Transluminal angioplasty for atherosclerotic disease of the vertebral and basilar arteries

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Transluminal angioplasty for hemodynamically significant stenosis (>70%) involving the posterior cerebral circulation is now being performed by the authors in selected cases. A total of 42 lesions affecting the vertebral or basilar artery have been successfully treated by percutaneous transluminal angioplasty techniques in 41 patients. The lesions involved the proximal vertebral artery in 34 cases, the distal vertebral artery in five, and the basilar artery in three. Patients were examined clinically at 1 to 3 and 6 to 12 months after angioplasty. Three (7.1%) permanent complications occurred, consisting of stroke in two cases and vessel rupture in one. There were four (9.5%) transient complications (<30 minutes): two cases of vessel spasm and two of cerebral ischemia. Clinical follow-up examination demonstrated improvement of symptoms in 39 cases (92.9%). Radiographic follow-up studies demonstrated three cases (7.1%) of restenosis involving the proximal vertebral artery; two were treated by repeat angioplasty without complication, and the third is being followed clinically while the patient remains asymptomatic.

In patients with significant atherosclerotic stenosis involving the vertebral or basilar artery territories, transluminal angioplasty may be of significant benefit in alleviating symptoms and improving blood flow to the posterior cerebral circulation.

KEY WORDS • percutaneous transluminal angioplasty • interventional neuroradiology • atherosclerosis • stroke • brachiocephalic angioplasty

Percutaneous transluminal angioplasty (PTA) techniques to treat high-grade hemodynamically significant lesions involving the extracerebral and intracranial territories have slowly evolved into a viable treatment alternative over the past decade. A growing number of centers in North America, Europe, and Japan have reported on the excellent clinical, radiographic, and hemodynamic improvement that PTA can provide. In 1980, Sundt et al. reported the first successful treatment of basilar artery atherosclerotic stenosis by transluminal angioplasty. Courtheoux et al., Theron and coworkers, Higashida and coworkers, Tsai et al., and others have since reported series of patients successfully treated by these techniques in the brachiocephalic territory. The technique of PTA has been slower to evolve for lesions affecting the posterior circulation due to the potential risk of distal embolization to the central nervous system which may result in thromboembolic stroke or ischemia to the brain. However, with improvements in microballoon and catheter technology, high-resolution radiographic imaging, proper neurological monitoring, and patient selection, PTA of the proximal and distal vertebral artery and of the basilar artery can now be performed.

Clinical Material and Methods

Patient Selection

Transluminal balloon angioplasty was performed in 41 patients (18 female and 23 male) for clinically symptomatic, hemodynamically significant (defined as >70% stenosis), atherosclerotic lesions involving the vertebral or basilar arteries. A total of 42 vascular territories were treated, including 34 proximal vertebral artery lesions (in one patient both the right and left vertebral
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Arteries were treated, five distal vertebral artery lesions located between the C-1 and C-3 segments, and three basilar artery lesions.

Clinically, the presentation varied: patients exhibited symptoms of posterior fossa cerebral ischemia including dizziness, diplopia, ataxia, nausea, vomiting, vascular headaches, bilateral facial numbness, cortical blindness, memory disturbance, and/or nystagmus; stroke secondary to thromboemboli to the brain stem, cerebellum, or occipital lobe; or altered mental status due to verteobasilar insufficiency. All patients were initially managed by medical therapy including antplatelet medications and/or anticoagulation drugs consisting of heparin or warfarin. Only if patients failed to respond to medical therapy were they considered for PTA.

Radiological Evaluation

Baseline radiographic studies included a magnetic resonance (MR) image or computerized tomography (CT) scan of the brain, with close evaluation of the posterior fossa and brain stem. Angiography was performed to evaluate the subclavian and vertebral arteries bilaterally as well as the intracranial distribution of the posterior and anterior circulation in order to determine if symptoms were secondary to ischemia from a hemodynamically critical stenosis or to a thromboembolic stroke with occlusion of an intracranial vessel. Angiography was also important in evaluating the collateral circulation beyond the lesion. Since only one vertebral artery may be critically narrowed, it is useful to study the contralateral vertebral artery to determine if there is sufficient blood flow to obviate the need for interventional or surgical therapy.

Endovascular Technique

In 39 cases the endovascular technique was performed from a transfemoral approach under local anesthesia. In one case the stenosis site was difficult to reach and a transaxillary approach was utilized. In two cases intraoperative exposure of the C-1 vertebral artery was performed, followed by PTA via direct puncture of the vertebral artery under general anesthesia. Both of these operations were performed prior to the availability of the newer PTA microcatheter balloon systems.

The balloon diameter for angioplasty was determined by measuring the normal caliber of the vessel both above and below the site of stenosis; the diameter of the balloon chosen approximated but did not exceed the normal luminal diameter. Typically, for lesions involving the proximal and mid-vertebral artery, the balloon diameter ranged from 3 to 6 mm and an over-the-wire PTA device was used.* For lesions involving the distal vertebral or basilar artery, the balloon diameter ranged from 2 to 4 mm (in 0.50-mm increments), and an over-the-wire PTA microballoon system was utilized† (Fig. 1).

* Catheters manufactured by Medi-Tech, Watertown, Massachusetts; Olbert, Meadow Surgimed, Oakland, New Jersey; and Cordis Corp., Miami Lakes, Florida.
† Transluminal balloon system manufactured by Target Therapeutics, Fremont, California.

In all cases involving the transfemoral or transaxillary approach, a sheath was inserted into the artery and systemic anticoagulation was achieved by giving intravenous heparin (5000 U for a 70-kg patient) and determining the activated clotting time (1.5 to 2.0 times the baseline value). A diagnostic catheter was then guided to the site of stenosis, and an angiographic “road map” made of the lesion. This road map displays the vascular anatomy on the fluoroscopic monitor and simultaneously allows real-time fluoroscopy over this image. An exchange guidewire (length 300 cm, diameter 0.035 in. for larger lesions and 0.016 in. for smaller lesions) was then placed across the lesion and into the distal segment of the artery. The PTA balloon catheter was then placed over the guidewire, across the stenosis site. The balloon was then inflated up to the maximum recommended balloon pressure of 6 to 12 atm for less than 10 to 20 seconds. Fluoroscopy should reveal a definite dilatation of the lesion; if this was not seen, then a second or third dilatation is performed. In order not to induce further ischemia in an already compromised area, it is better to inflate the balloon for less than 10 to 20 seconds for lesions involving the extracranial and intracranial territories.23

Pre- and Postangioplasty Evaluation

Following angioplasty, arteriography was performed to assess the degree of dilatation obtained, to look for evidence of intimal and medial damage, and to evaluate the intracranial circulation for signs of distal embolization. Careful evaluation was performed in the neurological observation unit before and immediately after angioplasty, then for 24 to 48 hours following the procedure. If their condition was stable, patients were discharged home and received aspirin and/or dipyridamole for at least 6 months.
Patients were followed clinically 1 to 3 months and 6 to 12 months after angioplasty. Follow-up Doppler ultrasound studies, MR-angiography, and/or conventional angiography were also performed to assess the long-term results of therapy.18,34

**Illustrative Cases**

**Case 1: Proximal Vertebral Artery Angioplasty**

This 41-year-old man presented with the sudden onset of severe headache, vomiting, unsteadiness, and abrupt changes in vision. An MR image demonstrated a right infaromedial cerebellar infarct in the distribution of the right posterior inferior cerebellar artery. Two weeks later, he had recurrence of headache, nausea, vomiting, and vertigo. A second MR image revealed a new left infaromedial cerebellar infarct in the distribution of the left posterior inferior cerebellar artery. In both instances a lumbar puncture showed no evidence of acute hemorrhage. Physical examination was significant for diminished temperature sensation in the right side of the body and diminished pinprick sensation on the left.

Cerebral arteriography demonstrated complete occlusion of the right vertebral artery. In addition, there was a high-grade stenosis of greater than 75% involving the proximal left vertebral artery (Fig. 2 left). A 4.0-mm PTA balloon catheter was navigated across the stenosis via a transfemoral arterial approach, dilatation of the stenosis was performed for 8 seconds, and the balloon was rapidly deflated. The postangioplasty arteriogram demonstrated wide patency at the angioplasty site, with excellent blood flow to the distal posterior circulation (Fig. 2 right). The patient was discharged home several days later in stable condition with no further neurological symptoms.

**Case 2: Distal Vertebral Artery Angioplasty**

This 57-year-old man presented with sudden loss of vision involving the left eye and difficulty with vision in the right eye. Physical examination demonstrated a right inferior temporal field cut and a left superior and inferior temporal field cut. Cerebellar testing disclosed incoordination on finger-to-nose testing and rapid alternating motions. His medical history was significant for diabetes and hypertension.

An MR image and CT head scan demonstrated small focal areas of cerebral infarction involving both occipital lobe territories. Cerebral angiography revealed complete occlusion of the left vertebral artery; in addition, there was a high-grade stenosis of greater than 80% involving the distal right vertebral artery just proximal to the right posterior inferior cerebellar artery (Fig. 3 left). Clinically, it was determined that this patient had suffered both thromboembolic and posterior fossa ischemic symptoms due to the stenosis.

A 3.5-mm PTA balloon was introduced via a transfemoral approach and three dilatations were performed without any focal complications. The post-angioplasty arteriogram demonstrated a widely patent distal vertebral artery, with excellent distal blood flow (Fig. 3 right). The patient was discharged on a course of aspirin therapy alone and has exhibited no further recurrent symptoms on follow-up examination.

**Case 3: Basilar Artery Angioplasty**

This 52-year-old man, who had suffered two previous myocardial infarctions at the ages of 38 and 40 years, presented with the acute loss of consciousness. He was in a coma for several days, and clinical workup demonstrated a brain-stem infarction. He was treated with anticoagulation therapy and eventually regained consciousness, although he was left with residual ataxia,
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FIG. 4. Case 3. Angiograms in a patient presenting with brain-stem and posterior fossa stroke. Left: High-grade stenosis due to atherosclerosis of the mid-basilar artery is seen (arrow). Right: Following angioplasty with a 2.5-mm followed by a 3.0-mm angioplasty balloon catheter, the luminal caliber of the artery is improved (arrow).

inability to walk, right hemiparesis, and partial cortical blindness. An MR image demonstrated bilateral occipital lobe infarctions and a thalamic stroke. Cerebral angiography revealed a high-grade (> 80%) stenosis of the mid-basilar artery due to atherosclerosis (Fig. 4 left). Under local anesthesia, a 2.5-mm angioplasty balloon was introduced via a transfemoral approach to dilate the basilar artery stenotic lesion. This resulted in only mildly increasing the luminal diameter; therefore, a second angioplasty was performed using a 3.0-mm PTA balloon. This resulted in a 60% to 70% improvement in luminal diameter of the basilar artery (Fig. 4 right).

Follow-up cerebral angiography and transcranial Doppler ultrasound studies demonstrated continued patency at the angioplasty site. Clinical follow-up examination at 1 year showed continued improvement of the patient's neurological status with reduction of the hemiparesis enabling him to walk by himself. His cognition and memory have increased and he has now returned to part-time work.

Results

Percutaneous transluminal angioplasty was successfully performed in 42 cases for critical and symptomatic stenosis, with postoperative improvement (< 30% residual stenosis) on follow-up angiographic studies. The lesions included 34 affecting the proximal vertebral artery, five the distal vertebral artery, and three the basilar artery. On post-dilatation angiograms no distal occlusions of major branches were observed intracranially.

Proximal Vertebral Artery Stenosis

The 34 lesions involving the proximal vertebral artery were associated with three (8.8%) transient and no permanent complications. Two of the transient complications consisted of arterial spasm following angioplasty, which resolved with treatment by intra-arterial nitroglycerin (400 to 500 μg over 30 minutes). One patient experienced a transient cerebral ischemia (TIA) following bilateral staged angioplasty of both the right and left vertebral arteries for critical stenosis involving both proximal vertebral arteries. This TIA resolved after 30 minutes of continued neurological observation.

Follow-up radiography demonstrated three patients (8.8%) with restenosis which occurred 2, 3, and 5 months postangioplasty. Two of these patients were treated by a second angioplasty procedure and continue to do well; the third patient remains asymptomatic, and is therefore being followed clinically. Long-term follow-up examination at 6 to 12 months disclosed improvement of symptoms in all but one patient, who died from rupture of a distal left vertebral artery aneurysm unrelated to the PTA treatment for a right vertebral artery lesion.

Distal Vertebral Artery Stenosis

Five patients were treated for a distal vertebral artery stenosis, occurring between the C-1 and C-3 portion of the artery. There were two major complications in this group, both in patients whose contralateral vertebral artery was occluded, with progressive neurological deterioration at the time of treatment. One of these patients had vessel occlusion and died as a result of stroke 48 hours following the procedure; the second patient suffered vessel rupture and died several months later due to other medical complications. One minor complication occurred due to transient basilar artery ischemia resulting in a TIA during the procedure, which resolved after 30 minutes of continued observation. Follow-up examination in this group of patients demonstrates improvement in the three patients who presented with symptoms of vertebrobasilar insufficiency.

Basilar Artery Stenosis

Three patients were treated for symptomatic basilar artery stenosis, refractory to medical therapy. One permanent complication occurred following direct intraoperative exposure of the C-1 vertebral artery, with PTA performed via direct puncture of this segment under general anesthesia. Although the procedure resulted in a widely patent basilar artery on follow-up angiography, the patient suffered from a pontine stroke following the procedure, presumably due to occlusion of brain stem-perforating vessels arising from the treated segment. This patient died 6 weeks later.

Two other patients were treated with a newer PTA balloon system via a transfemoral approach under local anesthesia with close neurological monitoring. These patients continue to do well on long-term follow-up evaluation.

Discussion

Symptomatic posterior fossa stenotic lesions can now be approached by endovascular techniques. Technological improvements in balloon catheter systems, microguidewires, and flexible introducing microcatheters

† Stealth PTA balloon system manufactured by Target Therapeutics, Fremont, California.
have facilitated safer access across intracranial and extracerebral territories. The majority of patients presenting with symptoms of posterior fossa ischemia can be managed by medical therapy consisting of anticoagulation and antiplatelet medications. Most patients tolerate occlusion of one vertebral artery due to sufficient blood flow from the contralateral side; however, for patients with stenosis of both vertebral arteries, severe narrowing of the basilar artery, or long segments of stenosis with irregularity and evidence of thromboemboli, PTA may be a viable alternative to improve blood flow to the posterior circulation and reduce the risk of distal embolization.

Patient Evaluation for Angioplasty

Angioplasty involving the extracranial and intracranial territories differs from that in other regions of the body. It is important initially to screen symptomatic patients by noninvasive tests as well as angiography. It is also important to obtain an MR image or CT scan before considering PTA in order to evaluate for hemorrhagic versus nonhemorrhagic infarction, and to assess ischemic changes in the involved areas. Hemorrhagic stroke is a contraindication to immediate anticoagulation; therefore, angioplasty should not be performed in the acute setting. In patients with impending stroke, such as those with crescendo TIA's, in spite of full anticoagulation therapy, emergency angioplasty or surgical intervention should be seriously considered.

Meticulous angiography is required of both the right and left vertebral arteries as well as the anterior circulation. Occlusion or near-occlusion of one vertebral artery is not sufficient to warrant an invasive procedure if there is excellent collateral blood flow from the contralateral vertebral artery or around an occlusion site. It is not uncommon to have occlusion of the proximal vertebral artery with reconstitution by cervical collateral vessels beyond the site of stenosis or by the ipsilateral external carotid artery. In addition, patients with excellent filling via the posterior communicating arteries may tolerate marked stenosis of one or both vertebral vessels.

Angioplasty for Vertebral Artery Stenosis

Thus far, several centers including ours have reported excellent results from PTA involving the proximal vertebral artery as it arises from the subclavian artery. This may be due to the fact that atheromatous lesions associated with the proximal vertebral artery tend to be smooth and non-ulcerated, in contrast to atheroma in other extracranial territories such as the proximal internal carotid artery. In the 34 patients treated by our group for proximal vertebral artery stenosis, no significant technical difficulties were encountered. One patient had a TIA following the procedure and two had arterial spasm which resolved; there was no permanent morbidity. Long-term clinical and radiographic follow-up examination demonstrated three cases of restenosis, two of which were treated by repeat angioplasty with good results.

Angioplasty of the distal vertebral artery is technically more difficult due to the tortuous bends and kinks of the high cervical portion, especially in older patients with severe atherosclerotic changes. In patients with severely narrowed vessels, merely introducing the guidewires and catheters into the vessels can compromise blood flow, which may result in cerebral ischemia. The three major complications in our series involved the distal vertebral artery and basilar artery regions.

Angioplasty for Basilar Artery Stenosis

Stenosis of the basilar artery is much more difficult to treat than proximal vertebral artery occlusion, and carries a worse prognosis. The major reason is that multiple small brain stem-perforating vessels arise from the distal vertebral artery and throughout the entire basilar artery to provide blood to the proximal spinal cord, brain stem, hypothalamus, and thalamus. Therefore, occlusion of these small perforating arteries by either atherosclerosis, thrombus, or injury to the intima and media during the angioplasty procedure can have devastating consequences and may result in infarct of the brain stem, spinal cord, or thalamus. We therefore believe that only patients who have failed maximum medical therapy with anticoagulation medications should be considered for angioplasty in this region. In one of our three cases undergoing basilar artery angioplasty, there was an excellent angiographic result following treatment, with wide patency of the basilar and distal posterior circulation. The patient, however, suffered from a pontine infarct as a result of injury to the small perforating vessels of the brain stem at the angioplasty site.

Technically, it is more difficult to reach these areas due to the acute angulation of the high cervical segment of the vertebral artery as it enters the subarachnoid space. Therefore, newer angioplasty balloon catheters on very flexible No. 2.2 French catheters and microguidewires 0.016 in. in diameter have been developed to reach these regions.

Potential Complications From Angioplasty

Potential complications specifically related to PTA of the vertebral and basilar arteries include stroke, intracerebral hemorrhage, thromboemboli, and brainstem ischemia resulting in respiratory and/or cardiac arrest, sudden changes in blood pressure due to rapid changes in blood flow to the posterior circulation, and occlusion of brain stem-perforating arteries that may not be apparent angiographically. Therefore, careful neurological monitoring throughout the procedure is mandatory. If any change in neurological status is noted, the procedure should be immediately halted and cerebral perfusion restored by removing the catheters and/or guidewires from the selected vessel. Any reduction in blood flow for longer than several minutes can result in completion of a stroke in an already compromised area of the brain. A neuroanesthesiologist should be readily available to monitor any sudden changes in blood pressure, pulse, respiration, and level of consciousness that may occur during the procedure.
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Conclusions

Transluminal angioplasty of the vertebral and basilar artery is now technically feasible in selected cases. It is important that patients first be treated by maximum medical therapy before proceeding to more invasive techniques. The majority of symptomatic lesions involve the proximal vertebral artery as it arises from the subclavian artery. These lesions can be treated by PTA techniques with relatively low morbidity. Long-term follow-up examination is still important to document patency and improvement in hemodynamic blood flow.

Distal lesions of the vertebral artery and the basilar artery are more difficult to reach. They require special microballoons and guidewires due to their extreme tortuosity. In addition, the important perforating arteries (which may not be angiographically apparent) that arise from this region and supply the brain stem and other critical areas of the brain make this territory a much more difficult region to treat, which carries significantly higher morbidity.

References

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