

Endovascular Occlusion of the Carotid or Vertebral Artery with Temporary Proximal Flow Arrest and Microcoils: Clinical Results

Virgil B. Graves, John Perl II, Charles M. Strother, Robert C. Wallace, Prabhakar P. Kesava, and Thomas J. Masaryk

PURPOSE: To determine the clinical effectiveness of parent artery occlusion of the carotid or vertebral artery by means of temporary proximal flow arrest and microcoils. **METHODS:** Nineteen parent artery occlusions (15 carotid, four vertebral) were performed in 19 patients who successfully passed a balloon test occlusion. In these patients, endovascular occlusion of the carotid or vertebral artery was accomplished with the use of temporary proximal flow arrest and microcoils. **RESULTS:** All 19 parent arteries were occluded. Eighteen patients (95%) had good outcomes and one (5%) had a poor outcome. Fourteen patients (74%) had no complications and five (26%) had complications, of whom only one was left with a permanent neurologic deficit. Three (60%) of the complications were the result of delayed ischemic events after parent artery occlusion and were not predicted by balloon test occlusion. **CONCLUSION:** Endovascular occlusion with temporary proximal flow arrest and microcoils can be done effectively and successfully. The predictive value of the balloon test occlusion is the major complicating factor, as it is with balloon occlusion. This technique offers an additional tool that can be used for endovascular occlusion of the carotid or vertebral artery and seems to be less difficult technically. It is our primary technique for parent artery occlusion.

Index terms: Arteries, therapeutic blockade; Interventional instruments, coils

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Endovascular occlusion has been used to treat a variety of aneurysms, pseudoaneurysms, traumatic injuries, carotid cavernous fistulas, presurgical tumor resections, and direct fistulas of the carotid and vertebral arteries. Historically, detachable balloons have been the most frequently used device for occlusion of these vessels (1-4). Recently, however, because of the limited availability of detachable balloons and because of the need for endovascular occlusion in patients in whom either the arterial anatomy or disease process precludes

the safe delivery of detachable balloons, a technique consisting of temporary proximal flow arrest and microcoils has been used to occlude the carotid or vertebral artery. In this article, we report the results in 19 patients in whom temporary proximal flow arrest and microcoils were used to achieve endovascular occlusion of the carotid or vertebral artery.

Materials and Methods

From May 1994 to August 1996, 19 patients underwent balloon test occlusion and subsequent temporary proximal flow arrest and endovascular occlusion with microcoils. The patients included 13 male and six female subjects who ranged in age from 2 to 81 years (mean, 44 years). Fifteen carotid arteries and four vertebral arteries were treated. Six patients had endovascular occlusion for pseudoaneurysms, six for saccular aneurysms, four for carotid cavernous fistulas, two for presurgical tumor resections, and one for a direct vertebral fistula (Table).

Balloon test occlusion, which was performed in each patient before the permanent endovascular occlusion, was done in either of two ways, depending on the institution at which it was performed. At both institutions, the prospec-

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From the Departments of Radiology (V.B.G., C.M.S., P.P.K.) and Neurosurgery (V.B.G., C.M.S.), University of Wisconsin, Madison; and the Neuroradiology Section, Department of Radiology, Cleveland (Ohio) Clinic Foundation (J.P., R.C.W., T.J.M.).

Address reprint requests to Virgil B. Graves, MD, Department of Radiology, Clinical Science Center E1/334, University of Wisconsin, 600 Highland Ave, Madison, WI 53792.

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Clinical results in group of patients in whom endovascular occlusion was performed with proximal flow arrest and microcoils

Age, y/Sex	Diagnosis	Location	Complications	Treatment	Outcome
48/M	Cavernous aneurysm	L ICA	R upper extremity paresis, hypoperfusion	STA-MCA bypass	Good
39/M	CCF	L ICA	Embolic infarct, hemiparesis	Medical	Poor
59/M	CCF	R ICA	L upper extremity paresis, hypoperfusion	STA-MCA bypass	Good
64/F	Cavernous aneurysm	L ICA	None	None	Good
2/M	Pseudoaneurysm	R ICA	None	None	Good
61/M	CCF	L ICA	None	None	Good
17/F	Cavernous aneurysm	L ICA	None	None	Good
46/F	Aneurysm	L vert	None	None	Good
35/M	Cavernous aneurysm	L ICA	TIA aphasia, hemiparesis	Volume expansion, hypertension	Good
34/M	Fistula	L vert	TIA dizziness	Aspirin	Good
52/F	Cavernous aneurysm	R ICA	None	None	Good
35/F	Pseudoaneurysm	L ICA	None	None	Good
35/M	Pseudoaneurysm	R vert	None	None	Good
47/M	Tongue carcinoma	L ICA	None	None	Good
81/F	CCF	L ICA	None	None	Good
12/M	Neck mass	L vert	None	None	Good
64/M	Pseudoaneurysm	L ICA	None	None	Good
60/M	Pseudoaneurysm	R ICA	None	None	Good
44/M	Pseudoaneurysm	R ICA	None	None	Good

Note.—ICA indicates internal carotid artery; STA-MCA, superficial temporal artery-midline cerebral artery; CCF, cavernous carotid fistula; vert, vertebral artery; and TIA, transient ischemic attack.

tive artery was test occluded in proximity to the actual site of the permanent occlusion.

At one institution (13 patients), a 5.4F Zeppelin double-lumen nondetachable balloon catheter (Medtronic Micro Interventional Systems, Sunnyvale, Calif) was used for the test occlusion. A bolus injection of 5000 U of heparin was given prior to placement and inflation of the test occlusion balloon, and the central lumen was perfused with heparinized saline (6000 U/L normal saline) during the test and coil occlusion procedures. The activated clotting time was maintained at 250 to 300 seconds during both procedures. All patients underwent neurologic testing before and throughout the balloon test occlusion at 5- to 10-minute intervals. The procedure lasted 40 minutes, with a hypotensive challenge begun at 15 minutes with a nitroprusside drip (100 μ m/mL dextrose [5%] in water) titrated to establish a level of two thirds the normal baseline mean arterial pressure.

At the other institution (six patients), a 5F double-lumen nondetachable balloon (Medi-Tech/Boston Scientific, Watertown, Mass) was used for the test occlusion. A 3000-U bolus of heparin was given prior to placement and inflation of the test occlusion balloon, and the central lumen was perfused with heparinized saline (6000 U/L normal saline) during the balloon test and coil occlusion procedures. Additional boluses of 500 to 1000 U of heparin were given every hour during the test and coil occlusion procedures. The patients underwent neurologic testing before and throughout the test occlusion at 5- to 10-minute intervals. The balloon test occlusion lasted 30 minutes. In one patient, electroencephalography replaced concurrent neurologic testing, as the patient required general anesthetic.

At both institutions, dual arterial access was used during the test occlusion procedure for simultaneous cerebral

angiography to define intracranial collateral circulation. Transcranial Doppler sonography (EME TC 2000, Pioneer TC 2020, Nicolet, Madison, Wis) was used to monitor the velocity of the ipsilateral middle cerebral artery before and during the test occlusion. A patient was considered to be a candidate for permanent occlusion if no neurologic deficit developed during the balloon test occlusion or, in the case of the patient under general anesthesia, if the electroencephalogram showed no change, angiographic intracranial collateral circulation was present, and if the Doppler sonogram showed no greater than a 50% drop from baseline velocity in the ipsilateral middle cerebral artery during the test occlusion.

Permanent occlusion was carried out while proximal flow arrest was maintained in the parent artery with the test occlusion balloon. The test occlusion balloon was not deflated after the procedure. A microcatheter (Tracker 18, Target Therapeutics, Fremont, Calif) was passed through the central lumen of the test balloon catheter to the level selected for permanent occlusion. Multiple coils were deployed via the microcatheter to achieve occlusion. Various numbers of microcoils and a variety of types, configurations, and lengths were used, depending on individual preferences and parent artery configurations. The types of microcoils used included complex fibered platinum coils, Guglielmi detachable coils, and Vortex coils (Target Therapeutics) and Hilal and Tornado coils (Cook, Bloomington, Ind). The sizes varied from 2 to 8 mm in diameter and from 3 to 7 cm in length. Initially, as many as 30 coils were used to occlude an artery. With the advent of more occlusive coil designs, as few as 10 coils have been required to achieve parent artery occlusion.

Coils were placed in the parent artery until it was occluded. Occlusion was achieved by first using larger coils to form a framework, which was used to contain progres-

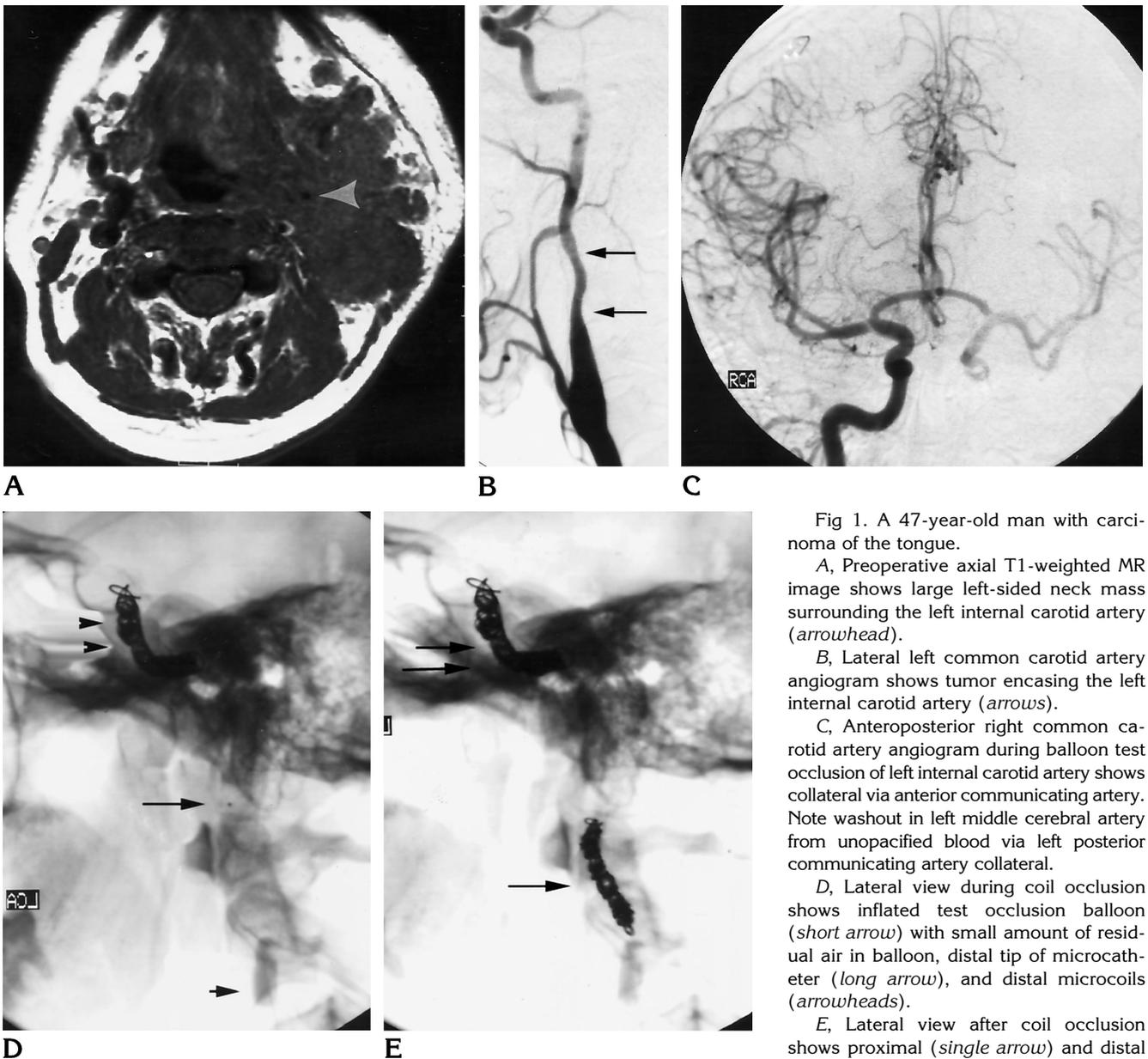


Fig 1. A 47-year-old man with carcinoma of the tongue.

A, Preoperative axial T1-weighted MR image shows large left-sided neck mass surrounding the left internal carotid artery (arrowhead).

B, Lateral left common carotid artery angiogram shows tumor encasing the left internal carotid artery (arrows).

C, Anteroposterior right common carotid artery angiogram during balloon test occlusion of left internal carotid artery shows collateral via anterior communicating artery. Note washout in left middle cerebral artery from unopacified blood via left posterior communicating artery collateral.

D, Lateral view during coil occlusion shows inflated test occlusion balloon (short arrow) with small amount of residual air in balloon, distal tip of microcatheter (long arrow), and distal microcoils (arrowheads).

E, Lateral view after coil occlusion shows proximal (single arrow) and distal (double arrows) microcoils.

sively smaller coils. The coils were deployed in such a manner as to densely pack a segment of the parent artery lumen. The microcatheter was repositioned to a more proximal location in the parent artery and the coiling process repeated to provide additional proximal protection, similar to the proximal balloon placement in detachable balloon occlusion (Fig 1). The test occlusion balloon was left inflated for 10 to 30 minutes after coil placement and then slowly deflated.

After the procedure, all patients were taken to the intermediate intensive care unit, where they were placed on bed rest with the bed flat for the first 24 hours, followed by gradual elevation and activity over the next 2 to 4 days. Heparin was not routinely reversed, and in six cases was continued for 24 to 48 hours at a rate of 500 U/h intravenously.

In this group of 19 patients, all passed the balloon test occlusion. Had a patient not passed, he or she would have been considered for a superficial temporal artery–middle cerebral artery bypass. After this, retesting and coil occlusion would have been performed. This is the method we have used with balloon occlusions.

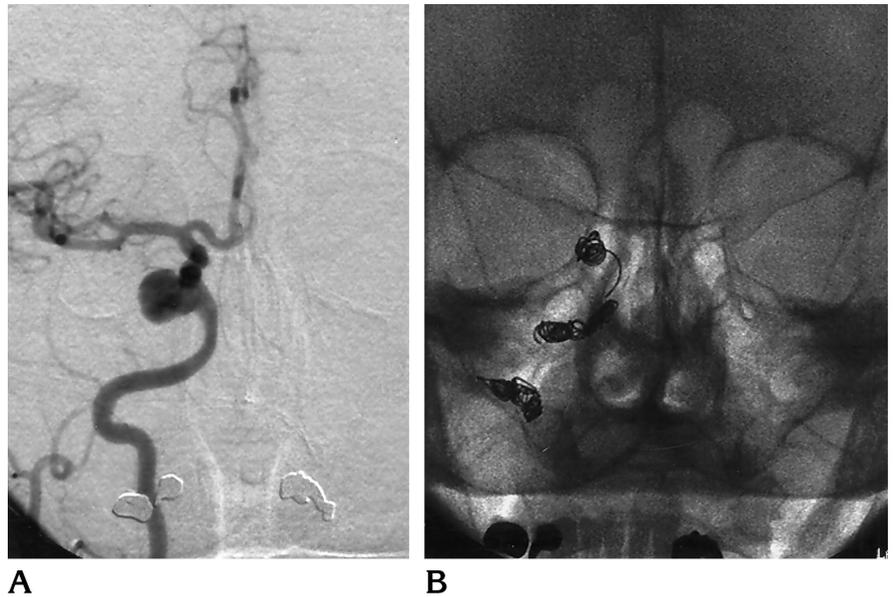
Results

All 19 parent arteries were occluded. The follow-up period was 1 to 24 months (mean, 8 months), during which there was no clinical evidence of recanalization. All lesions were successfully treated, resulting in good outcomes for

Fig 2. A 52-year-old woman with right cavernous carotid aneurysm.

A, Anteroposterior right common carotid artery angiogram shows cavernous aneurysm with wide neck associated with dysplastic segment of right internal carotid artery.

B, Anteroposterior view of skull after treatment shows three groups of deployed microcoils used to occlude the right internal carotid artery and trap the aneurysm.



18 patients (95%) and a poor outcome for one patient (5%).

Fourteen patients (74%) had no complications from the procedure and no delayed ischemic events as a result of the parent artery occlusion. Five patients (26%) had complications, but only one (5%) resulted in a permanent deficit. This deficit was caused by a dissection/embolic event after early deflation and repositioning of the test occlusion balloon before coil deployment. The patient had a hemiparesis that has improved with time and rehabilitation, although there is still a residual deficit.

Three patients (16%) had temporary neurologic deficits related to hypoperfusion states, occurring 10 to 24 hours after parent artery occlusion. All three had passed the balloon test occlusion procedure, which included a hypotensive challenge. These three patients accounted for 60% of the complications. One patient had aphasia and hemiparesis, which resolved with volume expansion and blood pressure elevation. Findings at single-photon emission computed tomography (SPECT) with acetazolamide were normal. Two patients had paresis of the upper extremity and changes in mental status. Both had abnormal findings on an acetazolamide SPECT scan, consistent with hypoperfusion in the vascular territory of the occluded artery. Both patients were treated with superficial temporal artery–middle cerebral artery bypass, resulting in resolution of the symptoms and normalization of the SPECT findings, with no evidence of hypoperfusion.

Two weeks after parent artery occlusion, one patient had intermittent dizziness and hand numbness, which was thought to be the result of emboli from clot in the stump of the occluded vertebral artery. He was placed on aspirin (300 mg per day) and has had no further symptoms.

Discussion

Endovascular occlusion of the carotid and vertebral arteries is an accepted and effective treatment of certain aneurysms, pseudoaneurysms, carotid cavernous fistulas, traumatic injuries, presurgical tumor resection, and direct vertebral artery fistulas. Historically, the most frequently used endovascular device for carotid or vertebral artery occlusion has been detachable balloons. Recently, because of the limited availability of detachable balloons and the need for endovascular occlusion in some patients in whom either the arterial anatomy or disease process precludes the safe delivery and deployment of detachable balloons, a technique consisting of temporary proximal flow arrest and microcoils has been used to occlude the carotid or vertebral artery.

Several case reports have described the successful use of coils as endovascular occlusive devices in the carotid and vertebral arteries (5, 6). However, these procedures were done without proximal flow arrest, and there is still considerable concern as to the safety and precision of coil placement for endovascular occlusion. The primary concern relates to the risk of distal

embolization due to the gradual occlusion of the parent artery that occurs with coils, as compared with the immediate occlusion that occurs with the use of detachable balloons. Also, the deployment of coils in the arterial flow stream carries the added risk of imprecise coil placement and distal coil migration. Single cases of the use of proximal flow arrest and microcoils for carotid and vertebral occlusion have been reported (7, 8). In the case of carotid occlusion, a detachable balloon was used for proximal occlusion and backup, imposing the additional risks attendant to deflating and exchanging the test balloon catheter and replacing it with a detachable balloon and guiding catheter.

The use of temporary proximal flow arrest during coil deployment and occlusion offers a technique that can reduce the risk of distal emboli and the complications and difficulties of deploying coils in the arterial flow stream. Hughes et al (9) demonstrated in an experimental canine model that endovascular occlusion with coils done with proximal flow arrest virtually eliminated the risk of distal emboli during coil deployment and arterial occlusion. Proximal flow arrest also reduced the difficulty of precise placement and deployment of coils in an arterial flow stream and reduced the risk of coil migration.

The techniques of temporary proximal flow arrest and coil deployment are easily incorporated into the balloon test occlusion procedure. The nondetachable double-lumen balloon used for balloon test occlusion remains inflated for coil deployment and arterial occlusion, thus reducing risk by precluding the need to deflate or exchange the test balloon catheter before occlusion. Overall, the use of proximal flow arrest and deployment of microcoils to the parent artery seems to be less technically difficult than the use of detachable balloons.

The only permanent complication in this series occurred as a result of having to deflate the test occlusion balloon before effecting arterial occlusion owing to the difficulty of advancing the microcatheter. Moreover, aspirin was not included as part of the routine procedure, and the use of an antiplatelet medication, such as aspirin, might have offered some protection from embolic complications both during and after occlusion. Indeed, aspirin seemed to be effective in preventing further embolic events in the one patient who was treated with this drug after a transient ischemic attack.

The major complicating factor for both balloon and coil occlusion is the imperfect predictive value of the balloon test occlusion procedure in identifying patients at risk for developing delayed ischemic events after parent artery occlusion (10). To date, no combination of tests has been able to eliminate completely the risk of delayed ischemic events after successful parent artery occlusion (11–26). As demonstrated in this series, three (16%) of 19 patients had delayed ischemic events related to hypoperfusion states not predicted by the balloon test occlusion and ancillary tests. These cases accounted for 60% of the complications.

Conclusions

Endovascular occlusion of the carotid and vertebral arteries done with temporary proximal flow arrest and microcoils can be accomplished effectively, successfully, with more control of coil deployment, and with reduced risk of distal embolic events during the procedure than realized without proximal flow arrest. This technique can easily be combined with the balloon test occlusion procedure, and provides an additional tool for endovascular occlusion of carotid and vertebral arteries. It seems to be technically easier to use than detachable balloons and requires less manipulation within the artery. The major complicating factor is the same as for balloon occlusion; that is, the imperfect predictive value in identifying patients at risk for delayed ischemic events. It is our primary technique for parent artery occlusion.

References

1. Fox A, Viñuela F, Pelz D, et al. Use of detachable balloons for proximal artery occlusion in the treatment of unclippable cerebral aneurysms. *J Neurosurg* 1987;66:40–46
2. Larson J, Tew J, Tomsick T, vanLoverm H. Treatment of aneurysms of the internal carotid artery by intravascular balloon occlusion: long term follow-up of 58 patients. *Neurosurgery* 1995; 36:23–30
3. Lewis A, Tomsick T, Tew J. Management of 100 consecutive direct carotid-cavernous fistulas: results of treatment with detachable balloons. *Neurosurgery* 1995;36:239–244
4. Gonzales C, Moret J. Balloon occlusion of the carotid artery prior to surgery for neck tumors. *AJNR Am J Neuroradiol* 1990;11: 649–652
5. Baun I, Hoffman J, Casarella W, Davis P. Use of coils for transcatheter carotid occlusion. *AJNR Am J Neuroradiol* 1985;6:953–956
6. Rossi P, Passariello R, Simonetti G. Control of a traumatic vertebral arteriovenous fistula by a modified Gianturco coil embolus system. *AJR Am J Roentgenol* 1978;131:331–333
7. Cross D, Moran C, Brown A, et al. Endovascular treatment of

- epistaxis in a patient with tuberculosis and a giant petrous carotid pseudoaneurysm. *AJNR Am J Neuroradiol* 1995;16:1084-1086
8. Bergsjordet B, Strother C, Crummy A, Levin A. Vertebral artery embolization for control of massive hemorrhage. *AJNR Am J Neuroradiol* 1984;5:201-203
 9. Hughes S, Graves V, Kesava P, Rappe A. The effect of flow arrest on distal embolic events during arterial occlusion with detachable coils: a canine study. *AJNR Am J Neuroradiol* 1996;17:685-691
 10. Eskridge J. The challenge of carotid occlusion. *AJNR Am J Neuroradiol* 1991;12:1053-1054
 11. Askienazy S, Lebtahi R, Meder J. SPECT HMPAO and balloon test occlusion: interest in predicting tolerance prior to permanent cerebral artery occlusion. *J Nucl Med* 1993;34:1243-1245
 12. Giller C, Mathews D, Walker B, Purdy P, Roseland A. Prediction of tolerance to carotid artery occlusion using transcranial Doppler ultrasound. *J Neurosurg* 1994;81:15-19
 13. Keller E, Ries F, Grunwald F, et al. Multimodal carotid occlusion test for determining risk of infarct before therapeutic internal carotid artery occlusion. *Laryngorhinootologie* 1995;74:307-311
 14. Kofke W, Brauer P, Policare R, Pentheny S, Barker D, Horton J. Middle cerebral artery blood flow velocity and stable xenon-enhanced computed tomographic blood flow during balloon test occlusion of the internal carotid artery. *Stroke* 1995;26:1603-1606
 15. Linskey M, Jungreis C, Yonas H, et al. Stroke risk after abrupt internal carotid artery sacrifice: accuracy of preoperative assessment with balloon test occlusion and stable xenon-enhanced CT. *AJNR Am J Neuroradiol* 1994;15:829-843
 16. Mathews D, Walker B, Purdy P, et al. Brain blood flow SPECT in temporary balloon occlusion of carotid and intracerebral arteries. *J Nucl Med* 1993;34:1239-1243
 17. Monsein L, Jeffrey P, vanHeerden B, Szabo Z, Camargo E, Chazaly J. Assessing adequacy of collateral circulation during balloon test occlusion of the internal carotid artery with ^{99m}Tc-HMPAO SPECT. *AJNR Am J Neuroradiol* 1991;12:1045-1051
 18. Moody E, Dawson R, Sandler M. ^{99m}Tc-HMPAO SPECT imaging in interventional neuroradiology: validation of balloon test occlusion. *AJNR Am J Neuroradiol* 1991;12:1043-1044
 19. Morgan M, Grinnell V, Sorby W, Wong J, Rowe D, Stroud J. EEG monitoring during angiographic balloon test carotid occlusion: experience in 16 cases. *Clin Exp Neurol* 1993;30:98-103
 20. Origitano T, Al-Mefty O, Leonetti J, DeMonte F, Reichman O. Vascular considerations and complications in cranial base surgery. *Neurosurgery* 1994;35:351-363
 21. Peterman S, Taylor A, Hoffman J. Improved detection of cerebral hypoperfusion with internal carotid balloon test occlusion and ^{99m}Tc-HMPAO cerebral perfusion SPECT imaging. *AJNR Am J Neuroradiol* 1990;12:1035-1041
 22. Simonson T, Ryals T, Yuh W, Farra G, Rezai K, Hoffman H. MR imaging and HMPAO scintigraphy in conjunction with balloon test occlusion: value in predicting sequelae after permanent carotid occlusion. *AJR Am J Roentgenol* 1992;159:1063-1068
 23. Standard S, Ahuja A, Guterman L, et al. Balloon test occlusion of the internal carotid artery with hypotensive challenge. *AJNR Am J Neuroradiol* 1995;16:1453-1458
 24. Vincent D, Pentheny S, Horton J. Temporary balloon test occlusion of the internal carotid artery: experience in 500 cases. *AJNR Am J Neuroradiol* 1995;16:749-754
 25. Witt J, Yonas H, Jungreis C. Cerebral blood flow response pattern during balloon test occlusion of the internal carotid artery. *AJNR Am J Neuroradiol* 1994;15:847-856
 26. Brunberg J, Frey K, Horton J, Deveikis J, Ross D, Koeppe R. [¹⁵O]H₂O positron emission tomography determination of cerebral blood flow during balloon test occlusion of the internal carotid artery. *AJNR Am J Neuroradiol* 1994;15:725-732