

Carotid Artery Balloon Test Occlusion

Advances in skull base surgery have resulted from the ability to perform large scale en bloc resections of neoplasms affecting the clivus, sphenoid wings, and other deep structures. Such tumors frequently involve the internal carotid artery (ICA), and complete resection may require dissection or sacrifice of the ICA. Occlusion of the ICA without bypass graft placement is performed for the treatment of certain aneurysms. These and other less common indications for ICA sacrifice necessitate our ability to predict the result of ICA occlusion.

Without any type of temporary test occlusion, the incidence of stroke after permanent carotid artery occlusion ranges from 17% to 30% (1–5). In 1911, Matas (6) described temporary arterial occlusion by manual compression of the common carotid artery to determine tolerance for permanent arterial occlusion. Serbinenko (7) introduced the concept of endovascular arterial occlusion using small endovascular balloons in the early 1970s. His novel method of endovascular arterial occlusion has since been widely adopted and remains the current foundation for temporary arterial test occlusion.

When carotid artery Balloon Test Occlusion (BTO) is clinically tolerated, the morbidity and mortality associated with permanent arterial occlusion are reduced but, unfortunately, not eliminated. Since the report of endovascular temporary arterial occlusion presented by Serbinenko (7) was published, a variety of adjunctive methods have been tested to improve the sensitivity and specificity of clinical neurologic evaluation alone for the detection of insufficient cerebral blood flow to allow safe permanent arterial occlusion. Evaluation of regional cerebral blood flow during BTO using radioactive xenon with external probes (8, 9), stable xenon-enhanced CT (10–14), technetium-99m hexamethylpropyleneamine oxime single photon emission CT (15–17), and [^{15}O] labeled H_2O positron emission tomography (18) has been reported. Other indirect indicators of regional cerebral blood flow, including perfusion CT and MR imaging, angiography of collateral vessels (9, 19–21), measurement of arterial stump pressure (10, 22–26), EEG (27, 28), and transcranial Doppler ultrasonography (8), have been tested. Pharmacologic induction of hypotension during BTO has also been used to attempt to elicit clinical signs of inadequate perfusion (29, 30).

Although it seems logical that cerebral blood flow evaluation and/or other adjunctive tests described above performed during BTO should help to reveal marginal areas of perfusion that might lead to neurologic deficits after permanent arterial occlusion,

this has not been convincingly shown. After BTO with clinical evaluation only, 198 patients underwent permanent ICA occlusion without bypass graft placement, with a 3.0% incidence of permanent neurologic deficits (20, 21, 31). After BTO combined with cerebral blood flow analysis or induction of hypotension, 120 patients underwent arterial occlusion without graft placement and had a 6.7% incidence of permanent complications (9, 15, 18, 29, 30, 32). Because the numbers of patients is relatively small and reported incidences of neurologic complications are low, statistically significant differences between the different techniques are very difficult to show. Considering the wide variations in occlusion techniques, post-occlusion care, patient selection, and limited numbers of patients in reported series, it is impossible to prove superiority for any particular method of BTO.

Indications

The indications for BTO include an aneurysm or pseudoaneurysm arising from the ICA (treatment by permanent ICA occlusion [Hunterian ligation] planned; at risk for inadvertent ICA occlusion during a difficult open or endovascular surgical approach); cranial and cervical neoplasms with ICA involvement; hemorrhage related to trauma, infection, or neoplasm; arterial dissection when anticoagulant therapy is contraindicated; and carotid-cavernous fistula, which may not be treatable with arterial preservation.

Threshold: 100%. A review should be conducted whenever BTO is performed for other indications.

Efficacy

Technical success or efficacy is defined as the ability to complete the BTO procedure. Atherosclerotic changes identified during the diagnostic angiographic portion of the procedure may prevent safe performance of BTO and should not be considered as a technical failure.

Threshold for technical success: 95%.

Clinical success or efficacy is defined as the ability to accurately predict the outcome of permanent arterial occlusion in terms of whether a permanent post-occlusion neurologic deficit develops.

Threshold for clinical success: 95%.

BTO of the vertebral arteries may also be performed for similar indications. Depending on the sizes of the vertebral arteries, tolerance for permanent vertebral artery occlusion is generally greater than that of the ICA. Thresholds for indications, success, and complications associated with

BTO of the ICA can be applied to BTO of the vertebral artery as well.

Safety

Reported complications associated with BTO include arterial dissection (both asymptomatic and symptomatic), transient and permanent neurologic deficits, death, and puncture site hematoma. The largest reported series of carotid artery BTO examined 500 cases treated by multiple operators at the University of Pittsburgh (13). They reported rates of 1.2% transient and 0.4% permanent neurologic complications, which are within the ranges reported for diagnostic angiography alone (33–35). Using other techniques, complication rates from carotid artery test occlusion as high as 15% have been reported (36). With careful attention to technique, complications associated with BTO should only slightly exceed those associated with diagnostic neuroangiography (37). A review should be prompted when the complication rate surpasses the following threshold value.

Indicator	Threshold (%)
Asymptomatic arterial dissection	4
Transient neurologic deficit (persisting after balloon deflation)	5
Permanent neurologic deficit	5
Death	0

References

- Schorstein J. Carotid ligation in saccular intracranial aneurysms. *Br J Surg* 1994;28:50–70
- Olivecrona H. Ligation of the carotid artery in intracranial aneurysms. *Acta Chir Scand* 1944;91:353–368
- Norlen G. The pathology diagnosis and treatment of intracranial saccular aneurysms. *Proc R Soc Med* 1952;45:291–302
- Moore OS, Baker HW. Carotid artery ligation in surgery of the head and neck. *Cancer* 1955;8:712–726
- Moore OS, Karlan M, Sigler L. Factors influencing the safety of carotid ligation. *Am J Surg* 1969;118:666–668
- Matas R. Testing the efficiency of the collateral circulation as preliminary to the occlusion of the great surgical arteries. *Ann Surg* 1911;53:1–43
- Serbinenko FA. Balloon catheterization and occlusion of major cerebral vessels. *J Neurosurg* 1974;41:125–145
- Braun IF, Battery PM, Fullenwider JT, Per-Lee JH. Transcatheter carotid occlusion: an alternative to the surgical treatment of cervical carotid aneurysms. *J Vasc Surg* 1986;4:299–302
- Fox AJ, Viñuela F, Pelz DM, et al. Use of detachable balloons for proximal artery occlusion in the treatment of unclippable cerebral aneurysms. *J Neurosurg* 1987;66:40–46
- de Vries EJ, Sekhar LN, Horton JA, et al. A new method to predict safe resection of the internal carotid artery. *Laryngoscope* 1990;100:85–88
- Erba SM, Horton JA, Latchaw RE, et al. Balloon test occlusion of the internal carotid artery with stable xenon/CT cerebral blood flow imaging. *AJNR Am J Neuroradiol* 1988;9:533–538
- Johnson DW, Stringer WA, Marks MP, Yonas H, Good WF, Gur D. Stable xenon CT cerebral blood flow imaging: rationale for and role in clinical decision making. *AJNR Am J Neuroradiol* 1991;12:201–213
- Mathis JM, Barr JD, Jungreis CA, et al. Temporary balloon test occlusion of the internal carotid artery: experience in 500 cases. *AJNR Am J Neuroradiol* 1995;16:749–754
- Yonas H, Gur D, Claassen D, Wolfson SK Jr, Moossy J. Stable xenon-enhanced CT measurement of cerebral blood flow in reversible focal ischemia in baboons. *J Neurosurg* 1990;73:266–273
- Eckard DA, Purdy PD, Bonte FJ. Temporary balloon occlusion of the carotid artery combined with brain blood flow imaging as a test to predict tolerance prior to permanent carotid sacrifice. *AJNR Am J Neuroradiol* 1992;13:1565–1569
- Monsein LH, Jeffrey PJ, van Heerden BB, et al. Assessing adequacy of collateral circulation during balloon test occlusion of the internal carotid artery with 99mTc-HMPAO SPECT. *AJNR Am J Neuroradiol* 1991;12:1045–1051
- Moody EB, Dawson RC III, Sandler MP. 99mTc-HMPAO SPECT imaging in interventional neuroradiology: validation of balloon test occlusion. *AJNR Am J Neuroradiol* 1991;12:1043–1044
- Brunberg JA, Frey KA, Horton JA, Deveikis JP, Ross DA, Koeppe RA. [15O]H₂O position emission tomography determination of cerebral blood flow during balloon test occlusion of the internal carotid artery. *AJNR Am J Neuroradiol* 1994;15:725–732
- Beatty RA, Richardson AE. Predicting intolerance to common artery ligation by carotid angiography. *J Neurosurg* 1968;28:9–13
- Higashida RT, Hieshima GB, Halbach VV, et al. Intravascular detachable balloon embolization of intracranial aneurysms: indications and techniques. *Acta Radiol Suppl* 1986;369:594–596
- Raymond J, Theron J. Intracavernous aneurysms: treatment by proximal balloon occlusion of the internal carotid artery. *AJNR Am J Neuroradiol* 1986;7:1087–1092
- Ehrenfeld WK, Stoney RJ, Wylie EJ. Relation of carotid stump pressure to safety of carotid ligation. *Surgery* 1983;4:382–384
- Boysen G. Cerebral blood flow measurements as a safeguard during carotid endarterectomy. *Stroke* 1971;2:1–10
- Jeffreys RV, Holmes AE. Common carotid ligation for the treatment of ruptured posterior communicating aneurysms. *J Neurol Neurosurg Psychiatry* 1971;34:576–579
- Kelly JJ, Callow AD, O'Donnell TE, et al. Failure of carotid stump pressures: its incidence as a predictor for a temporary shunt during carotid endarterectomy. *Arch Surg* 1979;114:1361–1366
- Steed DL, Webster MW, DeVries EJ, et al. Clinical observations on the effect of carotid artery occlusion on cerebral blood flow mapped by xenon computed tomography and its correlation with carotid artery back pressure. *J Vasc Surg* 1990;11:38–44
- Leech PJ, Miller JD, Fitch W, et al. Cerebral blood flow, internal carotid artery pressure, and the EEG as a guide to the safety of carotid ligation. *J Neurol Neurosurg Psychiatry* 1974;37:854–862
- Morioka T, Matsushima T, Fujii K, Fukui M, Hasuo K, Hisashi K. Balloon test occlusion of the internal carotid artery with monitoring of compressed spectral arrays (CSAs) of electroencephalogram. *Acta Neurochir (Wien)* 1989;101:29–34
- Standard SC, Ahuja A, Guterman LR, et al. Balloon test occlusion of the internal carotid artery with hypotensive challenge. *AJNR Am J Neuroradiol* 1995;16:1453–1458
- Chaloupka JC, Dare AO, Putman CM, et al. Limitations of the hypotensive challenge with balloon test occlusion for predicting delayed hemodynamic ischemia: the Yale experience. Presented at the 34th Annual Meeting of the American Society of Neuroradiology, Seattle, 1996
- Gonzalez CF, Moret J. Balloon occlusion of the carotid artery prior to surgery for neck tumors. *AJNR Am J Neuroradiol* 1990;11:649–652
- Linskey ME, Jungreis CA, 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
- Dion JE, Gates PC, Fox AJ, Barnett HJ, Blom RJ. Clinical events following neuroangiography: a prospective study. *Stroke* 1987;18:997–1004
- Earnest F IV, Forbes G, Sandok BA, et al. Complications of cerebral angiography: prospective assessment of risk. *AJR Am J Roentgenol* 1984;142:247–253
- Heiserman JE, Dean BL, Hodak JA, et al. Neurologic complications of cerebral angiography. *AJNR Am J Neuroradiol* 1994;15:1401–1407
- Mehta B, Landi J, Sanders W, et al. Safety and cost effectiveness of carotid balloon occlusion test. Presented at the 31st Annual Meeting of the American Society of Neuroradiology, Vancouver, 1993
- Meyers P, Thakur G, Tomsick TA. Temporary endovascular balloon occlusion of the internal carotid artery with a nondetachable silicone balloon catheter: analysis of technique and cost. *AJNR Am J Neuroradiol* 1999;20:559–564