Update on Transluminal Angioplasty of Vasospasm

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The recent development of transluminal angioplasty for the treatment of symptomatic cerebral vasospasm following subarachnoid hemorrhage has generated considerable interest over the past 2 years. Recent promising reports by Eskridge[1] and Hagashita et al.[2] have led to more widespread use of this mode of treatment, originally described in 1984 by Zubkov, Nikiforov, and Shustin[3] from the Soviet Union. There is considerable follow-up data available from the North American and Japanese experience since these original papers, but as of yet, there has been no significant follow-up from the original series.

Interest in this technique results from the high morbidity and mortality associated with symptomatic cerebral vasospasm. Delayed ischemic deficit occurs in approximately one third of those patients who survive the initial hemorrhage.[4,5] The pathophysiology of vasospasm remains poorly understood. Theories include increase in vascular tone in the vessel wall, intimal proliferation and myonecrosis, and contraction of the vessel wall with subsequent intimal hypertrophy.[6-8] Despite much research, the development of numerous pharmacological agents, and increased interest in early surgery once the delayed ischemic deficit occurs, no entirely effective agent or protocol has been discovered.[9-11]

Angioplasty refers to the mechanical dilation of a vessel by an inflatable intravascular balloon. The technique is similar to that which has been successfully used for dilatation of coronary and peripheral arteries, except it requires much less balloon inflation pressure to dilate intracranial arteries with vasospasm than to dilate atherosclerotic arteries. The low-pressure balloons used for intracranial vasospasm are much less likely to damage endothelium than the high-pressure balloons required to dilate vessels with atherosclerotic disease.

RECENT DEVELOPMENTS

We have continued to successfully use angioplasty for the treatment of vasospasm at the University of Washington.[12] Our criteria for selecting patients for this treatment include (1) new onset of a neurological deficit after sub-

arachnoid hemorrhage that is not attributable to other causes (e.g., hydrocephalus, hematoma, mass effect); (2) no evidence of infarction on computed tomography (CT) within the previous 12 hours; (3) neurological deficit not reversed by hypervolemic, hypertensive therapy; and (4) angiographically visible vasospasm in a location that could explain the neurological deficit.

The timing of angioplasty relative to the onset of symptoms remains important. Angioplasty should be performed soon after the onset of the deficit, with the most dramatic improvements occurring when angioplasty is performed within 6 to 12 hours. Complete recoveries, however, can occur when as much as 48 hours have elapsed between neurological deterioration and angioplasty.[12]

We still feel it is vitally important for the aneurysm to be clipped before angioplasty. In our original series only two patients had unclipped aneurysms when angioplasty was performed.[12] Both of these patients rebled and died while they were awaiting surgery. There is no doubt that the marked increase in cerebral perfusion that follows angioplasty can increase the risk of rehemorrhage from an unprotected aneurysm. Patients who are transferred to our institution with severe cerebral vasospasm caused by hemorrhage from an unclipped aneurysm undergo repeat angiography as soon as they arrive. They are then taken to surgery where the aneurysm is clipped and returned immediately to the angiography suite where angioplasty is performed.

At the present time 22 patients have been treated with angioplasty, and there has been a marked improvement in neurological status in 16 of these patients. Improvement has been defined as a two-level increase in Glasgow Coma Scale or a two-level increase in motor strength within 48 hours. There have been no delayed complications other than the one originally reported, which was delayed thrombosis of a previously dilated middle cerebral artery M2 branch that occurred following rupture of an experimental high-pressure balloon within the vessel.[12] Immediately following angioplasty, the patient's right hemiparesis resolved. The patient returned 6 weeks later with a small middle cerebral distribution infarct and mild right upper extremity paresis. At that time angiography revealed thrombosis of the middle cerebral branch in which the high-pressure balloon had ruptured. Over the next week the patient made a full recovery from the arm weakness.

Two patients in this series have returned for follow-up angiography at 18 months (Figs. 1 and 2). These patients remain normal neurologically, and the previously dilated vessels remain normal angiographically. Two other patients with clinical follow-up evaluation at 18 months also are doing well and remain normal. Based on this information, we do not think there will be any long-term damage to the endothelium of these dilated vessels.

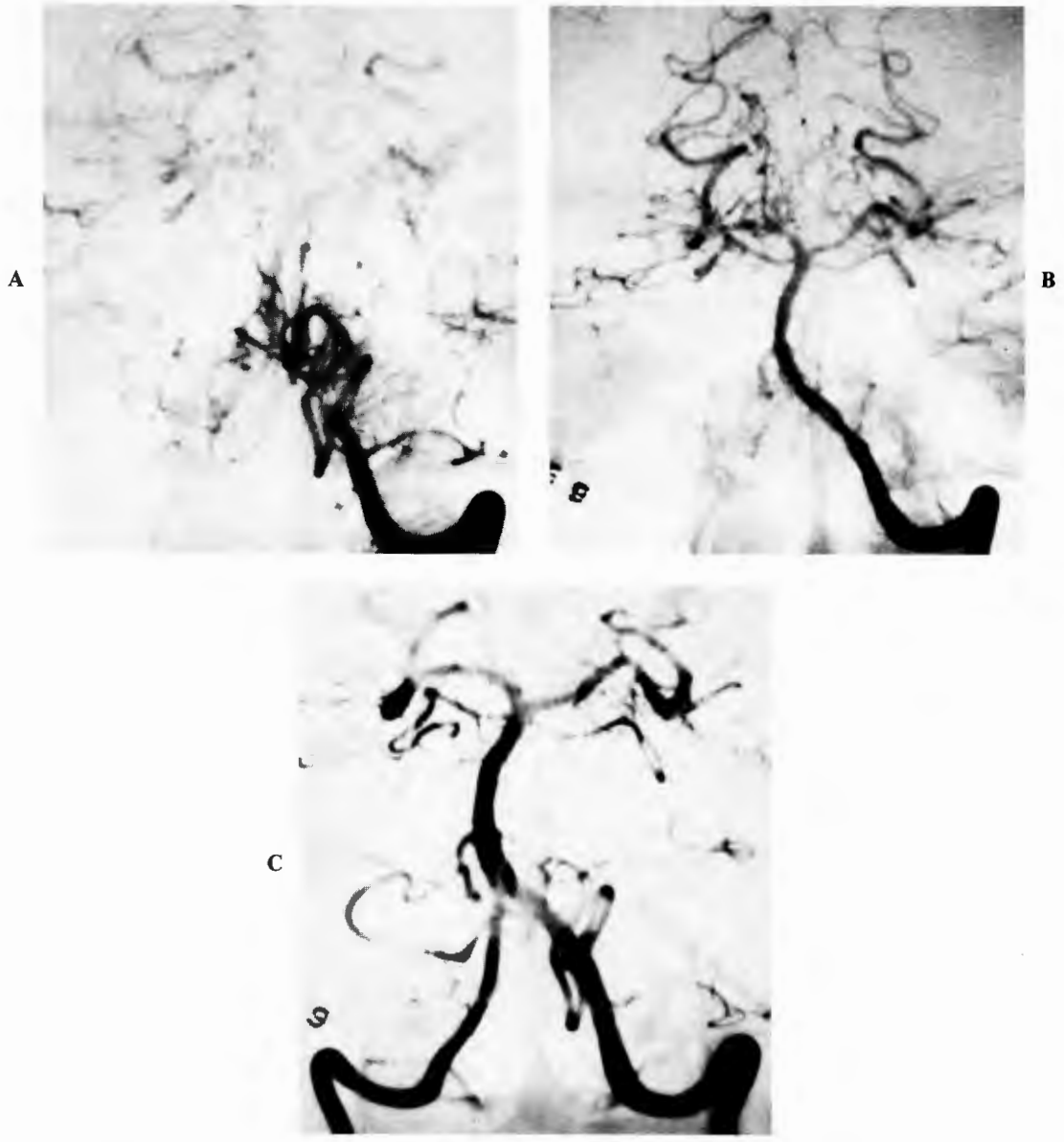

Fig. 1 A 48-year-old woman became comatose, unresponsive, and had a respiratory arrest 6 days after subarachnoid hemorrhage from a left ophthalmic artery aneurysm that was treated 2 days after the hemorrhage. **A,** Left vertebral angiography demonstrates severe vasospasm of the distal left vertebral and proximal basilar artery with severe flow restriction. **B,** Immediately after angioplasty of the vertebral basilar system, the arteries are widely patent and normal flow has been reestablished. Within 12 hours the patient was normal neurologically and extubated. **C,** Angiography 18 months later shows that the vertebral basilar system is normal. The patient remains normal neurologically.

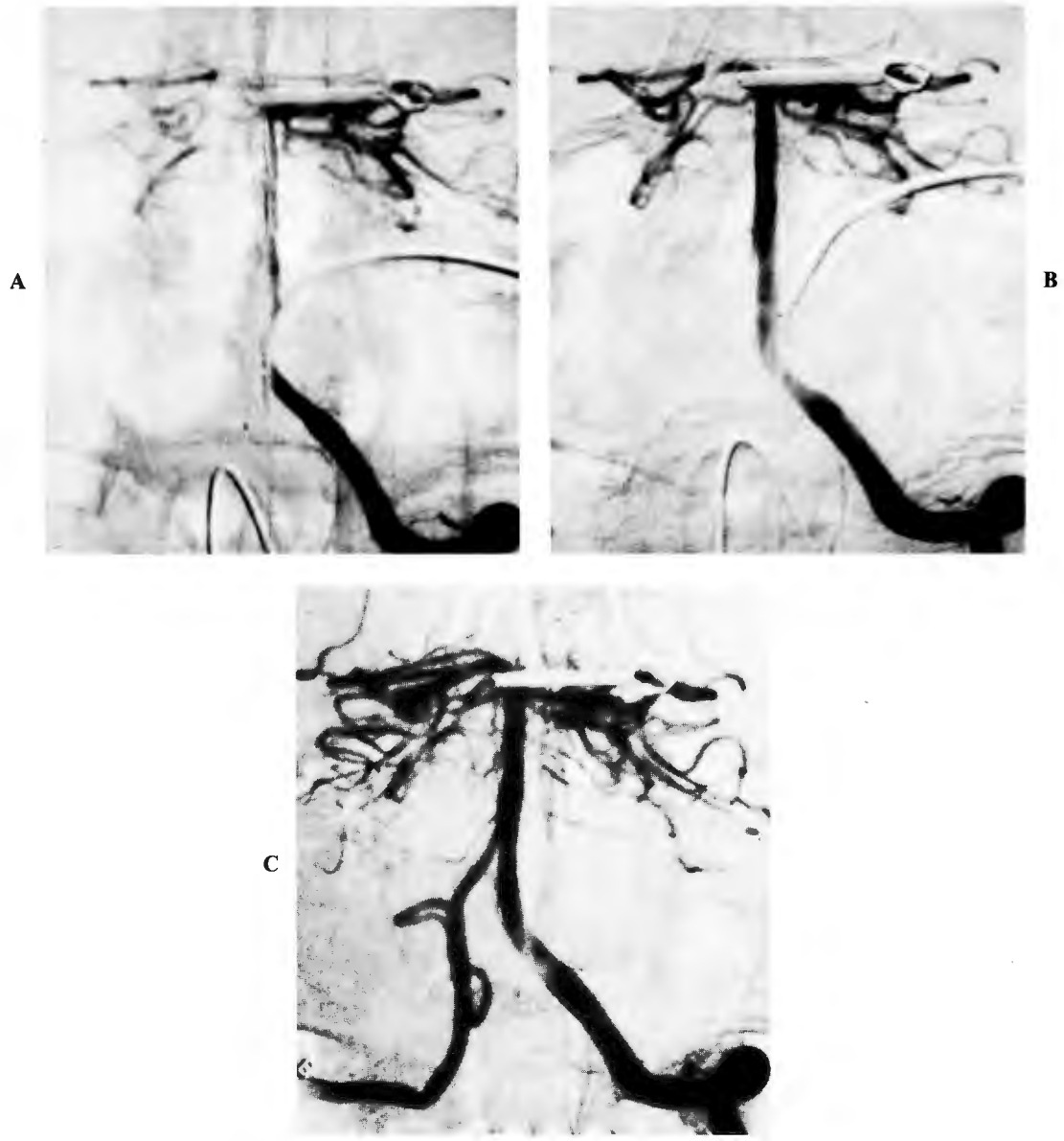

Fig. 2 A 44-year-old man hemorrhaged from a basilar tip aneurysm, which was clipped the following day. Seven days later he became comatose, unresponsive, and had a respiratory arrest. **A,** Angiography reveals severe spasm of the entire basilar artery. **B,** Immediately following angioplasty, the caliber of the basilar artery is normal and normal blood flow has been reestablished. The patient recovered over the next 3 days and was normal neurologically when he was discharged 10 days later. **C,** The patient remains normal neurologically 18 months later and angiography shows that the vertebral basilar system is normal.

NATIONAL AND INTERNATIONAL RESULTS

Recent reports from Japan support the initial experience in the United States. One Japanese series of 20 patients undergoing angioplasty showed improvement in two thirds of patients.[13] Another report showed increased cerebral perfusion following angioplasty for cerebral vasospasm when measured by xenon-133.[14] More centers in the United States are beginning to perform angioplasty for cerebral vasospasm. Unfortunately, at many of these centers individuals trained in endovascular techniques are not available. This has resulted in a number of serious complications. Most notably, there have been a number of anecdotal reports of fatalities caused by overdistention and rupture of intracranial arteries.

The primary error in these cases seems to have been the use of a balloon with a diameter larger than the size of the artery before it developed vasospasm. A basic principal of angioplasty is that a vessel should not be dilated beyond its prestenotic, normal diameter. In many cases vasospasm angioplasty was performed with a balloon diameter more than twice the diameter of the basilar artery before it developed vasospasm. Another error is placing the balloon out beyond the A1 segment of the anterior cerebral and the M2 segment of the middle cerebral arteries where the diameter of the inflated balloon greatly exceeds the size of the normal distal anterior and distal middle cerebral arteries. The present 0.85 mm silicone balloon (Interventional Therapeutics Corporation, South San Francisco, Calif.) is adequate for dilatation of the vertebrobasilar system and proximal posterior cerebral, supraclinoid carotid, proximal anterior cerebral, and proximal middle cerebral arteries.

TECHNICAL DEVELOPMENTS

Advances in silicone balloon technology have resulted in curved balloons into which steerable, curved guidewires can be advanced. This makes entry into A1 branches of the anterior cerebral artery more routinely possible. This also allows selective dilatation of both proximal posterior cerebral arteries.

A slightly higher pressure polyethylene balloon (Target Therapeutics Corporation, San Jose, Calif.) has been developed that has the advantage of greater steerability related to the ability to pass a guidewire through the balloon. This balloon also uses a slightly higher inflation pressure, which sometimes is necessary to dilate more chronic vasospasm where fibrosis has developed within the vessel wall. This fibrosis results in a stiffer vessel that the low pressure silicone balloon cannot dilate. Unfortunately, production

of this polyethylene balloon is bogged down with regulatory restraints and may not be available for some time.

CONCLUSION

Angioplasty as a technique for treating cerebral vasospasm continues to show promising results at the major institutions in North America and Japan. It will continue to be a valuable tool in the effort to combat cerebral vasospasm following aneurysmal subarachnoid hemorrhage. When the procedure is performed by properly trained individuals, it is a safe and effective therapeutic modality.

If more untrained personnel perform this procedure, more anecdotal reports of complications can be expected. As these individuals gain experience, the complication rate should decrease.

The single most important factor for the safety of the procedure is to avoid using a balloon with a diameter larger than the diameter of the parent vessel before the development of vasospasm. The 2.5 to 3.0 mm diameter balloons suffice for all intracranial vessels.

Another important factor in safety is to avoid catheterizing vessels beyond the A1 segments and proximal M2 segments with the currently available balloons. When smaller balloons become available, this may be feasible.

The importance of performing angioplasty soon after the patient becomes symptomatic cannot be overemphasized. The best results occur when the vessels are dilated within 6 to 12 hours after the symptoms begin. At our institution all patients with subarachnoid hemorrhage have intracranial arterial velocities monitored with transcranial Doppler. When velocities increase, indicating early vasospasm, treatment is initiated with standard hypervolemic and hypertensive therapy in addition to calcium channel blockers. If the vasospasm progresses and the patient deteriorates neurologically in the face of maximal medical therapy, the patient is taken immediately for angioplasty.

Unfortunately at some institutions hypervolemic and hypertensive therapy is initiated after the delayed ischemic deficit occurs. There is a tendency to wait and see if this medical therapy will reverse the symptoms. If this does not occur, the patient is then considered for angioplasty. Unfortunately, the long delay reduces the effectiveness of this technique. More widespread use of transcranial Doppler velocity measurements will hopefully result in earlier detection and treatment of vasospasm.

Overall, the future of balloon angioplasty for the treatment of cerebral vasospasm looks promising. This technique should continue to have a major, positive impact in the management of subarachnoid hemorrhage.

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