Endovascular detachable balloon embolization therapy of cavernous carotid artery aneurysms: results in 87 cases

RANDALL T. HIGASHIDA, M.D., VAN V. HALBACH, M.D., CHRISTOPHER DOWD, M.D., STANLEY L. BARNWELL, M.D., PH.D., BILL DORMANDY, B.S., JULIE BELL, M.S., AND GRANT B. HIESHIMA, M.D.

Departments of Radiology and Neurological Surgery, Interventional Neuroradiology Section, University of California Medical Center, San Francisco, and Interventional Therapeutics Corporation, South San Francisco, California

Interventional neurovascular techniques for treating patients with intracranial aneurysms are now being performed in selected cases. In certain anatomical locations that are difficult to reach surgically, such as the cavernous portion of the internal carotid artery (ICA), this technique may be especially useful. The procedure is performed from a transfemoral approach, using local anesthesia, thus permitting continuous neurological monitoring.

Between 1981 and 1989, 87 patients diagnosed as having an intracavernous aneurysm were treated with endovascular detachable balloon embolization techniques. The patients ranged in age from 11 to 84 years. The presenting symptom was mass effect in 69 cases (79.3%), rupture of a preexisting aneurysm resulting in a carotid-cavernous sinus fistula in eight cases (9.2%), trauma resulting in a cavernous pseudoaneurysm in seven cases (8.0%), and hemorrhage in three cases (3.4%). Therapeutic occlusion of the ICA across or just proximal to the aneurysm neck was performed in 68 patients (78.2%). Since 1984, with the development of a permanent solidifying agent (2-hydroxyethyl methacrylate) to fill the balloon, it is now feasible in some cases to guide the balloon directly into the aneurysm and preserve the parent artery; this was achieved in 19 cases (22%). Follow-up examination has demonstrated complete thrombosis with partial or total alleviation of symptoms in all patients with therapeutic occlusion of the parent vessel. Of the 19 patients with preservation of the parent artery, follow-up studies have demonstrated total exclusion in 12 cases (63%) and subtotal occlusion of greater than 85% in seven cases (37%), with clinical improvement in all cases. Complications from therapy included transient cerebral ischemia during or after therapy requiring volume expansion in seven cases, embolic symptoms requiring antiplatelet medication in two cases, and stroke in four cases; there were no deaths. Detachable balloon embolization therapy, particularly for large and giant symptomatic aneurysms of the cavernous ICA, can be an effective mode of treatment.

KEY WORDS • cavernous internal carotid artery • aneurysm • balloon occlusion • endovascular therapy • interventional radiology • detachable balloon

ANEURYSMS arising from the cavernous portion of the internal carotid artery (ICA) are difficult to treat by direct surgery due to the surrounding cavernous sinus. Smaller aneurysms in this location are usually asymptomatic and, if they do rupture, result in a carotid-cavernous sinus fistula. Large and giant aneurysms may produce symptoms resulting from mass effect with compression of the adjacent third through sixth cranial nerves, headache, pain, transient ischemic attacks and stroke from emboli, and occasionally hemorrhage, if the aneurysm extends into the subarachnoid space.

Surgical management has included cervical common carotid artery or ICA ligation or clamping, direct microneurosurgical exposure of the cavernous ICA aneurysm, and (more recently) endovascular detachable balloon embolization therapy. For large and giant ectatic aneurysms without a well-defined neck, occlusion is performed by placement of a balloon just proximal to or across the aneurysm neck, following successful test occlusion for patient tolerance. Over the past several years, with improvements in microballoon technology and development of permanent solidification agents, it is now possible to guide a balloon directly into the aneurysm and preserve the parent vessel if an aneurysmal neck can be identified. We report our
experience in the treatment of 87 patients diagnosed as having an intracavernous aneurysm and treated by detachable balloon embolization therapy.

**Clinical Material and Methods**

Between 1981 and 1989, 87 patients presenting with an intracavernous aneurysm were treated by detachable balloon embolization techniques. There were 68 females and 19 males, ranging in age from 11 to 84 years (mean 47.5 years). The clinical presentation included mass effect in 69 cases (79.3%) with symptoms of ophthalmoplegia, diplopia, headache, retro-orbital pain, and visual disturbance. Eight patients (9.2%) had spontaneous rupture of an intracavernous aneurysm resulting in a direct carotid-cavernous sinus fistula. These patients had symptoms of chemosis, retro-orbital bruise, diplopia, and/or visual decline. Seven patients (8.0%) presented with a pseudoaneurysm of the cavernous carotid artery following trauma to the skull base, transsphenoidal surgery, or biopsy with resultant epistaxis, or as a result of incomplete closure of a carotid-cavernous sinus fistula. In six patients (7.3%) the aneurysm caused thromboembolic symptoms requiring treatment. Three patients (3.4%) presented with hemorrhage due to rupture of the aneurysm into either the subarachnoid space or the sphenoid sinus. Of the 87 patients, 39 (45%) presented with a giant aneurysm greater than 2.5 cm in diameter. In 19 patients (22%), a well-defined neck could be delineated for direct balloon embolization of the aneurysm with preservation of the parent vessel.

All procedures were performed in the Interventional Neuroangio graphic section under direct fluoroscopic visualization and with local anesthesia. The femoral region was anesthetized with 1% Xylocaine (lidocaine) and a No. 18 single-wall puncture needle was used to enter the femoral artery via the Seldinger technique. A No. 7.5 French sheath was then inserted into the femoral artery, and a baseline activated clotting time was measured. A diagnostic cerebral arteriogram with high-magnification, rapid-sequence, digital subtraction angiography techniques was obtained initially to assess the size, shape, configuration, and relationship of the neck to the intracavernous carotid artery. The contralateral carotid artery and dominant vertebral artery were studied with compression of the ipsilateral carotid artery to evaluate the collateral circulation across the circle of Willis, and to exclude aneurysms in other locations. Correlation with magnetic resonance (MR) images and computerized tomography (CT) scans was made to determine intraluminal thrombus formation.  

This is important if direct balloon embolization therapy is contemplated. In general, we believe that if there is evidence of fresh thrombus within an aneurysm diagnosed less than 6 weeks before, there is a higher incidence of thrombus being dislodged during balloon placement into the aneurysm.

In all cases of intracavernous aneurysm therapy, a test occlusion of the cervical ICA was performed initially. For a 70-kg patient, 5000 U of heparin was given intravenously for systemic anticoagulation. A No. 7.0 French fixed balloon catheter with a distal end-hole* was then guided into the cervical ICA just above the carotid bifurcation. To insure temporary occlusion of the ICA, arterial pressures were measured and the balloon was inflated until stasis of contrast material was apparent. Arterial back-pressure measurements were repeated and then the distal catheter tip was perfused with heparinized saline to avoid thrombus formation above the occluded segment. Serial neurological testing was performed for 30 minutes during temporary carotid occlusion to insure patient tolerance.

In the patients who could tolerate test occlusion and in whom the aneurysmal neck was broad-based or not apparent, permanent balloon occlusion therapy was then performed. A No. 7.3 French nontapered catheter was inserted through the femoral sheath and placed into the proximal ICA. A silicone detachable balloon, measuring 1.50 x 3.90 mm uninflated, was attached onto a No. 2.0/4.0 French coaxial catheter system† (Fig. 1). The balloon and catheter system were inserted into the No. 7.3 French introducing-catheter and the space between the two catheters was perfused with heparinized saline to avoid thrombus formation. Under direct fluoroscopic visualization, the balloon was guided up the carotid artery and inflated just proximal to the aneurysmal neck, then detached by gentle traction on the No. 2.0/4.0 French catheter. The balloon, which has an internal miter valve that will cause it to self-seal when detached from the catheter, can contain a maximum volume of 0.50 cc and expand to 7.5 x 13.5 mm. A second balloon was placed just proximal to the first balloon to ensure complete occlusion in case the first balloon should prematurely deflate.

In patients with a well-defined aneurysmal neck, it was possible to enter the aneurysm directly and obliterate it with the balloon while preserving the parent artery. A road-mapping technique, which displays a subtracted image of the neurovascular architecture over a fluoroscopic image, allows placement of a balloon directly into the aneurysm. For large and giant aneurysms, more than one balloon was often required to completely fill the aneurysm. Once the balloon(s) were positioned within the aneurysm sac, they were filled with a liquid polymerizing material, 2-hydroxyethyl methacrylate (HEMA); HEMA is a liquid monomer that, when activated and catalyzed, will solidify within the balloon in 40 to 60 minutes.  

Use of HEMA provides a permanent embolic material within the aneurysm should the silicone balloon shell deteriorate over time or the valve mechanism fail. A postembolization

---

* Fixed balloon catheter manufactured by Meditech, Inc., Watertown, Massachusetts.
† Coaxial catheter system manufactured by Interventional Therapeutics Corp., South San Francisco, California.
Endovascular embolization for intracavernous aneurysms

FIG. 1. Detachable silicone balloon used for the intracranial aneurysm embolization procedures described. The medium-sized balloon, shown uninflated, measures 1.5 \times 3.9 mm. When fully inflated, it contains a maximum volume of 0.50 cc and expands to 7.5 \times 13.5 mm.

arteriogram was obtained in all cases to evaluate aneurysmal obliteration and patency of the parent vessel.

After the procedure, all patients were monitored in the hospital for 2 to 4 days. Skull radiographs and/or thin-section CT scans were obtained to ensure that the balloons had not deflated or shifted and that the aneurysm was occluded. Neurological evaluation and blood pressure parameters were closely monitored. Following carotid occlusion therapy, blood pressures were kept in the range of 110 to 160 mm Hg systolic and 60 to 110 mm Hg diastolic. If neurologically stable, patients were discharged home and assessed at 1, 3, and 12 months after surgery by clinical evaluation for alleviation of symptoms. Radiological studies at 1 to 3 months and 3 to 12 months following therapy included skull films, CT, and/or MR imaging to insure balloon placement, thrombosis of the aneurysm, and alleviation of mass effect. In cases of direct balloon embolization therapy, a follow-up arteriogram was obtained between 1 and 12 months after surgery to evaluate aneurysmal thrombosis and patency of the parent artery.

Representative Case Reports

Carotid Artery Occlusion for Giant Cavernous Aneurysm

Case 1. This 65-year-old woman presented with severe retro-orbital pain and diplopia due to a third and sixth cranial nerve palsy. A CT head scan demonstrated a giant, 2.5-cm, partially thrombosed aneurysm involving the left cavernous ICA, with displacement of the cavernous sinus (Fig. 2 left). Cerebral angiography demonstrated the giant intracavernous aneurysm to be ectatic without a well-defined neck, and with a separated inflow and outflow (Fig. 2 center). Test occlusion of the proximal cervical ICA was well tolerated for 30 minutes without the development of focal neurological problems, and the carotid artery was therefore occluded using two detachable silicone balloons placed just proximal to the neck of the aneurysm in the horizontal cavernous carotid artery. The patient was discharged home 3 days later without any neurological problems.

A follow-up MR image 6 months later demonstrated complete thrombosis of the aneurysm with a marked decrease in the size of the aneurysm (Fig. 2 right). Clinically and neurologically the patient’s symptoms have completely resolved and she continues to do well 2 years after treatment.

FIG. 2. Case 1. Radiography in a patient treated for a giant cavernous aneurysm. Left: Computerized tomography scan demonstrating a 2.5-cm aneurysm (arrows). Center: Left internal carotid arteriogram, lateral view, confirming the giant, ectatic aneurysm involving the cavernous segment of the carotid artery. The inflow and outflow of the aneurysm are separate (arrows). Right: Follow-up magnetic resonance image obtained 6 months following carotid artery occlusion using detachable balloons placed at the neck of the aneurysm. There is complete thrombosis with a dramatic decrease in size of the aneurysm (arrows).
Direct Balloon Occlusion of Aneurysm

Case 2. This 42-year-old woman presented with headaches and diplopia of the right eye. Cerebral angiography demonstrated an intracavernous aneurysm of the right ICA measuring 10 x 12 x 12 mm. The aneurysm projected medially, and angiographically appeared to have a good anatomical neck (Fig. 3 left). From a transfemoral approach, a 1.5-mm detachable balloon was guided through the ICA and directed into the aneurysm. The balloon was then filled with HEMA for solidification and detached (Fig. 3 center). The postembolization angiogram 2 days later demonstrated complete obliteration of the aneurysm by the balloon with normal filling of intracerebral vessels (Fig. 3 right). At her 21-month follow-up examination, the patient continued to do well and remained asymptomatic.

Direct Balloon Embolization of Large Irregular Aneurysm

Case 3. This 50-year-old woman presented with severe headaches, diplopia, and retro-orbital pain. A CT head scan demonstrated a large intracavernous aneurysm of the left ICA. Cerebral angiography confirmed the presence of a large, irregular aneurysm measuring 14 x 14 x 18 mm in diameter, with demonstration of a neck which projected posteriorly and laterally (Fig. 4 left). Due to the size of the aneurysm, a large, 1.8-mm detachable balloon was directed into the aneurysm, filled with HEMA, and detached. Follow-up angiography performed the next day demonstrated total occlusion of the aneurysm (Fig. 4 right). There was normal filling of the cavernous and supraclinoid carotid artery distal to the aneurysm, and the patient was discharged home in stable condition. At her 4-month follow-up examination, the patient was clinically stable with alleviation of headaches and pain.

Summary of Results

Between 1981 and 1989, a total of 87 patients were treated by endovascular detachable balloon embolization techniques for an intracavernous aneurysm. In 68 cases (78.2%), following a test occlusion of the cervical ICA for patient tolerance, treatment was performed by primary occlusion of the ICA with balloons across or just proximal to the aneurysm neck. Only two patients did not tolerate the test occlusion and required an extracranial-intracranial (EC-IC) bypass procedure. Complications in this subgroup of 68 patients included transient cerebral ischemia following balloon occlusion
Endovascular embolization for intracavernous aneurysms

therapy in seven (10.3%). Of these seven patients, five had symptoms of global hemispheric ischemia with transient hemiparesis and/or sensory deficits which responded to volume expansion; the other two patients had symptoms of visual disturbance with evidence of retinal emboli and received antiplatelet therapy with resolution of symptoms.

Three (4.4%) of the 68 patients developed a stroke following balloon occlusion therapy. One of these patients did not tolerate initial test occlusion and underwent an EC-IC bypass procedure followed by balloon occlusion therapy. This patient subsequently suffered a seizure then a stroke 48 hours after carotid artery occlusion. The second patient initially did well following carotid artery occlusion therapy, but 6 weeks later developed a delayed embolic stroke of the ipsilateral middle cerebral artery. She was managed with heparin and volume expansion, and 2 years later has mild residual weakness and a mild expressive dysphasia. The third patient presented with a subarachnoid hemorrhage (SAH) due to rupture of an intracavernous aneurysm which extended into the subarachnoid space. She initially did well following carotid artery occlusion therapy; however, 7 days later she developed a urinary tract infection with sepsis and hypotension, and suffered an ischemic infarct of the ipsilateral hemisphere with a dense hemiparesis.

Two (2.9%) of the 68 patients had an aneurysm with a broad-based neck and were initially treated by placement of balloons within the aneurysm. Subsequent follow-up studies demonstrated occlusion of the ICA, but the patients remained clinically stable. All other patients have done well following balloon occlusion therapy, and at 1 to 3 and 3 to 12 months after surgery most demonstrated thrombosis of the aneurysm with alleviation of mass effect. In giant aneurysms with heavy calcification of the walls, thrombosis of the aneurysm was demonstrated by CT and/or MR imaging; however, decrease in size and mass effect was not as apparent. In spite of this, there was alleviation of symptomatic headache and pain following occlusion therapy.

In 19 (22%) of the total 87 patients, direct balloon embolization of the cavernous aneurysm was performed with preservation of the ICA. In four patients, rupture of an intracavernous aneurysm resulted in a carotid cavernous-sinus fistula. Direct placement of a balloon into the aneurysm was performed to close both the aneurysm and the fistula. The remaining 15 patients had symptoms of mass effect and/or thromboembolic episodes. Complications in this group included transient cerebral ischemia following balloon therapy in two patients (managed by volume expansion), and a thromboembolic stroke in one patient due to inadvertent rupture of the balloon within the aneurysm during inflation. At the 1-year follow-up examination the latter patient had residual hemiparesis and a mild expressive aphasia. In seven patients, complete obliteration of the aneurysm was not obtained; follow-up angiography demonstrated greater than 85% occlusion with some opacification of the aneurysm base or around the periphery of the balloon. In four patients subsequent follow-up studies showed a shift of the balloon within the aneurysm requiring a second balloon occlusion procedure. Particularly in cases of a giant aneurysm, which requires more than one balloon or in which a large amount of thrombus is present, follow-up studies may demonstrate a change in the balloon position with opacification of portions of the aneurysm.

Discussion

Aneurysms arising from the intracavernous portion of the ICA usually present with symptoms of headache, retro-orbital pain, and mass effect, with compression of the adjacent third, fourth, and sixth, and divisions of the fifth cranial nerves. The majority of patients we treated (69 of 87 cases, or 79.3%) presented in this fashion. If rupture does occur it usually results in a carotid-cavernous sinus fistula; this was present in eight of our cases (9.2%), with the clinical presentation of proptosis, retro-orbital bruit, chemosis, and visual decline. Only rarely, if the aneurysm protrudes into the carotid cistern and subarachnoid space does SAH result; this occurred only once in our series. Giant aneurysms may occasionally compress the optic nerve and chiasm resulting in visual disturbance, or they may lead to thromboembolic complications; six patients in our series (6.9%) presented in this fashion. The other common cause for an intracavernous aneurysm is trauma, which was the etiology in seven (8.0%) of our patients.

In the past, therapeutic approaches have included common carotid artery or cervical ICA ligation by use of various clamps, including those of Selverstone, Crutchfield, and Saliba. The incidence of complications in patients treated by this technique has varied. In the report by Scott and Skwarok, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%. A fairly substantial incidence of late complications has been described following cervical carotid ligation with clamps, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%. A fairly substantial incidence of late complications has been described following cervical carotid ligation with clamps, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%. A fairly substantial incidence of late complications has been described following cervical carotid ligation with clamps, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%. A fairly substantial incidence of late complications has been described following cervical carotid ligation with clamps, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%. A fairly substantial incidence of late complications has been described following cervical carotid ligation with clamps, in which 909 patients were reviewed, the operative mortality rate was 6% for ICA ligation and 11% for common carotid artery ligation. The overall morbidity from ICA ligation was an additional 22% and for common carotid artery ligation 11%.
rysm and Parkinson described direct operative exposure of the cavernous sinus under hypothermia and cardiac arrest for surgical clipping. However, due to the usual benign course of aneurysms in this location, such aggressive therapy has not been widely advocated.

Over the past several years, treatment of cavernous and intracranial aneurysms by means of endovascular occlusive techniques has been described from various centers. In 1974, Serbinenko reported 82 patients who were successfully treated by occlusion of the carotid siphon by latex detachable balloons. In 1981, Debrun, et al., described the successful occlusion of giant unclippable aneurysms involving the carotid artery in eight patients. In 1982, Romodanov and Shcheglov reported 137 patients treated by endovascular balloon embolization, of whom 67 were treated for an ICA aneurysm. In 49 (73%) of these 67 cases they were able to successfully occlude the aneurysm and preserve the parent vessel. Their series had a mortality rate of 8.95% and a morbidity rate of 4.48%. In 1984, Kupersmith, et al., and Berenstein, et al., reported a total of 12 patients treated by balloon occlusion techniques without any serious or permanent neurological complication. In 1987, Fox, et al., reported 68 patients with unclippable aneurysms (of which 37 were infraradion in origin) treated by proximal artery occlusion with detachable balloons. They reported nine cases (13.2%) of delayed cerebral ischemia, with only one instance of permanent stroke in their series.

In our current series treated by detachable-balloon embolization, we report an overall morbidity rate for transient ischemic of 10.34% due to ischemia or embolus, and a permanent morbidity rate of 4.6%; there were no deaths. Endovascular detachable balloon occlusion therapy has several advantages over Hunterian ligation by carotid clamping or direct operative exposure. The patient is awake for the entire procedure, since it is performed under local anesthesia from a transfemoral arterial approach. Continuous neurological monitoring of the patient can therefore be performed during test occlusion and during positioning of the balloon prior to detachment. If the test occlusion is not tolerated or if arterial back-pressures are too low, the possibility of an EC-IC bypass procedure can be assessed.

In general, we prefer neurological testing for at least 30 minutes with arterial pressures greater than 40 mm Hg prior to balloon occlusion of the carotid artery. This correlates with the recommendations of Miller, et al., who established criteria for carotid occlusion by clamping. Since the balloon is placed across or at the neck of the aneurysm, there is far less risk of the aneurysm filling from collateral branches of the infarolateral trunk, meningohypophyseal trunk, or a low origin of the ophthalmic artery. In our current series, all patients treated by detachable balloon embolization of the carotid artery demonstrated aneurysmal thrombosis. Since occlusion is performed at the aneurysmal neck, there is presumably a lower incidence for delayed washout of emboli during thrombosis of the aneurysm and carotid artery.

In our subseryes of patients treated by direct balloon embolization of the aneurysm, complete occlusion has been obtained in 63.2%; those patients with subtotal occlusion continue to be monitored. We believe that, if an aneurysm does have a well-defined neck, it is feasible to guide a balloon directly into the aneurysm, fill it with a polymerizing substance, and occlude the aneurysm while maintaining patency of the parent vessel. Several centers have successfully shown that this is a viable technique for treating patients with intracranial aneurysms.

In regard to the type of balloons utilized for endovascular occlusion therapy, we favor the use of silicone over latex balloons for several reasons. Silicone balloons are inherently softer and more pliable within a blood vessel than latex. It will therefore tend to conform to the shape of the vessel or aneurysm with less tendency for rupture of the vessel. Silicone is also biocompatible and the shell will not degrade over time within the vessel as latex does. For direct balloon embolization of an aneurysm, we have found that HEMA is an excellent agent to polymerize and solidify the silicone balloon. Preliminary studies have shown that HEMA may cause early degradation of latex balloons, which may result in premature rupture during the exchange or curing of HEMA within the latex balloon. In conclusion, we believe that treatment of symptomatic aneurysms of the cavernous ICA can be effectively treated by endovascular detachable balloon embolization therapy. The short- and long-term morbidity and mortality rates are better than those associated with ligation by carotid clamping techniques. If carotid test occlusion is not tolerated, either due to global ischemia during the monitoring procedure or because arterial back-pressures are too low, an EC-IC bypass procedure followed by a second test occlusion is warranted prior to balloon occlusion. If an aneurysmal neck can be identified, we consider that direct balloon occlusion of the aneurysm with preservation of the parent artery is warranted. However, long-term follow-up monitoring, both clinically and radiographically, is still required for these patients to insure continued aneurysm occlusion by this technique.

References


R. T. Higashida, et al.
Endovascular embolization for intracavernous aneurysms


J Neurol Neurosurg Psychiatry 40:64–72, 1977


Manuscript received August 10, 1989.
Accepted in final form November 24, 1989.
Address reprint requests to: Randall T. Higashida, M.D., Department of Radiology, University of California Medical Center, 305 Parnassus Avenue, L-352, San Francisco, California 94143-0628.