Temporary Balloon Occlusion of the Carotid Artery Combined with Brain Blood Flow Imaging as a Test to Predict Tolerance Prior to Permanent Carotid Sacrifice

Donald A. Eckard,[1] Phillip D. Purdy, and Fred J. Bonte

PURPOSE: To describe the technique of using SPECT brain blood flow imaging to identify patients at risk for having strokes after balloon or surgical ligation of an internal carotid artery. **PATIENTS AND METHODS:** 29 patients underwent temporary balloon occlusion of the internal carotid artery and blood flow imaging studies were obtained prior to sacrifice of the vessel; 11 internal carotid arteries were indeed sacrificed and form the basis of our study. Follow-up of these patients ranged from 3 to 65 days. **RESULTS:** Three groups emerged: group I, patients with symptoms during occlusion and an abnormal blood flow study (one patient); group II, patients with no symptoms during the occlusion but with an unequivocally abnormal blood flow study (two patients); group III, patients without symptoms during occlusion and a normal or slightly abnormal blood flow study (eight patients). **CONCLUSION:** Carotid sacrifice without initial and temporary balloon occlusion is unnecessarily risky. Imaging of blood flow in the brains of these patients can further improve the safety of occlusion procedures in the internal carotid artery.

Index terms: Single photon emission computed tomography (SPECT); Arteries, therapeutic blockade; Arteries, carotid (internal); Cerebral blood, flow

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Sacrifice of the internal carotid artery (ICA) is sometimes necessary in treating patients with ICA aneurysms or tumors of the skull base. Prior to sacrifice, it is important to know that the patient will tolerate this condition without developing ischemic neurologic deficits. Temporary occlusion of the ICA with an inflatable balloon while monitoring neurologic function is the most common test used to predict tolerance of permanent occlusion (1–4). Despite tolerance to such testing, a small number of patients develop ischemic events following permanent occlusion. In some instances this seems related to decreased flow. In an effort to reduce the number of low flow ischemic complications following permanent carotid sacrifice, we have been evaluating our patients with brain blood flow imaging combined with temporary ICA occlusion prior to permanent sacrifice.

Temporary balloon occlusion of the ICA combined with brain blood flow imaging using stable xenon/computed tomography (xe/CT) has been previously reported in a limited number of patients (1). Results suggested that patients who tolerated the temporary occlusion clinically may still be at risk for infarction after sacrifice of the ICA if they had an abnormal blood flow study with xe/CT. We supply further data which would also indicate this is true and also discuss the use of technetium-99m-labeled hexamethyl-propyleneamine oxine (Tc-99m HMPAO) single photon emission CT (SPECT) as a brain blood flow imaging agent during temporary balloon occlusion.

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All authors: The University of Texas Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75235-8896. Address reprint requests to Phillip D. Purdy, MD.

[1] Present address: Department of Diagnostic Radiology, The University of Kansas Medical Center, 39th and Rainbow Boulevard, Kansas City, KS 66103.

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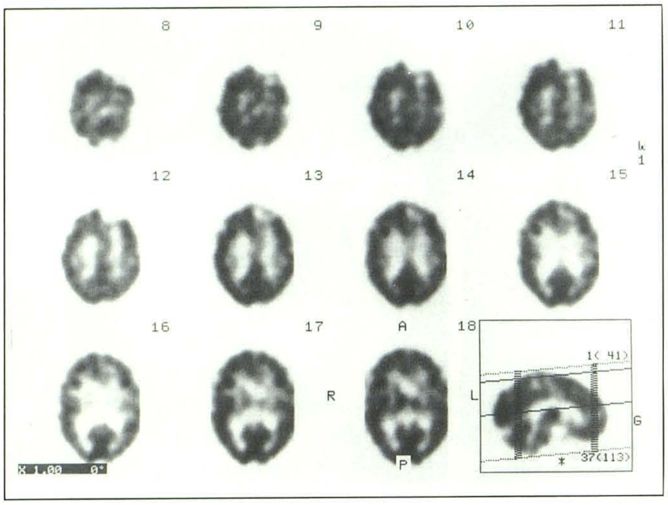

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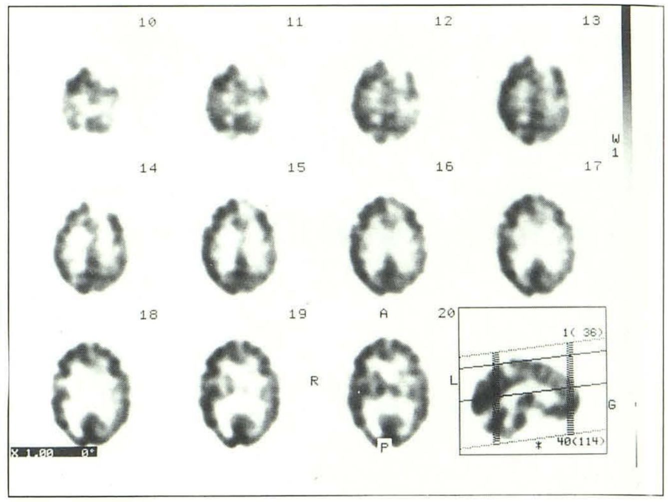

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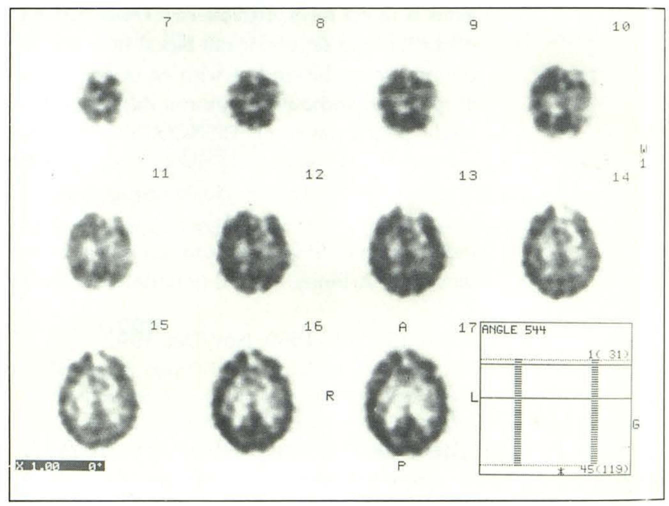

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Fig. 1. This 58-year-old woman (see Table 1, patient 9) presented with dysphasia and right hemiparesis believed secondary to an embolus from a left petrous ICA aneurysm.

A, Baseline axial Tc-99m HMPAO SPECT images show a defect in the left frontal region from the patient's infarct.

B, Images obtained during the temporary ICA occlusion show worsening of flow in the left frontal region compared to baseline.

C, Following EC/IC bypass, there is improved flow despite temporary ICA occlusion.

Materials and Methods

Twenty-nine patients were evaluated with temporary balloon occlusion of the ICA and brain blood flow imaging prior to planned carotid sacrifice. Eleven ICAs were subsequently sacrificed, forming the basis of this study. Temporary occlusion was performed for 30–55 minutes in 10 patients. One patient tolerated the occlusion for less than 5 minutes. Blood flow imaging was performed with Tc-99m HMPAO SPECT in 10 patients and with Xe/CT in one patient. The patients who underwent brain blood flow imaging with SPECT were injected with 23 mCi of Tc-99m HMPAO as an intravenous bolus during the temporary balloon occlusion. All patients were then imaged within the next 4 hours, after completion of the temporary balloon occlusion procedure, on a high-resolution Three-camera SPECT (Toshiba Medical Systems, Tustin, CA). Sagittal, axial, and coronal images were obtained. Baseline images (ie, images without temporary balloon occlusion) were obtained in most patients if abnormality was detected on the temporary occlusion images. The records of the patients who underwent carotid sacrifice were evaluated for related complications and compared with the results of the temporary occlusion and the brain blood flow images. Follow-up ranged from 3 to 65 days.

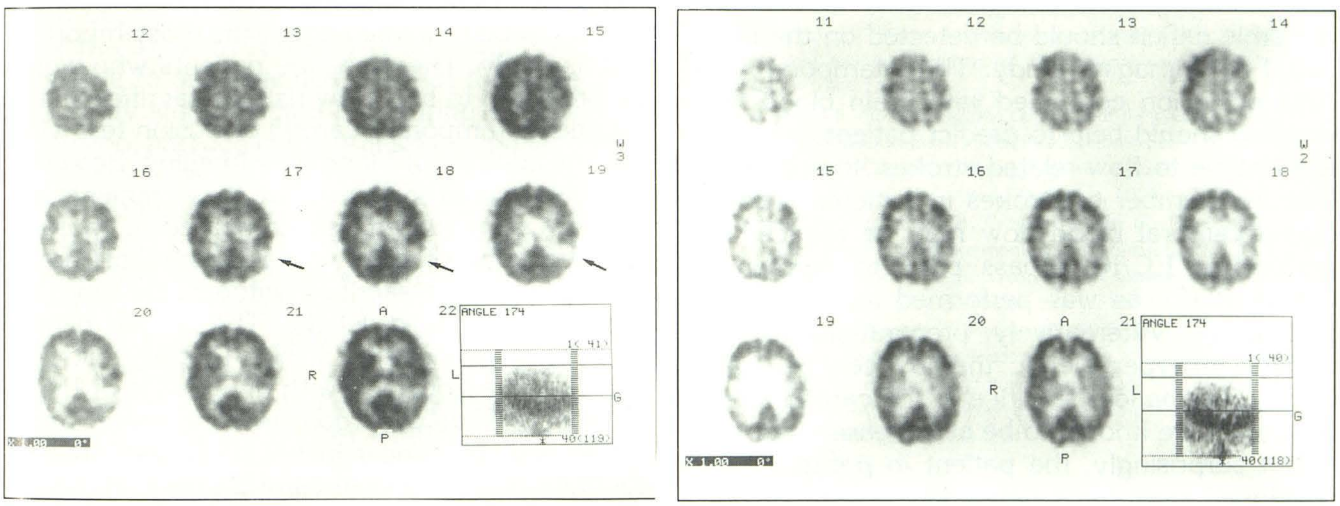
Results

The patients can be divided into three groups: group 1—patients with symptoms during occlusion and an abnormal blood flow study (one patient); group 2—patients with no symptoms during the carotid occlusion but with an unequivocally abnormal blood flow study (two patients); and group 3—patients with no symptoms during carotid occlusion and a normal or minimally abnormal blood flow study (eight patients). One of the patients (patient 9) in this group was initially in group 2 but after extracranial-to-intracranial (EC/IC) bypass fell within group 3 (Fig. 1).

Following ICA sacrifice, the patient in group 1 developed hemiparesis as predicted. One patient (patient 2) in group 2 did well. The second patient (patient 3) developed right hemiparesis 17 days following an episode of hypotension believed secondary to aspiration (Fig. 2). Of the eight patients in group 3, seven did well without the development of any neurologic symptoms related to the occlusion. One patient (patient 4) developed left hemiparesis 1 week after surgical sacrifice of the ICA and clipping of a middle cerebral artery (MCA) aneurysm (see Table 1).

Discussion

Following carotid occlusion, a stroke may develop from stump emboli to the intracranial vasculature or from reduced cerebral perfusion (1). It is believed that the risk of cerebral stump emboli can be reduced by occluding the ICA as distally as possible, thus reducing the amount of stump for thrombus formation (4). It is hoped that by combining brain blood flow imaging with temporary ICA occlusion the number of strokes from reduced cerebral perfusion can be limited. Normally, average cerebral blood flow is approximately 54 mL/100 g·min over a wide range of blood pressures due to cerebral autoregulation (5). It is believed, for neuronal dysfunction to occur, that flow must fall to approximately 20 to 25 mL/100 g·min (6). In patients with marginal collaterals, carotid occlusion may drop cerebral blood flow below the normal level but not to the



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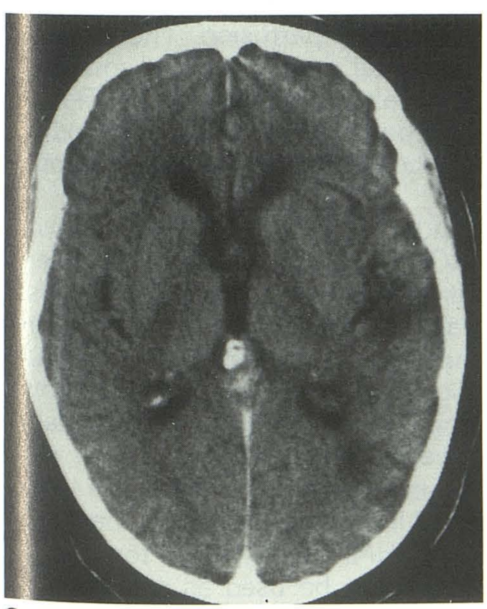

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Fig. 2. This 67-year-old woman (see Table 1, patient 3) with recurrent squamous cell cancer of the neck was asymptomatic during the temporary occlusion of the left ICA but subsequently developed right hemiparesis 17 days following ICA sacrifice believed due to reduced flow.

A, Axial Tc-99m HMPAO SPECT images show decreased perfusion in the left posterior border zone (watershed) area (*arrows*) during temporary balloon occlusion of the left ICA.

B, Baseline axial images do not show any abnormalities.

C, CT scan obtained 2 weeks following onset of right hemiparesis shows a border zone infarct that correlates precisely with the brain blood flow study.

TABLE 1: Summary of findings

Patient No.	Group	Age (years)	Diagnosis	Blood Flow Result	Method of Carotid Sacrifice	Outcome
1	1	45	Cavernous aneurysm	Markedly abnormal	Surgical	Stroke
2	2	52	Squamous cell cancer	Small area of abnormality	Balloon	No deficit
3	2	67	Squamous cell cancer	Small area of abnormality	Surgical	Stroke
4	3	47	Cavernous aneurysm	Normal	Surgical	Stroke
5	3	50	Cavernous aneurysm	Normal	Balloon	No deficit
6	3	14	Cavernous aneurysm	Normal	Balloon	No deficit
7	3	77	Cavernous aneurysm	Minimal abnormality	Balloon	No deficit
8	3	46	Cavernous aneurysm	Minimal abnormality	Balloon	No deficit
9	3	58	Petrous aneurysm	No change from baseline[a]	Balloon	No deficit
10	3	69	Cavernous aneurysm	Normal	Balloon	No deficit
11	3	51	Cavernous aneurysm	No change from baseline	Balloon	No deficit

[a] This patient initially showed decreased flow but underwent EC/IC bypass and, on repeat testing, showed no change in blood flow compared to a baseline blood flow study.

critical level. However, these patients who are presumably more vulnerable to a flow-related ischemic deficit should be detected on the brain blood flow imaging study. Thus, temporary carotid occlusion combined with brain blood flow imaging should help to predict patients who are susceptible to flow-related strokes. It is possible that the number of strokes in patients with reduced cerebral blood flow may be reduced by performing EC/IC bypass prior to permanent occlusion (7), as was performed in one of our patients (2). Alternatively, preparations for hypertensive/hypervolemic therapy can be made prior to permanent sacrifice of the carotid artery if patients are known to be at increased risk.

Not surprisingly, the patient in group 1 who developed symptoms (left-sided weakness) during temporary occlusion of the right ICA and also had an abnormal brain blood flow study developed a stroke. Seven of the eight patients in group 3 with a normal or minimally abnormal blood flow study did well as predicted. Patient 4 developed a stroke (mild left hemiparesis) 1 week following surgical occlusion of the right ICA and concomitant clipping of a right MCA aneurysm. The ICA was occluded in the neck and just proximal to the ophthalmic artery in order to trap her cavernous carotid aneurysm. It is likely that this patient's stroke was related to poor perfusion following her ICA ligation. It is possible, although we believe less likely, that her stroke was secondary to an embolus or spasm of the MCA 1 week following surgery. Therefore, we suspect that even temporary occlusion combined with brain blood flow imaging will not detect all patients who are vulnerable to strokes related to decreased perfusion.

The patients in group 2 who were asymptomatic during temporary occlusion but had a defect on blood flow imaging are the most important in this study. These are the patients who would be predicted to be at low risk for sacrifice with a traditional temporary carotid occlusion test without the addition of blood flow imaging. However, our data would indicate that these patients are actually at increased risk compared to those in group 3. One of the two patients in this group tolerated carotid sacrifice without the development of neurologic deficits. The second patient (patient 3) developed a stroke 17 days following sacrifice in association with an episode of hypotension. She had undergone resection of recurrent squamous cell cancer in her neck with surgical sacrifice of her cervical carotid artery. Although she potentially could have had a stump embolus, her history strongly favors that her stroke was due to reduced cerebral perfusion. The CT scan obtained 2 weeks after her stroke also correlates exactly with the brain blood flow study (Fig. 2). Larger series of patients would be needed to permit statistical comparisons between groups 2 and 3.

We have found brain blood flow imaging with Tc-99m HMPAO SPECT to be very convenient and easy to perform without increasing the risk of the temporary occlusion procedure. Tc-99m HMPAO is a substance that is regionally distributed in proportion to regional cerebral blood flow. It is lipophilic and becomes trapped intracellularly because it converts to a hydrophilic form that cannot pass the cell membrane. After the initial lipophilic phase of less than 5 minutes, the distribution of Tc-99m HMPAO is stable for several hours (8). Thus, it can be used as a marker of blood flow during the temporary occlusion and then imaged several hours later using a SPECT camera.

It is noteworthy that the blood flow images that are acquired using Tc-99m HMPAO provide only a snapshot of the point in time when the drug is administered. We now routinely use a 30-minute occlusion test. Since HMPAO requires fresh technetium and is stable for only approximately 30 minutes, coordination between the nuclear medicine department and the neuroangiography suite is needed to time Tc-99m HMPAO availability with the balloon occlusion test. At our institution, technetium generators are not maintained in the department, and it takes approximately 45 minutes to get fresh technetium. Thus, this timing becomes a factor. We cannot control the moment during balloon occlusion when the Tc-99m HMPAO will be administered except by way of delaying balloon inflation until the Tc-99m HMPAO is on hand. We have not done so as a practice. Most of the patients in this study were injected late during their balloon occlusion, and occlusion times were longer during this study than we now routinely use. The timing of the administration of Tc-99m HMPAO during the balloon occlusion was not examined specifically in this study but is worthy of investigation.

In conclusion, we feel carotid sacrifice without preliminary testing by temporary balloon occlusion carries an unacceptable risk. The addition of brain blood flow imaging, which is especially convenient using Tc-99m HMPAO, can further improve the safety margin of ICA occlusion procedures. If patients do not tolerate the occlusion, either because they develop symptoms or have an abnormal brain blood flow study, flow augmentation may be desirable.

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