Percutaneous embolization of spinal cord arteriovenous malformations

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A technique is described for embolically occluding the feeding arteries of spinal cord arteriovenous malformations by non-operative means. Following the identification of each feeder by selective arteriography, a system of coaxial catheters is introduced percutaneously and each feeding artery is occluded within the spinal canal using metallic pellets, gelfoam, and muscle fragments. Technical details of the procedure are described and the choice of embolic material discussed. Embolization has been successfully accomplished in five patients. None were made worse, and three have shown progressive neurological improvement. The simplicity of the procedure and the absence of morbidity are stressed. Percutaneous embolization should be considered as an alternative to operative ligation of feeding arteries.

Key Words: spinal cord • arteriovenous malformation • spinal cord arteriography • spinal cord angioma • transcatheter embolization

There is at present a renewal of interest in the surgical treatment of spinal cord arteriovenous (AV) malformations, stimulated principally by the recent developments in selective arteriography and microsurgical techniques. Two therapeutic approaches appear to be emerging, namely, total excision, and the ligation of all arterial feeders without attempting to resect the angioma itself. We have summarized our experience in 18 cases with "ligation" while the case for "excision" has recently been well presented by Krayenbühl, et al.

Both techniques are immeasurably facilitated by accurate and complete preoperative arteriography. However, even with such angiographic assistance, malformations with extensive intramedullary components or those lying anterior to the cord are not suitable for excision. Posterior extramedullary malformations are theoretically resectable but extensive arachnoiditis resulting from previous laminectomies, bleeding episodes or residual Pantopaque may make total excision very difficult; under such circumstances, even the identification and ligation of feeding arteries may be a tedious undertaking. Overlying cutaneous angiomas may also complicate the surgical approach.

For these reasons, we have developed a technique for embolically occluding the feeding arteries of spinal cord AV malformations through the same percutaneous catheter used for angiographic studies, and are reporting herein our experience with five patients. A similar approach has been recently reported by Newton and Adams.

Theoretical and Technical Considerations

In many ways spinal cord AV malformations are more suitable for embolic occlusion than intracranial angiomas. Anatomically...
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and hemodynamically, there are several important differences between angiomas in these two locations. The intercostal and lumbar arteries from which the feeding arteries to most spinal angiomas arise are "non-essential" vessels, and one need not be concerned about occluding them. Intracranial angiomas, on the other hand, are supplied by anterior or middle cerebral branches and an embolus "gone astray" or arresting too proximally can be a serious complication. When a spinal malformation involves the upper cervical cord and is supplied by feeders from the vertebral artery, as in Fig. 1, it must be considered as an intracranial lesion and embolization should not be undertaken unless, as is highly unlikely, the feeders can be selectively catheterized.

Spinal cord arteriovenous malformations, especially in adults, are "slow flow" lesions. For this reason, embolic material is not "sucked into" the malformation; spinal angiomas do not exert the vortex or sump effect that Luessenhop, et al., have used to advantage in embolizing cerebral angiomas. Therefore, it is often necessary to deliberately occlude the parietal branches of an intercostal or lumbar artery before the branch supplying the spinal malformation can be successfully embolized.

In most instances, arterial feeders supplying a spinal cord AV malformation have a focal area of narrowing just inside the spinal canal. The luminal diameter often decreases by 50% (Fig. 2 left). We suspect that this constriction represents the point of dural penetration but have no anatomical proof of this. Regardless of its cause, this focal narrowing is an ideal site for embolic impaction (Fig. 2 right) since it accomplishes essentially what one surgical approach seeks to achieve, namely, intradural occlusion of the spinal feeder.

The ideal material for embolizing arteries through a catheter is not available. We are currently using stainless steel pellets, available in varying diameters and selected on the basis of corrected measurements from the arteriogram. However, large pellets require large catheters and their percutaneous introduction is associated with a higher incidence of femoral artery complications. In addition, highly polished stainless steel pellets are not particularly thrombogenic and thrombosis would be desirable to fix the embolus in position. We have recently been abrading the smooth surface of our pellets in the hope of further stimulating clot formation.

The use of muscle fragments to occlude abnormal vessels has had extensive application in carotid-cavernous fistulas. Newton and Adams used muscle to successfully occlude a spinal angioma. Because of its plasticity, muscle can be forced through catheters of conventional diameter and muscle fragments probably have some thrombogenic properties. However, since the size of the muscle emboli cannot be standardized, the ultimate site of impaction is unpredictable. Occlusion of the arterial feeder within the spinal canal is most desirable, to exclude the potential collateralization from adjacent intercostal or lumbar vessels. Also, the site of impaction by muscle emboli can only be determined by repeated contrast injections and its position cannot be easily verified radiographically over pro-

Fig. 1. High cervical AV malformation (large arrow) supplied by enlarged anterior spinal artery (small arrow) from both vertebral arteries. Embolization not feasible in such cases.
longed intervals as is true of metallic pellets. In addition to metallic or plastic pellets and muscle fragments, gelfoam \(^9\) and porcelain beads \(^10\) have been used recently to occlude carotid-cavernous sinus fistulas embolically.

An inert plastic that can be injected as a liquid and polymerizes rapidly in the blood stream has many of the characteristics of an ideal embolizing agent. Such a material could be deposited directly into the feeding artery through small, highly maneuverable catheters, perhaps positioned by some of the catheter-directing systems that have been recently developed. \(^5,8,24\) Silastic preparations fulfill many of these requirements and have been used successfully by the authors (Doppman and Zapol, unpublished data) to occlude multiple vessels in the dog. A preliminary injection of epinephrine through the catheter permits the occlusion of even high flow vessels such as the main renal artery, and a small admixture of powdered tantalum with the plastic allows one to visualize the
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occluding process fluoroscopically. Shimosmura, et al.,23 have used a similar material for occluding anterior spinal arteries in dogs, and Sano, et al.,22 have successfully embolized intracranial angiomas in patients with “liquid plastic.” However, the viscosity of silastic preparations when injected through long catheters and the difficulty of predicting exact polymerization times remain minor problems. Any clinical applications must await the completion of toxicity studies.

Method

We currently use a combination of steel pellets, muscle fragments, and gelfoam for embolizing spinal AV malformations; but primary occlusion is always achieved with the pellets, muscle and gelfoam being used secondarily to trap the pellet and, hopefully, stimulate thrombosis. Initially, the malformation is completely studied arteriographically and all feeding vessels are identified. The arteriographic catheter is then replaced by a Mueller deflecting catheter* over which a thin-walled Teflon catheter has been tapered for easy percutaneous introduction. The inner diameter of the Teflon catheter is 2.7 mm, but its tip, drawn down over the No. 7 French Mueller catheter, narrows to 2.5 mm, permitting the introduction of pellets up to this diameter. The Mueller deflecting catheter is introduced into the appropriate intercostal or lumbar artery, and, with the curve maintained by the deflecting wire, the larger Teflon catheter can be threaded over it into the same vessel. The inner catheter is then removed and embolization can be performed.

If the artery to the AV malformation is the largest branch arising from the intercostal or lumbar artery, a pellet of appropriate

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* Obtained from U.S. Catheter Co., Glens Falls, N.Y.

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Fig. 3. Arteriograms of large low thoracic AV malformation supplied by feeder from right 11th intercostal artery. Left: Clips mark previous unsuccessful attempt at surgical occlusion. Right: Selective 11th intercostal arteriogram demonstrating complete occlusion of feeder to angioma. Silastic pellet with faintly visible metallic marker (arrow) is arrested just proximal to clip.

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size is introduced and occlusion is generally accomplished on the first attempt. If the anterior intercostal or lumbar is the largest branch, large pellets must be introduced to occlude this vessel before smaller pellets will pass into the spinal feeder. Aside from some mild chest wall or loin soreness for 24 hours, no other consequence seems to attend the embolic occlusion of these parietal branches of the intercostal or lumbar arteries.

Injection of contrast material immediately confirms occlusion of the artery feeding the malformation. We then embolize muscle fragments or gelfoam to occlude the major segmental vessel but wish to stress the point that selective occlusion of the spinal feeder is

Fig. 4. Selective right spinal arteriograms: Top Left: Anterior intercostal branch is larger than feeder supplying AV malformation. Top Right: Large anterior intercostal has first been deliberately occluded by large (2.5 mm) pellets (curved arrow) so that subsequent small (1.5 mm) pellet (straight arrow) now enters and occludes feeder to malformation. Bottom Right: Segmental artery has been occluded with gelfoam (straight arrow).
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the essential maneuver to avoid collateralization from adjacent intercostal or lumbar arteries. Identification and embolization of as many as three separate feeders has been accomplished at a single catheterization session.

Results

Percutaneous embolic occlusion of spinal cord arteriovenous malformations has been successful in five of seven patients. One case has been previously reported.\(^4\) Our two failures occurred early in the series before the system of coaxial catheters had been developed to allow the use of large pellets. As in Newton and Adams' case,\(^{2,8}\) pellets introduced through conventional arteriographic catheters are generally too small to occlude the feeding vessels and simply lodge within the malformation.

The successful occlusion of a large malformation in a 33-year-old man is illustrated in Fig. 3. An attempt at operative ligation had failed because of extensive arachnoiditis (two previous laminectomies, four previous myelograms), and the clip only partially narrowed the feeding artery. A silastic pellet with a small metallic core was used to occlude the feeder in this case. We no longer use silastic-coated pellets as they appear to offer no advantages and are not as readily visualized fluoroscopically during the embolization procedure.

Successful occlusion of two feeders in a 32-year-old paraplegic patient is shown in Figs. 4 and 5. The largest branch arising from the right T-11 artery was the anterior intercostal (Fig. 4 top left), and pellets of a proper size to occlude the spinal feeder invariably embolized this larger vessel. Consequently, 2.5 mm pellets were used to partially occlude and reduce flow into this major branch, and the spinal feeder was then successfully embolized with a 1.5 mm pellet (Fig. 4 top right). Gelfoam was used to occlude the segmental vessel after the spinal feeder had been selectively obstructed (Fig. 4 bottom right). Figure 5 demonstrates the use of multiple pellets to successfully occlude a second feeder. A repeat arteriogram 2 weeks later showed that both feeders had remained occluded.

Figure 6 records occlusion in the case of a 19-year-old boy whose low thoracic malformation was supplied by a single feeding artery. Operative ligation had been unsuccessful.
fully attempted 1 year previously. Occlusion was successfully accomplished with a single pellet. Follow-up films have shown no change in pellet position, and a repeat arteriogram 4 weeks after embolization showed persistent occlusion of the feeder.

All patients tolerated the embolization procedure well under local anesthesia. No deterioration of cord function was noted in any of the cases. Three patients have shown progressive neurological improvement. In the paraplegic patient and one with a mild long-standing stable deficit, no change has been noted but, hopefully, progression of the disease has been arrested and the risk of hemorrhage lessened. A longer follow-up is required to evaluate the final results.

Until now, we have regarded percutaneous embolization as an ultimate or "last resort" approach, reserved for operative failures or for patients with severe, long-standing neurological deficits, as in paraplegia. As experience accumulates, the relative simplicity of the procedure, the absence of morbidity and the apparent stability of the occlusion have led us to reconsider our priorities. If percutaneous embolization proves to be as effective as operative arterial ligation, it may become the treatment of choice when total excision is not possible or when the lesion is bleeding acutely.

**Summary**

Five spinal cord arteriovenous malformations have been treated by embolizing the feeding arteries through a percutaneous catheter. The technical details and some examples of this method of treatment are presented. The method provides a valuable alternative to arterial ligation when total excision is not feasible.

**References**

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