomes positive and clotting results when the negatively charged circulating elements migrate to the injured intima (Fig. 10). With pilojection, the penetrating shaft of hair in wounding the intima might well create such a reversal in electropotential that finally causes clotting.

As mentioned above, there were 4 patients in the series in whom pilojection caused only partial clotting in the aneurysm. In each of these cases, the fact that incomplete clotting had occurred was recognized and accepted at the time of operation. It was assumed that the thrombotic process would proceed to completion and close the sac and, so, no additional shafts of hair were injected into the lesion. Three of these patients with partially closed lesions died later. The autopsy findings in 2 of them showed that even with the passage of considerable periods of time, in 1 case 8 weeks, no further buildup of the induced clot had occurred. The evidence furnished by these cases suggests that each shaft of hair is capable of inducing a limited amount of thrombosis and no more. Apparently clotting by pilojection ceases when the shaft of hair or the wall of the artery at the point of injury uses up its electric charge and finally becomes neutral.

The 2 patients in the series in whom pilojection produced no thrombosis were among the early cases treated by this method. There is a suspicion that in 1 of these, a patient with a large aneurysm, the shafts entered the sac and became free-floating. It has been learned since that in order to properly induce thrombosis, the shafts of hair must penetrate the intima of the aneurysm and stay impaled in the wall. If the shafts are allowed to enter the cavity for their full length (6 mm.) and become free-floating, no thrombosis will result. This situation can arise in the case of lesions with very thin walls. In the other patient in whom no thrombosis occurred, the error proved to be a purely technical one. The aneurysm at autopsy was examined under a dissecting microscope and 3 circular marks situated closely together were clearly seen in the wall of the sac; no shafts of hair were visible in the wall. These score marks represented the sites where the shafts struck the wall and instead of penetrating it, bounced away to some other part of the surgical field. Unfortunately the surgeon mistaken these score marks on the aneurysm for protruding ends of hair.

It is recognized that this new procedure must be properly evaluated by the entire neurosurgical community. Long-term study, especially by arteriography, is the most immediate requirement for the evaluation of its true worth. Increasing experience in the use
of this procedure should enable the neurosurgeon to avoid the pitfalls which resulted in the deaths reported here.

However, it is anticipated that pilojection will find a useful place in the treatment of intracranial aneurysms both large and small. It is also expected that this technique will be particularly useful for dealing with certain aneurysms that cannot be treated directly by any present known technique. This includes large aneurysms of the internal carotid artery and aneurysms of the basilar artery.

The cooperation of the following physicians in using the technique of pilojection on their patients is gratefully acknowledged: J. L. Pool, New York, N.Y.; W. B. Hamby, Cleveland, Ohio; A. W. Cook, Brooklyn, N. Y.; M. Baldwin, Bethesda, Md.; S. R. Snodgrass, Galveston, Texas; G. M. Swain, Arlington, Va.; and J. H. Van Landingham, Rockford, Ill.

References

Discussion

Dr. Wallace B. Hamby: [Slide] Here is our case, the lady who had a tremendous aneurysm at this site on the middle cerebral artery. In looking over the slides we found that this incorporated a considerable portion of the length of this vessel, from here to here. I had nothing constructive to offer to this patient to try to cure this lesion.

Dr. Gallager's report had recently come out and he was kind enough to come to Cleveland on one of the most horrid snowstorm nights and help us fix this thing up.

[Slides] The next series of slides shows three consecutive pictures made progressively during the course of injection of these hairs.

The dome of this lesion was so thin we could see the blood swirl through it, which frightened us no end.

[Slide] This was our final result, the angiogram done several days after operation.

The patient was discharged from the hospital and died a short time later of another hemorrhage, and we were not able to get an autopsy on her.

I would like to take a little of my remaining minute (we still have a half hour before our President is going to be able to talk) just to say something about this report. I have heard some adverse comment about Dr. Gallager's reporting of this work at the time he did. The literature is cluttered with preliminary reports. These reports stir positive and negative responses, the negative responses of incredulity, and cynical disbelief or of uncritical enthusiastic acceptance, with later disillusion and abandonment. The positive results are controlled by adequately testing the procedure, leading to acceptance of a useful procedure, or to rejection of a useless one.

I think it is important first to make an innovator prove his point and not for every one to jump in and make a group of similar mistakes.

The second thing is to permit him to do so. I think Dr. Gallager is controlling his work very well. He owns the only existing tool and, as far as I know, has not let it out of his hands. He is present whenever it is used. I congratulate him on his method of handling himself.