ROLE OF THE NEUROTOLOGIST IN THE DIAGNOSIS OF BRAIN ISCHEMIA

Glen D. Dobbett, M.D.* and Galdino E. Valvassori, M.D.†

Hindbrain problems resulting from poor blood circulation in the vertebral arteries are now well recognized. The most dramatic problems are the deaths that have occurred following chiropractic manipulation of the neck. These patients develop a dazed state, are vertiginous with nausea, lose vision, and have auditory tinnitus before death.1–8

Abnormality of the vertebral artery may include intima damage with clots, static or stenosed sites of atherosclerosis, narrowing produced by cervical spondylosis, and the hemodynamic obstruction associated with rotation and extension of the head. The hemodynamic problem has been well documented in cadavers by Tatlow and colleagues9 and DeKleyn and Versteegh.10 The same has been verified in live patients by Sheehan and others.11–16

Neurotologists are focusing more on vascular ischemia, as they are seeing many of these patients.17 Many patients do not have peripheral disease, such as Meniere's disease, acoustic trauma, or a retrocochlear acoustic neuroma.

Permanent or transient reduction of blood flow to the end-organs and to the hindbrain is the single major cause of vestibular disorders and a common cause of sensorineural hearing loss. Reversible deafness in some patients may be due to temporary obstruction or stasis within the capillaries in the stria vascularis, which produces strial hypoxia, resulting in a reduction in the endolymphatic potential, with subsequent hearing loss. Bailey and associates18 have shown reversal of neurosensory hearing loss, most probably by improved circulation or collateral supply to the stria vascularis. The vascular anatomy and territories of circulation in these areas are well demonstrated but not necessarily understood.19–22

This paper reviews the methods of assessing the hindbrain (or target site) circulation so revascular bypass surgery or medical treatment may be planned. Vertebral artery surgery for vascular improvement of the hindbrain is available in some neurovascular centers. Carney has done over 102 cases in 1981 and Keiffer of Paris over 60 cases.23–32 With the training of more neurovascular surgeons this procedure will be available at more clinical sites. The role of neurotologic studies in identifying suspected early hindbrain ischemia is also discussed.

The methods of assessing the target circulation of the brain have included isotope studies and dynamic computed tomography (CT) studies with xenon and iodinated contrast. In the future, nuclear magnetic resonance (NMR) flow analysis may be the method of choice.

The cerebral radionuclide angiogram (CRAG) isotope includes multiple rapid images of the brain and neck in a frontal projection. The images of the neck show both arterial and venous structures that can be confusing to interpret. The supratentorial detail shows the anterior and middle cerebral vessels. The posterior fossa or hindbrain and the vertebral arteries cannot be evaluated by this technique, since the overlapping neck, scalp musculature, and blood supply obscure useful information. In addition to the noise of this technique, it gives no brain tissue information regarding flow. The "flip-flop" image of middle cerebral artery stenosis and delayed collateral circulation over the brain to supply the depleted territory is well recognized and indicative of this single vessel anomaly. This, however, is not a common isotope diagnosis.

Buell and coworkers33 have shown recently

*Professor, Departments of Radiology and Neurosurgery, University of Illinois School of Medicine, Chicago, Illinois

†Professor, Departments of Radiology and Otolaryngology, University of Illinois School of Medicine, Chicago, Illinois

Reprint requests: Department of Radiology, University of Illinois School of Medicine, Chicago, IL 60612 (Dr. Dobbett)

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that the diagnostic accuracy of detecting supraten-torial blood flow alternations is improved by CRAG, if combined with carotid artery directional Doppler sonography. Thus, vascular changes in either the extracranial carotid vessels or supratentorial vessels are assessed and produce a diagnostic sensitivity of 93.3 percent.

Lassen and Ingvar in 1961 first used inert radioactive gas to measure regional blood flow. Intravascular radioactive xenon studies, although laborious and costly, when done for the total brain are useful in defining territories that need revascularization. For clinical regional cerebral blood flow studies, the xenon intracarotid injection method has been used abundantly, and several hundred papers have been published from many centers. This method has not been readily accepted because of the need for an invasive injection of the carotid artery.

The CT dynamic scan has been used with inhalation of inert xenon gas to saturate the brain and subsequently follow its washout from the brain after stopping the breathing of this gas. This technique has produced quantitative brain flow measurement. With proper patient monitoring, this study shows great possibility. The application of the CT scanner and inhalation studies has been best applied by Meyer and colleagues. After inhalation, xenon diffuses rapidly from the lungs into the arterial blood and brain tissue. The gas acts as a tracer that can be measured as it diffuses through tissue. The resulting changes in CT units have been used for measurements of local cerebral blood flow. Stable xenon is lipid soluble; hence, it is more soluble in white matter than in grey matter. In pathologic states such as brain edema, infarction, gliosis, and tumor, local tissue solubility is altered. These abnormal changes in tissue solubility may therefore be measured by CT scanning during xenon inhalation.

The positron emission tomography (PET) scan is a high cost, sophisticated instrument, which requires an associated cyclotron to produce krypton-77, 11C-iodoantipyrine, 18F-fluorooethanol, 18F-nicotine. Experienced specialty personnel are needed for proper operation. Using the PET scanner and a commercially available nondiffusible tracer, 68GA-EDTA, measurement of the transit time in the brain can be made. This technique is not a quantitative measurement of cerebral blood flow, but is similar to the dynamic CT circulation study. The latter, however, is less costly and does not require a radioactive tracer. This research will help understanding of brain circulation, but it does not appear to be of practical clinical use.

We have the greatest personal experience with the dynamic CT scan circulation study. It is the most practical and most available technique that only requires a rapid intravenous injection of nonradioactive iodinated contrast material. The passage of the contrast through a section of the brain may be plotted. To calculate the mean transit time of tissue, such as brain, from dynamic CT performed after a bolus injection of intravenous contrast material, the time dependence of the contrast material to the tissue must be "deconvolved" from the observed time course of the tissue contrast enhancement. If the approximate shape of the curve of the tissue response to an instantaneous injection of contrast material is assumed, the width of this curve that gives the best fit to the observed tissue response can be used to find a value for the tissue mean transit time. Axel by applying this technique to dynamic CT scans of two normal volunteers, yielded values comparable to those in the literature for other techniques. The method has the advantages of being simple to implement, relatively insensitive to noise, and of acceptable detail. The method does not require any curve fitting to correct for recirculation. Two injections are usually needed, with one through the hindbrain and the other through the forebrain. The sections give good representative data regarding circulation to the anterior and posterior sides of the circle of Willis. Patients who are sensitive to iodinated contrast cannot use this method or need premedication. Another limitation is the random selection for the level of testing which may not correspond to the level of poor circulation.

The CT dynamic scanner offers a practical and readily assessible circulation study to the neurologist. Many patients (87 percent) with hindbrain ischemia present with the common symptom of dizziness and visual disturbances such as blurred or tunnel vision. Partial or complete blindness accounts for 44 percent of cases. Our experience shows ataxia in 32 percent, spontaneous nystagmus in 27 percent, and sensorineural hearing loss in 22 percent.

In office practice, the neurologist is able to identify patients who have problems of the hindbrain and occipital lobes. The EEG extends over the cortical forebrain surface, but is limited within the hindbrain. The abnormal vestibular, brainstem, auditory or visual office tests have to be explained. The abnormal brainstem auditory evoked response test records multiple reflex complex sites. Vestibular testing gives a more diffuse central response. A more complete battery of testing should be developed to cover as many reflex complexes as possible for a reasonable cost.

Aschan and Hugosson in 1966 reported a case of a 53-year-old woman who had ligation of both common carotid arteries for bilateral carotid cavernous fistulas. This was a rare "experimental" situation in a human subject to demonstrate the dependence upon the vertebral arteries for the brain blood flow, and the opportunity to study the pre- and post-operative otoauditory conditions. Electronystagmography before the ligation showed no nystagmus, but neck rotation afterward provoked nystagmus. Positional testing without rotation of the neck gave no nystagmus. This shows the importance of studying the hemodynamic
changes about the circle of Willis. These pathophysiologic changes are not usually studied when doing vertebral angiography and are often missed.

In 1979, Causse and Causse emphasized the importance of nystagmography to elicit subclavical vertebrobasilar insufficiency and poor cochleoves-tibular vascularization. This is based upon the fact that inequality in the vascularization of the balance mechanism, the two posterior labyrinths, can create a nystagmus well in advance of the appearance of dizziness, deafness, or brainstem neurologic signs.

Today, a separation of central from peripheral abnormalities is usually quite easy. Central lesions or tumors can be excluded with high definition CT studies. In 1981 Kumar further defined the value of vestibular decruitment studies to determine "peripheral" or "central" lesions. In an analysis of 139 cases where vestibular decruitment was recorded, Torok found 105 patients with central or intracranial disorders. Most of the cases showed normal neurologic and conventional radiologic studies. Out of 72 consecutive cases with central vestibular findings, 66 had intracranial anomalies. Thus, the combination of electronystagmographic studies and CT dynamic circulation studies produced a diagnostic verification of 92 percent.

CASE REPORTS OF HINDBRAIN ISCHEMIA

Subclavian Artery Steal Syndrome

Case one: A 55-year-old female presented with a chief complaint of persistent vertigo since revision of a stapedectomy. No semicircular canal fistula or middle ear disease was evident. The vertigo remained undiagnosed for eight years. A CT circulation study demonstrated normal tissue mean transit times over the anterior aspect of the supratentorial sections and delay times over the occipital lobes and the infratentorial areas (Fig. 1). This was consistent with poor circulation to areas supplied by the vertebral arteries.

An aortic arch angiogram demonstrated complete occlusion of the left subclavian artery. When the right vertebral artery was injected, the contrast descended into the left vertebral artery to fill the left subclavian artery beyond the occlusion. This subclavian steal was surgically treated with a subclavian bypass graft. This corrected the patient's vertigo (Fig. 2).

Carotid-Vertebral Artery Disease

Case two: A 55-year-old male was seen for a sudden onset of left-sided sensorineural hearing
loss and tinnitus. The patient had no other symptoms or vestibular abnormalities.

The audiogram showed a pure tone within normal limits in the right ear through 2000 Hz, and dropped sharply to a severe high frequency hearing loss with a notched configuration. The poorest threshold was at 4000 Hz. The speech reception threshold was in good agreement with the pure tone findings. The left ear demonstrated a relatively flat sensorineural hearing loss (Fig. 3). Speech awareness threshold was in agreement with the pure tone findings.

Polytomographs of the inner ears showed partial obliteration of the left vestibular aqueduct. The cochlear capsules were normal. A CT dynamic study showed delayed circulation along the left side of the fourth ventricle, and the remaining areas were normal (Fig. 4).

Because of the CT dynamic study, a four-vessel neck and brain angiogram was obtained. This demonstrated a left internal carotid artery narrowing to about 50 percent of its normal diameter. No left vertebral artery was found except that distal portion at the level of Cl. This remained open by supply from collateral muscular branches (Fig. 5A).

The patient was treated with left carotid artery endarterectomy and vein patch angioplasty. A left common carotid artery to distal left vertebral artery bypass was performed from the vein patch angioplasty to the vertebral artery with an isolated vein segment from the left thigh (Fig. 5B).

The sensorineural hearing loss remained unchanged; however, the tinnitus disappeared. The patient was grateful for the relief of the tinnitus.

Figure 2. Case one: Postoperative CT dynamic section of the posterior fossa of 9-29-81 after surgical correction of the subclavian artery steal. The graph shows the symmetrical areas of the posterior cerebellum and a normal tissue transit time of 16 seconds.

Figure 3. Case two: Pure tone audiogram of the right ear (o) is normal through 2000 Hz and drops sharply for a severe high frequency hearing loss. The left ear (x) demonstrated a flat, moderate to severe sensorineural hearing loss.
Figure 4. Case two: A CT dynamic section of the posterior fossa with comparison of areas. The right side (white box) numbers one and two show a normal tissue transit time of 16 seconds. The left side (no box) show a tissue transit time delay of 20 seconds. This is consistent with a unilateral hindbrain circulation problem.

Figure 5. Case two: A, Composite lateral drawing of the left carotid angiogram and left subclavian angiogram. The internal carotid artery is narrowed to about 50 percent of its normal diameter by arteriosclerotic plaque formation. The left vertebral artery is occluded except for the distal C1 segment which remains open by collateral ascending cervical vascular blood supply. B, Drawing of neurovascular operative procedure of the left carotid artery endarterectomy and a vein patch angioplasty. A left distal vertebral artery bypass vein graft was added to this.
Vertebral Artery Bypass Surgery

Case three: A 67-year-old woman complained of a "floating" sensation of several weeks duration whenever she stood up. The symptoms progressed and eventually she was unable to walk without support. She had no complaints of hearing loss; however, a pure tone audiogram showed a symmetrical, high frequency sensorineural hearing loss of mild to moderate severity (Fig. 6).

The vestibular caloric test showed bilateral type II decruitment (Fig. 7). She had a positive Romberg test. The standard CT scan was normal, although the circulation study indicated vertebrobasilar insufficiency (Fig. 8). The angiogram showed an obstructed right internal carotid, left vertebral, and left subclavian arteries.

The surgical reconstruction of the right internal carotid artery and the left vertebral artery was done. The left subclavian artery was decompressed.

Two months following surgery, the patient was asymptomatic.

Diagnosis Of Hindbrain Disorders

Case four: A 65-year-old male presented with "dizziness" for several weeks and a feeling of being "light-headed". The symptoms were aggravated by movement. He had a known cardiac arrhythmia.

A noninvasive evaluation with auditory evoked brainstem potentials showed the absolute latency of wave V to be normal for the right ear and prolonged for the left. Also, there was a prolonged III to V interpeak latency consistent with an abnormal upper auditory brainstem pathway dysfunction for the left side (Fig. 9).

The CT circulation study confirmed delayed circulation about the left paraventricular area within the posterior fossa (Fig. 10).

The patient remains under treatment with beta-blocker medications to correct the cardiac arrhythmia and improve the stroke output of the heart. The patient is asymptomatic.

CONCLUSION

With the technological advances in the tools of the neurotologist to assess the reflex responses of the hindbrain, early ischemic changes are more easily detected. Whenever an abnormal vestibular, brainstem, auditory, or visual evoked response potential study is not specific for a definite condition, hindbrain ischemia should be considered.

The present noninvasive CT dynamic circulation studies are an effective way to include or

![CALORIC TEST RIGHT](image_url)

**Figure 6.** Case three: Although the patient had complaints of a hearing loss, a pure tone audiogram showed a symmetrical high frequency, mild to moderate sensorineural hearing loss.

![CALORIC TEST LEFT](image_url)

**Figure 7.** Case three: The vestibular caloric test showed a bilateral type II decruitment. (Reprinted with permission from Kumar A: Reliability of central vestibular signs in identification of posterior fossa pathology, Advances in Neurology, Volume 30, Raven Press, 1981.)
Figure 8. Case three: The CT dynamic posterior fossa study shows a normal tissue transit time; however, the peaks of the area about the fourth ventricle are depressed (C2, C12). This is indicative of hindbrain poor circulation.

Figure 9. Case four: Brainstem auditory evoked response showed the absolute latency of wave V to be normal for the right ear and prolonged for the left. A prolonged III to V interpeak is consistent with an abnormal upper auditory brainstem pathway dysfunction for the left side.
exclude ischemia of the hindbrain. If these studies are positive for a circulation problem, then it is necessary to decide if medical or surgical treatment is needed.

If carotid-vertebral bypass surgery is needed, an invasive angiogram will be done to plan the surgical approach.

NMR scanning may play an added role for hindbrain ischemic problems. It produces images without the use of radiation or injected contrast materials. The images are the result of magnetic movement of hydrogen nuclei, which emit specific energies from their location in the section of the body being studied.

This technology permits measurement of blood flow in vessels. When high magnetic fields are used, tissue chemical spectroscopy in vivo is possible.

NMR will be an added important testing tool to analyze the circulation problems of the brain and heart.

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