Therapeutic percutaneous embolization for extra-axial vascular lesions of the head, neck, and spine

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Therapeutic percutaneous embolization of extra-axial vascular tumors and arteriovenous malformations was performed 41 times in 27 patients. Twenty-one patients (78%) had a clinically favorable result. In 11 of these patients, the procedure was preoperative and caused a dramatic reduction of surgical blood loss. In the remaining 10 patients with a favorable result, therapeutic embolization alone resulted in a significant clinical amelioration documented by a detailed follow-up varying from 2 to 5 years. In patients with uncontrollable epistaxis, the procedure was life-saving. The guidelines and instrumentation for a safe and effective technique are presented, based on the authors' experience with more than 100 cases of vascular lesions of the brain and spinal cord. A low-viscosity silicone polymer was developed by the authors and used clinically as an intravascular adhesive for the embolization of vascular tumors.

KEY WORDS: embolization, extra-axial tumors, arteriovenous malformations, glomus jugulare tumors, epistaxis, intravascular adhesive, Silastic spheres

Therapeutic percutaneous embolization is a valuable adjunct in the management of vascular lesions of the head, neck, and spine. This technique allows selective obliteration of the arterial supply of neoplasms where vessels enter the tumor. Surgically inaccessible vessels may be embolized. Dramatic reduction of surgical blood loss may be achieved and, in some patients, the embolization alone has resulted in total amelioration of symptoms.

Arteriovenous malformations (AVM's) of the scalp and dura present similar problems requiring extensive and often mutilating dissection for their removal. Percutaneous embolization is an attractive alternative method of management. Embolization has been lifesaving in cases of uncontrollable epistaxis due to nasopharyngeal vascular lesion.

Since our report in 1970 of the first embolization of neoplasms of the head and neck, several publications have appeared on this subject. In this paper, we present the long-term clinical follow-up on our patient material and describe a new methodology of embolization which we believe emphasizes safety and effectiveness.

Clinical Material

Percutaneous therapeutic embolization of a vascular extra-axial tumor or an AVM was
TABLE 1

Extra-axial vascular lesions of the head, neck, and spine treated by therapeutic embolization

<table>
<thead>
<tr>
<th>Diagnosis*</th>
<th>No. of Embolization Procedures</th>
<th>Management</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>glomus jugulare tumors</td>
<td>8</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>dural AVM</td>
<td>6</td>
<td>11</td>
<td>—</td>
</tr>
<tr>
<td>intractable epistaxis</td>
<td>1</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>aneurysmal collateral of the nasopharynx</td>
<td>1</td>
<td>1</td>
<td>1†</td>
</tr>
<tr>
<td>ossifying fibroma of sphenoid bone</td>
<td>1</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>nasoparyngeal angiofibroma</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>meningiomas</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>giant cell tumor of petrous bone</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AVM of subtemporal fossa</td>
<td>2</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>vascular tumors of the vertebral body</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>angioma of the vertebral body</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>total</td>
<td>27</td>
<td>41</td>
<td>13</td>
</tr>
</tbody>
</table>

* AVM = arteriovenous malformation.
† Radical surgery was performed on the sphenoid bone 2½ years after the embolization. During this time there has been no recurrence of epistaxis.

Embolization was carried out preoperatively in 13 patients and was the only management in 14. Diagnosis of the lesion was established by extensive selective angiography in all patients. Patients with tumors of the head and neck underwent superselective angiography with opacification of individual branches of the external carotid artery and frequently with selective catheterization of the second order branches. In the case of spine lesions, the appropriate intercostal, vertebral, costocervical, or thyrocervical branches were studied. Angiography was generally carried out a few days prior to embolization, except for emergency procedures.

Embolization Technique

Embolization is usually started in the largest vessel supplying the lesion. Low common carotid artery puncture is usually performed for lesions of the head and neck because it allows selective catheterization of secondary or tertiary branches of the external carotid artery. Femoral catheterization was used for embolization of lesions of the vertebral bodies as well as lesions supplied by the thyrocervical and costocervical trunks.

The delivery of Silastic spheres into an artery requires a nontapered No. 8 or No. 9 French catheter. An advantage of a large catheter is that it can be completely wedged into the lumen of the proper arterial branch, preventing retrograde reflux of emboli. Catheter wedging is an absolute prerequisite for safe embolization of the external carotid system. Nontapered catheters may be introduced into an artery with a coaxial system or a Mylar sheath of appropriate size with a suitable Touhy Borst adapter (Fig. 1).* We have used the coaxial system for the carotid

*Hilal Coaxial Embolization Set manufactured by Cook Inc., 925 South Curry Pike, P. O. Box 489, Bloomington, Indiana 47401. Desilets Hoffman catheter introducer manufactured by United States Catheter, Billerica, Massachusetts 01821. Touhy Borst male adapter manufactured by Becton-Dickinson, Rutherford, New Jersey 07070.
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FIG. 1. Upper: A No. 8 French coaxial embolization catheter. The inner tapered catheter is first introduced in the artery by the Seldinger technique and is used to guide the outer non-tapered catheter into the artery. We used this technique in the cases requiring a carotid puncture. Lower: A No. 8 French Mylar sheath catheter introducer assembly (arrows), and a Touhy Borst male adapter (double arrows). This assembly is used when the embolization catheter is to be introduced through the femoral artery. The Touhy adapter permits a tight fit between the catheter and the Mylar sheath, preventing blood loss.

punctures and the Mylar sheath for the femoral punctures.

The embolization catheter is wedged into the desired arterial branch under fluoroscopic control. Complete wedging of the catheter without retrograde flow of the contrast medium should be confirmed by fluoroscopy and serial angiography. Double lumen balloon catheters varying in size from No. 2 to No. 6 French can also be used. They provide the only safe means for the delivery of an intravascular adhesive material and will be discussed later.

Radiopaque Silastic spheres* were most frequently used for embolization. They are durable and can be seen radiographically. The goal of embolization is to occlude the feeding arterial branches as close as possible to the lesion, and thereby reduce the opportunity for collateral supply. Therefore, embolization is started with the smallest sphere that can be trapped in the lesion. The number of spheres used ranged from 30 to 250 in a given patient and varied from 1 mm to 2.5 mm in diameter. In general, only one or two vessels are occluded in any one day. The spheres are delivered by the device illustrated in Fig. 2. Each pellet is individually sucked through one limb of the Y-tube and injected through the other limb into the catheter. It is important to note that the spheres are at all times immersed in a sterile physiological solution, a feature that permits the maintenance of sterility as well as quick delivery. The drawback of this system, however, is the large amount of fluid required for injection; this can become a limiting factor in certain cases.

*Radiopaque Silastic spheres manufactured by Heyer-Schulte Corporation, Goleta, California 93107.

FIG. 2. Drawing of embolization device for Silastic spheres. The system consists primarily of a Y-tube. Tube a suck's the spheres from Reservoir 1. Tube b is attached to the intracarotid catheter and Tube c is attached to a 30-cc syringe connected to a bottle of sterile physiological salt solution. Two stopcocks are attached to the c limb of the Y as well as to the syringe and the reservoir. The clamps 2a and 2b are opened and closed alternately to permit the suction of a sphere from Reservoir 1 through Tube a into Tube c, and its subsequent injection in the carotid catheter. The supporting platform, 3, helps stabilize the device during embolization. The Y connection, 4, is made of glass. All tubing is transparent and permits the passage of a sphere measuring up to 3 mm in diameter. (Available from Cook, Inc., P.O. Box 489, Bloomington, Indiana 47401.)
FIG. 3. Double lumen balloon catheter, No. 3 French, used for the injection of the intravascular adhesives. Diameter of catheter is 1 mm.

particularly in children suffering from AVM's with a marginal cardiac function.

If Gelfoam is used (infrequently now at our center), the material is cut in its dry state and suspended in a normal physiological solution. Because relatively large pieces of Gelfoam can squeeze their way through, a small catheter is adequate. The danger of reflux however, is high with small catheters and as a rule, if a piece of Gelfoam happens to reflux into the internal carotid circulation, it will occlude a vessel larger than that usually occluded when this happens with the Silastic spheres. Because of the high danger of retrograde flow with Gelfoam and the silicone polymers, small balloon catheters (size 4, 3, and 2, French) have been developed for this purpose and must be used* (Fig. 3).

Liquid Silastic† has recently been used as an intravascular adhesive, injected as a liquid and allowed to polymerize in the lesion. We have recently developed a new low-viscosity formulation of the Silastic Elastomer that can be readily injected through a No. 2 French double-lumen catheter. The Silastic Elastomer No. 382 is diluted 1:5 in silicone fluid No. 360. Polymerization of this dilute elastomer cannot be achieved by the addition of the catalyst stannous octoate alone. The addition of a drop of a 5% dilution of a cross-linker‡ permits the polymerization of the dilute elastomer into a hard rubbery substance in 5 to 6 minutes. This new Silastic formulation is approximately 10 times less viscous than that previously reported by Doppman, et al. When intravascular adhesive is used, the injections should be highly selective, with careful fluoroscopic control.

Radiographic control is essential during the procedure. Plain x-ray films are taken frequently to monitor the position of the emboli. When Gelfoam or the Silastic adhesive are used, they should be mixed with a radiopaque marker. We found tantalum powder (1-μ particles) quite adequate to permit detection of the emboli, both fluoroscopically and radiographically. In all procedures involving the external carotid artery, the monitoring x-ray films should include an anteroposterior and a lateral projection of the entire head to detect stray emboli in the internal carotid circulation.

Summary of Cases

A favorable clinical result was obtained in 21 of the 27 cases. No clinical effect was observed in four cases, and in two cases serious, but avoidable complications, including one death, occurred (Table 1). There have been no infections, vascular necroses or other complications. Of the 27 patients, 14 had embolization with Silastic spheres only, five with Gelfoam only, and one with a combination of Gelfoam and spheres. The remaining seven patients had embolization with Silastic adhesive; in five cases the adhesive alone was used, and in the remaining two, a combination of Silastic spheres and Gelfoam as well as the adhesive were used.

Glomus Jugulare Tumors

Of the eight patients in this group, three had complete resection of large, highly vascular tumors without need for transfusion (Fig. 4). In two other patients subtotal resection of the lesion was possible, leaving deep residual tumor which was supplied by feeders from the internal carotid artery and the vertebral artery (Fig. 5). Nevertheless, it was

*Hilal double lumen balloon catheters manufactured by Edwards Laboratory, Santa Ana, California.
†Liquid Silastic manufactured by Dow-Corning Corporation, Medical Products Division, Midland, Michigan 48640.
‡Information on cross-linker available from Alexander Kosseim, Ph.D., of Union Carbide, Tarrytown, New York.

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Fig. 4. Vascular glomus jugulare tumor in a 34-year-old woman treated by embolization and surgery. *Upper Left:* External carotid angiogram, lateral subtraction view, showing the tumor. *Upper Right:* Lateral radiograph showing the spheres embolized in the occipital, the ascending pharyngeal, and the internal maxillary branches of the external carotid artery. Three embolization procedures were necessary to achieve this result. *Lower Right:* Postembolization angiogram, lateral subtraction view. There is no opacification of the lesion except probably for a minor collateral flow from the superior thyroid artery.

felt that embolization permitted a larger resection than would have otherwise been possible. One patient, a 56-year-old man, declined surgery as his clinical symptoms disappeared after embolization, and he remains free of symptoms 5 years later (Fig. 6). His nuclear scan reverted to normal and remained normal after embolization. In another patient, a 68-year-old woman, surgery was deferred because it was felt that the tumor was virtually completely embolized with Silastic adhesive, and also because her symptoms disappeared after embolization (Fig. 7). The last patient in this group is the only death in our entire experience with therapeutic embolization which comprises more than 100 patients.

Dural Arteriovenous Malformations

All six cases with dural AVM's were considered inoperable and were treated with embolization only. One of these patients with a
FIG. 5. Selective internal carotid angiogram, lateral subtraction view, after embolization of a glomus jugulare tumor partially supplied by the internal carotid artery in a 20-year-old man. A meningeal branch of the internal carotid artery is seen supplying the lesion. This arterial supply caused sufficient bleeding when the deeper part of the tumor was reached surgically to prevent complete resection. A meningeal branch of the vertebral artery also supplied the lesion.

Intractable Epistaxis

The three patients with intractable epistaxis were clinically quite ill. One patient was in profound shock and aneuric. Embolization stopped the bleeding almost immediately in all patients, either during the procedure itself or shortly after. No recurrence of bleeding has occurred for 2½ years in two patients, one with ossifying fibroma of the sphenoid bone, and one with the abnormal collateral circulation in the nasopharynx between the external carotid and the internal carotid arteries. This patient was a 41-year-old woman who presented in shock, with anemia and a hemoglobin of 7 gm due to severe epistaxis. Twenty years prior to her admission, she had had a ligation of the internal carotid artery for a large intracerebral AVM (Fig. 10). In the third patient, with a juvenile nasopharyngeal angiofibroma, the epistaxis was controlled but there was no evidence that the embolization facilitated surgical removal.

Vascular Tumors at the Base of the Skull

Four patients had vascular tumors at the base of the skull treated with embolization. Three of the tumors were meningiomas; all but one, an inoperable meningioma, were removed with no blood loss. The fourth tumor was a giant cell tumor of the petrous bone extending through the floor of the middle cranial fossa into the subtemporal fossa (Fig. 11). An initial biopsy into the middle ear, where the tumor initially presented, resulted in a serious hemorrhage. The tumor became completely necrotic after embolization, allowing an easy, complete surgical removal.

AVM's of the Subtemporal and Pterygoid Fossae

Of the two patients in this group, one had complete obliteration of the malformation and the other had partial occlusion of a large lesion.

Vascular Lesions of the Vertebral Bodies

One patient had an embolization of a large aneurysmal bone cyst of C-6 and C-7 that was causing severe spinal cord compression. The ascending deep cervical artery and the costocervical trunks were embolized with a femoral catheter. After the procedure, two
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FIG. 6. **Upper Left:** Subtraction lateral angiogram showing a No. 8 French catheter completely wedged in the ascending pharyngeal artery with no reflux of contrast medium around the catheter. The glomus jugulare tumor is well outlined. **Upper Right:** Skull film, anteroposterior view after embolization, showing a few Silastic spheres at the base of the skull close to the tumor or within it. **Lower Right:** Postembolization common carotid arteriogram, lateral subtraction view, showing no tumor stain. The contrast medium flows in the internal carotid artery, although the tip of the catheter remains in the external carotid artery. No additional blood supply is seen from the internal carotid artery and there are no stray emboli intracranially.

The patient, a 56-year-old man, recovered from his symptoms during the procedure and remained clinically free of symptoms 5 years later.

Extensive operations were undertaken for removal of the lesion and spine fusion. Bleeding was not a problem.

The second patient in this group underwent emergency thoracic laminectomy for cord compression at which time an angioma of T-4 was discovered. Postoperative embolization of the lesion was performed with Silastic spheres. Six months later symptoms recurred and recanalization was noted. On this occasion, Silastic adhesive was injected into the tumor. The eventual outcome remains to be evaluated but the patient has done well for almost 2 years.

The third patient, a child, had a large vascular cartilagenous tumor arising from the body of L-4. Embolization was carried out with Silastic adhesive in the two segmental
FIG. 7. Glomus jugulare tumor in a 68-year-old woman embolized with Silastic adhesive only. Upper Left: Lateral subtraction carotid angiogram showing the stain of the tumor displacing the internal carotid artery. Upper Right: Postembolization lateral and base views of the skull show the tumor completely opacified with the tantalum-containing Silastic polymer selectively injected in the occipital ascending pharyngeal, and internal maxillary arteries. Lower Left: Base view. Surgery was deferred because the symptoms disappeared.

lumbar vessels feeding the lesion (Fig. 12). Complete surgical resection was possible with only minimal blood loss (300 ml).

The fourth patient had a large malformation of the vertebral bodies of C-7 and T-1 as well as a malformation of the spinal cord at the same level. The Silastic adhesive was injected into the arteries feeding the malformation of the vertebral bodies. This last patient had only limited observation.

Discussion

Therapeutic percutaneous embolization is a true interdisciplinary effort. The neuroradiologist and the neurosurgeon must work together closely throughout every phase of the procedure. Selection of case material, the decision on the vessels to be embolized, and monitoring the patient's condition as well as the continuously changing angiographic ap-
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FIG. 8. **Left:** Dural subtraction angiogram showing the supply from the internal carotid artery to the malformation in the wall of the cavernous sinus. The large superior ophthalmic vein is seen. **Upper Right:** Severe proptosis and chemosis is seen before the embolization of the external carotid. **Lower Right:** Resolution of the proptosis and chemosis a few hours after the embolization of the internal maxillary and middle meningeal arteries.

Pearlman of the lesion, all require joint assessment.

Luessenhop, \textit{et al.},\textsuperscript{10,11} introduced the technique of embolization of AVM's with radiopaque Silastic spheres, which has recently been used by other investigators also.\textsuperscript{2,9} The concept was extended for the management of bleeding in other parts of the body.\textsuperscript{3} Our group introduced the percutaneous approach, with careful radiographic control, and particularly the management of vascular tumors as either a definitive treatment or as an adjunct to surgery.\textsuperscript{8} Long-term clinical evaluation is an important feature of this work.

The patients reported in this study had either inoperable lesions or lesions with unusually high surgical risks. Favorable clinical results were achieved in 21 patients (78%), and no change in the clinical condition in four; serious complications occurred in two patients, with one death. These were the only two serious complications of our entire series of over 100 patients treated with therapeutic embolization. They were both due to the reflux of emboli in the internal carotid artery. Based on our experience we believe that these two complications are avoidable, if the guidelines listed above are followed and particularly if the newer balloon catheters are used.\textsuperscript{6,7} A third patient had a hematoma of the neck connected with the carotid artery puncture for angiography; this was felt to be more a complication of angiography, than one of therapeutic embolization.

Therapeutic embolization was carried out as a preoperative procedure in 13 patients. In 11 of these patients, there was a clearly favorable effect on surgery, namely, a very significant reduction of blood loss. In one patient, the effect was questionable and in the last patient, it was of no obvious assistance in
surgery. Therefore, we feel that embolization is an important preoperative adjunct in the management of vascular tumors.

Ten patients had a favorable long-term result following therapeutic embolization alone without surgery. Eight patients of this group were followed for a period varying from 2 to 5 years. One of these patients had a large glomus tumor and refused surgery as his symptoms disappeared after the embolization; he has remained free of symptoms for 5 years. Four patients had a dural AVM and one patient had an AVM of the subtemporal pterygoid fossae. The last two patients of this group had severe epistaxis which was controlled by embolization alone for a period of
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Fig. 10. *Left*: Lateral subtraction view of a common carotid arteriogram showing the collateral flow from the external carotid artery to the intracranial internal carotid artery which supplies a cerebral AVM. A small aneurysm (*arrow*) can be readily seen. The clamp on the internal carotid artery in the neck was placed 20 years previously. *Right*: Postembolization angiogram showing the complete obliteration of the abnormal collateral circulation.

Fig. 11. *Left*: Lateral angiogram in a 29-year-old woman with a vascular mass in the ear before embolization showing extent and vascularity of the lesion. *Right*: Lateral subtraction angiogram after the embolization showing complete disappearance of the vascular stain. The internal maxillary artery is totally occluded (*arrow*). Surgery was done a few days later and complete necrosis of the tumor was verified.
FIG. 12. Radiographs in a child, with a vascular chondrofibromyxoma embolized with Silastic adhesive. The tantalum-loaded silicone adhesive in the angioarchitecture of the tumor in both the anteroposterior (left) and the lateral (right) views. The catheter for the injection of the adhesive has been removed.

2½ years in both. Of the 10 patients in this group, two were observed for a period of less than a year. One had a glomus tumor embolized with Silastic polymer and the other had a malformation of the bony spine embolized with the same material.

In our experience, the use of Gelfoam as an embolization material was not highly satisfactory. It tends to recanalize in a few days, is difficult to see radiographically, and carries a higher risk of complication, as explained earlier. We believe its use should be limited to presurgical embolization.

Silastic spheres are stable and easily seen. The procedure using Silastic pellets, however, lasts about 3 hours, requires large amounts of fluids, and on occasion the spheres may prove cosmetically unsightly if they lodge in a scalp vessel.

More recently, we have tended to use a liquid Silastic material. The liquid is heavily impregnated with tantalum powder for easy x-ray visualization, both fluoroscopically and radiographically. In cases of vascular neoplasms, we have found that no magnetic fields were required for directing or holding the material in place, contrary to what other investigators have suggested. We favor this material now as the procedure is considerably faster and easier for the patient. We have used the Silastic adhesive in a total of eight patients. Three patients had a malformation of the spinal cord and five had extra-axial lesions of the spine and base of the skull. It should be noted however, that experience with this method is limited and a more complete evaluation of it requires more time for further study.

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References


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