Robert W. Tarr, M.D., Charles A. Jungreis, M.D.,
Joseph A. Horton, M.D., Susan Pentheny, PA-C,
Laligam N. Sekhar, M.D., Chandra Sen, M.D.,
Ivo P. Janecka, M.D., F.A.C.S., and Howard Yonas, M.D.

Complications of Preoperative Balloon Test Occlusion of the Internal Carotid Arteries: Experience in 300 Cases

Abstract—Treatment of some tumors and aneurysms of the skull base may require internal carotid artery (ICA) sacrifice. Preoperatively to determine the dependence of the cerebral blood flow on a particular vessel, we perform a balloon test occlusion (BTO) by temporarily occluding the vessel in an awake patient. During occlusion, clinical evaluations and cerebral blood flow measurements are assessed. We have performed 300 BTOs. Eleven patients (3.7%) have had complications. Six (2%) were asymptomatic dissections. Five (1.7%) had neurologic deficits that persisted beyond the test period. Of these five, one was back to baseline in less than 24 hours, one recovered completely in a week, and one (0.33%) had a minimal but persistent dysphasia. These latter three cases are unexplained but might have resulted from unrecognized dissections or embolic events. Finally, one patient with a persistent deficit required emergency surgery for reasons unrelated to the BTO and was therefore difficult to assess, and one required emergency middle cerebral artery embolectomy and repair of the dissection. The preoperative knowledge of carotid dependence in cases in which the ICA is at risk is essential, since vascular grafts or alternative surgical approaches are necessary in patients unable to tolerate carotid sacrifice. Since approximately 15 to 20% of the population falls into this category, a preoperative BTO appears justified. (*Skull Base Surgery, Volume 1, Number 4, 1991, p. 240*)

Carotid artery sacrifice is often required in the treatment of skull base tumors, internal carotid artery (ICA) aneurysms, and traumatic lesions involving the ICA.[1] Pretherapeutic knowledge of carotid artery dependence is essential in these patients, since vascular bypass or alternative surgical approaches may be necessary in patients unable to tolerate ICA sacrifice. Carotid compression combined with neurologic testing or contralateral carotid angiography have been used to test for carotid artery dependence.[2,3] However, both of these methods have had limitations.[3] For example, it is difficult to be certain that occlusion is complete during manual compression. Furthermore, contralateral carotid angiography during ipsilateral carotid compression only provides an anatomic assessment of cross circulation, but provides no information about the functional adequacy of cross circulation.

A method of combining balloon test occlusion (BTO) of the ICA with stable xenon and computed tomography cerebral blood flow (Xe/CT CBF) analysis to assess the tolerability of permanent ICA occlusion has been de-

Skull Base Surgery, Volume 1, Number 4, October 1991 Department of Radiology, University Hospital of Cleveland/Case Western Reserve University, Cleveland, Ohio; Departments of Radiology, Neurosurgery, and Otolaryngology, University of Pittsburgh School of Medicine, Presbyterian University Hospital, Pittsburgh, Pennsylvania Reprint requests: Dr. Jungreis, Department of Radiology, Presbyterian University Hospital, Pittsburgh, PA 15213

scribed.[4–6] Using this technique, we have examined 300 patients in the past 5 years. We present an analysis of the complications that have occurred from the procedure.

PATIENTS AND METHODS

Between June 1985 and June 1990 a BTO of the ICA was performed in 300 patients. The patients were being evaluated prior to either surgical resection of a skull base neoplasm in which the carotid artery was considered to be at risk, carotid occlusion for the treatment of an inoperable aneurysm, or carotid occlusion for traumatic lesions involving the carotid artery.

The BTO Xe/CT CBF technique has been described previously.[4–6] Briefly, an initial baseline neurologic examination is performed during which both hemispheres are evaluated for motor, sensory, and higher cortical function. Diagnostic angiography of both carotids and the vertebrobasilar arterial systems is performed to provide information regarding collateral vascular anatomy, tumor vascularity, vascular encasement by tumor, and atherosclerotic changes involving the ICA.

Following the diagnostic angiogram, the BTO is performed. Either a 110 cm, 5 F double-lumen Swan-Ganz catheter (Baxter Healthcare, Santa Anna, CA) or 110 cm 5 F steerable nondetachable double-lumen balloon catheter (Meditech, Watertown, MA) was used for all of our cases. The air within the nondetachable balloon is exchanged for iohexol (150 mg I/ml) (Winthrop Pharmaceuticals, New York, New York). The Swan-Ganz catheter is shaped over steam, advanced into the femoral artery through a 6 F introducer sheath, and flow directed into the appropriate cervical ICA to the level of the arch of C1. Alternatively, the steerable 5 F nondetachable balloon catheter is advanced into the femoral artery through a 6 F introducer sheath and positioned into the appropriate ICA over an 0.025 inch exchange wire.

Immediately prior to balloon inflation, 7000 U of heparin are given intravenously. The balloon is inflated under fluoroscopic control. A slight elongation of the normally spherical-shaped balloon determines an occlusive position. A constant drip of heparinized saline is infused through the end-hole of the catheter. The patients' neurologic status is assessed continuously following balloon inflation. If there is a change in the neurologic status, the balloon is immediately deflated and the procedure is terminated. If there is no change in neurologic status, the BTO is typically performed for 15 minutes.

In the group of patients who tolerate the 15-minute clinical BTO, the balloon is deflated but the catheter position in the ICA is maintained. A constant drip of heparinized saline is continued through the end-hole. The patient is transported to a CT scanner suite with careful attention to limiting any head motion. After the patient is positioned, the balloon is reinflated with an identical amount of contrast used during the clinical BTO. A digital scout radiograph of the head and neck confirms adequate balloon position and inflation. A Xe/CT CBF study is performed with the balloon inflated (GE Medical Systems, Milwaukee, WI). The Xe/CT CBF method has been described previously.[7–9] Following the inflated CBF study, the balloon catheter is removed. After allowing 20 minutes for xenon washout, a subsequent uninflated baseline Xe/CT CBF study is performed to allow assessment of changes in local CBF induced by the BTO. Protamine sulfate is used to reverse the heparinization.

RESULTS

Of the 300 patients in whom BTO Xe/CT was performed (Fig. 1), complications related to the procedure occurred in 11 patients (3.7%). Six patients (2%) experienced asymptomatic carotid artery dissections that were presumed to be related to the BTO procedure (Figs. 2, 3). These asymptomatic subintimal hematomas were either discovered during surgical exposure of the cervical carotid artery performed within 1 week of the BTO (three patients) or during routine postsurgical angiography (three

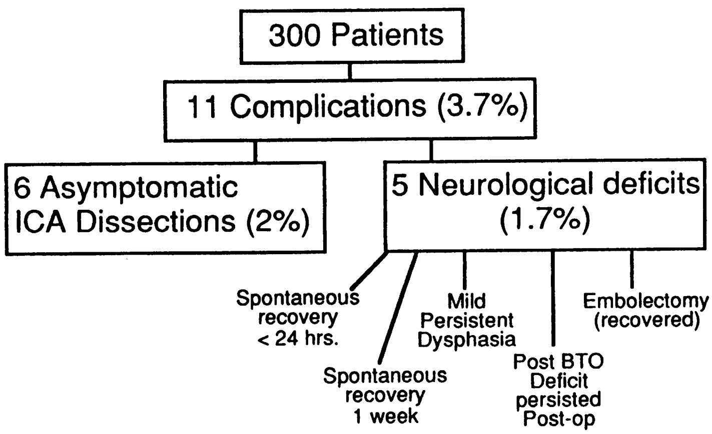

Figure 1. Summary of complications. ICA: internal carotid artery.

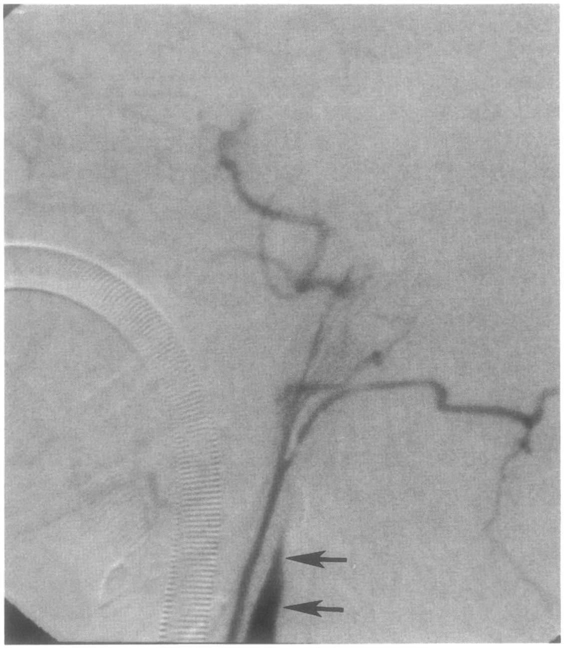

Figure 2. Lateral angiographic view of a common carotid artery angiogram. The internal carotid artery is completely occluded. The tapered narrowing (arrows) is characteristic of a dissection. This angiogram was obtained after skull base surgery. The vascular injury was not symptomatic and had not been suspected. Presumably, it occurred as a result of the preoperative balloon test occlusion.

Figure 3. Lateral angiographic view of a common carotid artery angiogram. Two well-defined short segments of narrowing (arrows) can be identified in the internal carotid artery. The intervening vessel is slightly narrow also when compared to the high cervical portion. This injury probably represents a subintimal hematoma without complete occlusion, was not symptomatic, and was only discovered on routine follow-up angiography postoperatively.

patients). In one of these six patients the dissected carotid was resected at surgery due to tumor encasement. In another patient who remained asymptomatic but showed an asymmetrical decreased blood flow on the Xe/CT CBF study, the dissected segment was bypassed and the carotid was resected due to tumor encasement. Two patients demonstrated healing of the dissected segment during follow-up angiography. No follow-up angiography data were obtained in the other two patients.

Five patients (1.7%) experienced neurologic deficits that persisted beyond the BTO procedure. Of these five, one patient had a carotid dissection and hemiparesis. The patient's neurologic deficit resolved within 24 hours. A second patient had a course similar to the first, but required one week to recover fully. Another patient who in retrospect had minimal atherosclerotic plaques involving the ipsilateral proximal ICA developed aphasia and hemiparesis during balloon positioning, which improved but did not completely resolve over a 2-week follow-up period. One patient required emergency middle cerebral artery embolectomy and repair of a carotid dissection following the BTO. This patient's neurologic deficit was resolved immediately following surgery. Another patient with a persistent deficit required emergency surgery for reasons unrelated to the BTO and her neurologic course was therefore difficult to assess.

There were no groin hematomas that required surgical evacuation. Likewise, there were no peripheral vascular injuries requiring surgery. No deaths occurred.

DISCUSSION

Although most patients can tolerate permanent carotid occlusion, there is a subset of approximately 15 to 20% who are unable to do so.[5,6] If possible, it is important to identify this subset prior to any therapeutic intervention during which the ICA may be at risk for occlusion. The risk of complications from permanent carotid occlusion depends on several factors. One is the state of the systemic circulation at the time of occlusion. Correctable factors such as hypovolemia, shock, and anemia increase the risk of neurologic complications following ICA ligation.[10] The risk of embolic complications can be minimized by occluding the ICA as far distally as possible, thereby decreasing the length of the distal stump.[11,12] Finally, the adequacy of collateral blood flow through the circle of Willis or via leptomeningeal collaterals is an important factor determining adequate hemispheric perfusion following ICA sacrifice.

The main rationale for preligation (BTO) testing is the evaluation of adequacy of hemispheric collaterals. Although contralateral carotid angiography using ipsilateral carotid comparison or temporary occlusion provides anatomic assessment of collateral circulation, it does not provide accurate functional information regarding the adequacy of cross circulation.[13] Similarly, intra-arterial pressure measurements and electroencephalographic recordings during temporary occlusions may give misleading results.[6,13–15]

Combining endovascular BTO techniques with CBF analysis provides a detailed predictive examination of the effect on cerebral hemodynamics of carotid occlusion.[4–6] Approximately 9% of patients will fail the clinical portion of the BTO and will inevitably experience a stroke if the carotid is permanently occluded.[6] Similarly, approximately 11% of patients will clinically tolerate temporary ICA occlusion during the BTO, but demonstrate an ipsilateral drop in CBF below approximately 30 cc/100 gm/min. These patients are at significant risk for delayed neurologic deterioration following permanent ICA sacrifice due to limited vascular reserve.[6] The 15 to 20% of the population who comprise these two groups is significantly greater than the 3.7% complication rate from the BTO procedure documented in our series.

The complication rate in our series of patients undergoing BTO with Xe/CT CBF analysis compares favorably with other series examining complication rates of routine diagnostic cerebral angiography. In our series of 300 patients 3.7% experienced complications. The occurrence of neurologic complications was 1.7%. The occurrence of permanent neurologic complications (lasting greater than 2 weeks) was 0.33%. A prospective analysis of 1517 cerebral angiographic procedures by Earnest et al[16] yielded an 8.5% incidence of all complications, a 2.6% incidence of all neurologic complications, and a 0.33% incidence of permanent neurologic complications. The incidence of permanent neurologic complications in other series examining routine cerebral angiography has varied from 0% to 5.4%.[17–21]

Our incidence of neurologic complications is based on multiple thorough clinical assessments and is therefore likely to be accurate. The asymptomatic cases of dissections and intimal tears were detected either angiographically on follow-up examinations or by direct observation at surgery. Most patients in the series have had follow-up angiography postoperatively. Nevertheless, some patients may have had intimal tears or dissections that have gone unnoticed. Thus, the true incidence of asymptomatic dissection related to the BTO procedure may be underestimated in our series.

There are several technical factors during the BTO procedure that may minimize the risk of complications. It is imperative to examine the ipsilateral as well as the contralateral carotid artery prior to attempting the BTO. Occlusion or severe stenosis of the contralateral carotid artery is a contraindication to performing the BTO. Similarly, atherosclerotic involvement of the ipsilateral carotid is a contraindication to BTO due to the risk of embolic complications during balloon positioning. Care must be taken in patients with a tortuous cervical ICA during balloon catheter placement either over an exchange wire or by flow-directed means. The tortuousity can increase the risk of either the exchange wire or the tip of the catheter distal to the balloon inducing a dissection. Prior to balloon inflation in the carotid artery, the patient should be systemically anticoagulated to prevent embolic complications when the balloon is deflated. Also, care must be taken to prevent overinflation of the balloon in the ICA, since this may result in arterial dissection or pseudoaneurysm formation. Normally when unrestricted during inflation, the balloon on either the Swan-Ganz or the Meditech system assumes a spherical configuration. Slight elongation of this spherical configuration indicates that the balloon is in an occlusive position. No additional inflation is required. If the patient is to be transported from the angiographic suite with the catheter retained in the ICA for CBF studies, adequate personnel must accompany the patient to ensure no head motion during transport or positioning.

An alternative CBF method for preoperative assessment that might decrease the complications related to the BTO procedure by decreasing catheter time is single photon emission CT (SPECT) with technetium 99m(^{99m}Tc) hexamethylpropyleneamineoxime (HMPAO).[22,23] The agent, ^{99m}Tc HMPAO, can be injected intravenously at the time of the clinical BTO. Since ^{99m}Tc HMPAO is a first-pass agent, its distribution reflects blood flow at the time of BTO. This negates the need to reinflate the balloon during the CBF study and may allow a shorter period of balloon inflation during the clinical portion of the examination. The main disadvantage of ^{99m}Tc HMPAO SPECT CBF analysis is the inability to quantitate blood flow.

In summary, we have found that the occurrence of complications in relation to the endovascular BTO technique combined with Xe/CT CBF analysis is less than 4%. In our series the risk of BTO procedure was no greater than that of routine cerebral angiography. In patients whose therapeutic options may necessitate ICA sacrifice the information gained regarding carotid artery dependency appears to justify the minimal risk involved with the BTO procedure.

REFERENCES

1. Sekhar LN, Schramm JL, Jones NF, et al: Operative exposure and management of the petrous and upper cervical internal carotid artery. Neurosurgery 19:967–982, 1986
2. Matas R: Testing the efficiency of the collateral circulation as a preliminary to the occlusion of the great surgical arterials. Ann Surg 53:1–43, 1911
3. Harris P, Vadvarhely GB: Aneurysms arising at the internal carotid posterior communicating artery junction. J Neurosurg 14:180–191, 1957
4. Erba SM, Horton JA, Latcharo RE et al: Balloon test occlusion of the internal carotid artery with stable xenon/CT cerebral blood flow imaging. AJNR 9:533–538, 1988
5. DeVries EJ, Sekhar LN, Horton JA, et al: A new method to predict safe resection of the internal carotid artery. Larygoscope 100: 85–88, 1990
6. 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 11:38–43, 1990

7. Gur D, Wolfson SK, Yonas H, et al: Progress in cerebral vascular disease: LCBF by xenon-enhanced CT. Stroke 13:750–758, 1982
8. Gur D, Good WF, Wolfson SK, et al: In vivo mapping of local cerebral blood flow by xenon enhanced computed tomography. Science 215:1267–1268, 1982
9. Yonas H, Good WF, Gur D, et al: Mapping cerebral blood flow by xenon enhanced computed tomography: Clinical experience. Radiology 152:425–442, 1984
10. Shorstein J: Carotid ligation in secular intracranial aneurysms. Br J Surg 28:50–69, 1940
11. Nighioka H: Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Section VIII Part I: Results of the treatment of intracranial aneurysms by occlusion of the carotid artery in the neck. J Neurosurg 25:660–682, 1966
12. Gonzalez CF, Monet J: Balloon occlusion of the carotid artery prior to surgery for neck tumors. AJNR 11:649–652, 1990
13. Wright RL, Sweet WH: Intra-arterial pressure determinations at the time of carotid occlusion. Correlation with clinical tolerance of occlusion and subsequent subarachnoid hemorrhage in: Fields WS, Sahs AL (eds). Intracranial aneurysms and subarachnoid hemorrhage. Springfield IL: Charles C Thomas, 1965, pp 324–326
14. Kelly JJ, Collar TF, McBride K, et al: Failure of carotid stump pressures. Arch Surg 114:1361–1366, 1979
15. Potter JM, Taylor FM: Electro-encephalography during carotid occlusion: Confusing results in thirty-four cases. Arch Neurol Psychiatry 74:414–423, 1977
16. Earnest F, Forbes G, Sandok BA, et al: Complications of cerebral angiography: Prospective assessment of risk. AJNR 4:1191–1197, 1983
17. Kerber CW, Cromwell LD, Drayer BF, et al: Cerebral ischemia 1. Current angiographic techniques, complications, and safety. AJR 130:1097–1103, 1978
18. Eisenberg RL, Bank WO, Hedgcock MW: Neurological complications of angiography for cerebrovascular disease. Neurology (NY) 30:895–897, 1980
19. Faught E, Trader SD, Hanna GR: Cerebral complications of angiography for transient ischemia and stroke: prediction of risk. Neurology (NY) 29:4–15, 1979
20. Dion JE, Gates PC, Fox AJ, et al: Clinical events following neuroangiography: A prospective study. Stroke 48:997–1004, 1987
21. Mani RL, Eisenberg RL, McDonald EJ, et al: Complications of catheter cerebral arteriography: Analysis of 500 procedures I. criteria and incidence. AJR 131:861–865, 1978
22. Podreka I, Suess E, Goldenberg G, et al: Initial experience with technetium 99m HM-PAO Brain SPECT. J Nucl Med 28:1657–1666, 1987
23. Nakano S, Kinoshita K, Jinnouchi S, et al: Comparative study of regional cerebral blood flow images by SPECT using xenon-133 iodine 133 IMP and technetium-99m HM-PAO. J Nucl Med 30: 157–164, 1989