# Interpretation of Cerebral Dynamic Perfusion Studies*

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A review of the literature for the preceding 20 years reveals that by radionuclide static imaging there has been little improvement in the detection rate of cerebral lesions (1–5). The overall accuracy of brain scans has been reported from 81% to 84%. For glioblastoma multiforme and meningioma, the detection rate is 90%–95%; for low-grade astrocytoma, 55%; and for ischemic strokes, from 10% to 50% depending on the elapsed time from the onset of symptoms. An aneurysm must be at least 2.5 cm in diameter and an arteriovenous malformation 3–4 cm in diameter before the information content is adequate for detection. In patients with transient ischemic attacks, static imaging has been unrewarding (6, 7). Why has there been little improvement in the detection of cerebral lesions by static imaging in spite of improved instrumentation and techniques? Visualization of abnormalities depends on a concentration of radioactivity that is greater in the lesion than in the surrounding tissue, and the mechanisms for nuclide concentration are similar for nearly all of the agents that have been used during the past 20 years. With few exceptions the brain-imaging radiopharmaceuticals are not target specific but depend on the nonspecific changes in vascular wall integrity (for example, dedifferentiation or focal increased intravascular volume, or shunts).

There are a number of lesions that may not be apparent on static images, which include early cerebral infarctions, early subdural hematomas, concussion, arteriovenous malformations of less than critical size for visualization, and neoplasms that are not sufficiently vascular or the vascular component is not sufficiently dedifferentiated to contribute to a preferential concentration of radioactivity. If radioactivity does concentrate in a lesion, the dynamic vascular character of the pathology has not been revealed without the appropriate study. During the first passage of the radiopharmaceutical, rapid sequential radionuclide images provide valuable information on the dynamics of the vasculature. Rapid imaging increases the sensitivity of the total study because an increase, decrease, or no change in the blood flow as reflected by the radiopharmaceutical, has diagnostic meaning when correlated with the static images. Correlations are made with both abnormal and normal scans, and the normal scan may provide diagnostic information relative to the character of the dynamic flow studies.

**Technique.** In order to obtain radionuclide images that provide the required information, precise attention must be given to the technique used in the study. The radionuclide bolus, method of intravenous injection, route of administration, patient position, and shielding—each must be given consideration.

Since the radionuclide bolus must transverse more than a meter of vascular channels, mix with blood from the inferior vena cava in the right heart, pass through the pulmonary capillary bed, return to the heart, and then be transported to the brain, a "tight" bolus is required; that is, less than 1 one ml. Two administrative techniques of the radionuclide bolus are commonly used: the Oldendorf technique (8) and the saline flush (9). Details of these procedures can be found in the original articles.

Most commonly, intravenous materials are ad-

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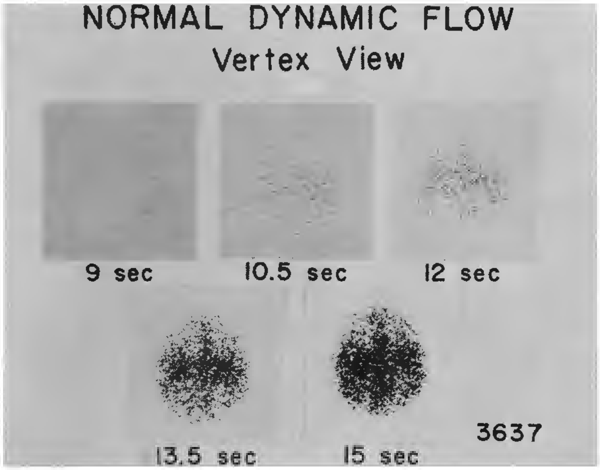


Fig. 1*A*—Early phases of normal dynamic flow (vertex).

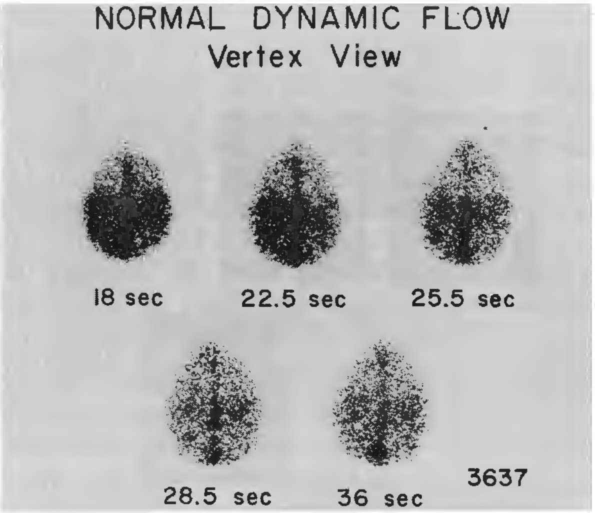


Fig. 1*B*—Venous and recirculatory phases of normal dynamic flow.

ministered in the veins of the antecubital fossa. It is imperative that the medial basilic vein be used whenever possible because this is the most direct route to the axillary vein. Injection into the lateral cephalic vein may result in: 1) delay and lengthening of the bolus because of the narrower caliber of the vessel and the right angle junction with the axillary vein, and 2) fractionation of the bolus because of anastamotic channels and the right angle junction (10). The Valsalva maneuver may also contribute to poor bolus characteristic.

Adequate shielding of the chest and shoulders with lead-impregnated drapes minimizes undesirable activity from the heart and great vessels. During the

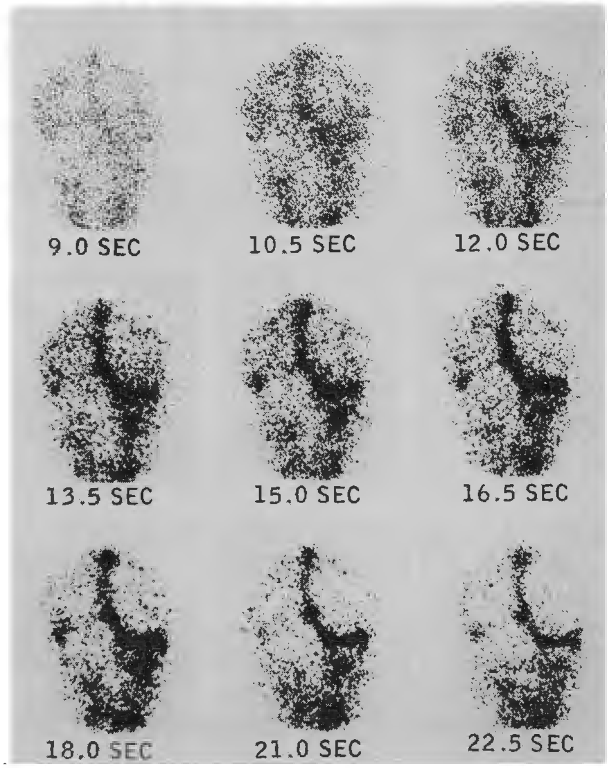


Fig. 2—Nuclear angiography on 65-year-old patient being evaluated for seizures.

first passage of the radionuclide bolus through the head, unwanted activity in the scalp can be eliminated by compression with a blood pressure cuff at the level of the external occipital protuberance and the forehead. When the cuff is inflated to above systolic pressure, the amount of radioactivity detected during the first transit is reduced about 15% to 30% (11).

We use the vertex projection as the position of choice for routine cerebral dynamic perfusion studies. This projection will provide data on the cortical distribution of most of the anterior cerebral artery, a portion of the posterior cerebral artery, and a splay of the middle cerebral artery. Not only is a greater area of cortex visualized, but a spread of the middle cerebral branches also provides greater sensitivity for the detection of partial decreases in blood flow. Other projections are used when the clinical information dictates, particularly in patients with suspected subdural hematomas.

**Cases.** Figure 1A illustrates the early phases of a normal dynamic flow (vertex). At 10.5 seconds after intravenous administration of $^{99m}TcO_4$, the activity is

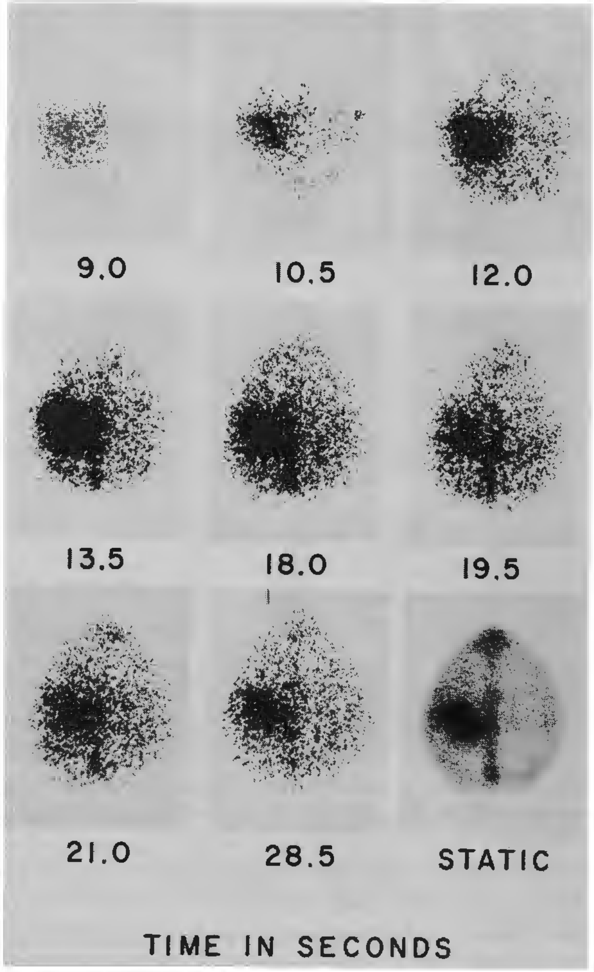


Fig. 3—Dynamic study on patient with left cortical lesion.

first noted in the head; at 12 seconds distribution can be observed in branches of the middle cerebral artery and early filling of the anterior and posterior cerebral arterial areas; further distribution in all three major cerebral arterial regions is demonstrated; and at the end of the early circulation, the cerebral cortex is perfused and activity is beginning to drain into the superior sagittal sinus. Figure 1B illustrates the "venous" and recirculatory phases. Venous drainage is noted throughout the sequence. Demarcated areas of persistent activity are found in the superior sagittal sinus, torcular Herophili, and the bilateral jugular bulbs (36-second frame).

Figure 2 illustrates the information that can be obtained from a dynamic study. The sequence was performed from the posterior projection. The patient, 65 years old, was being evaluated for the recent onset

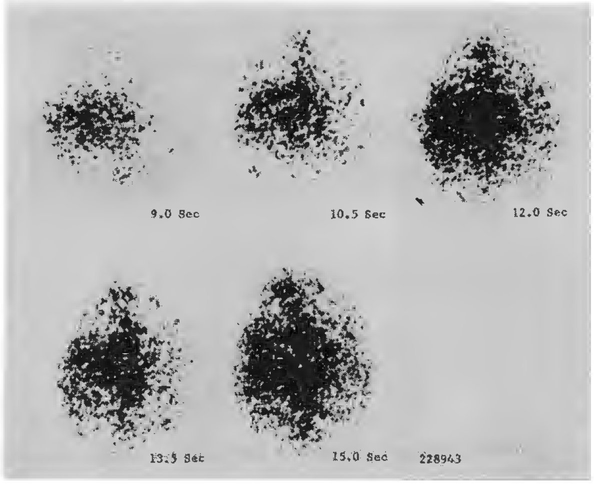


Fig. 4—Nuclear angiography on 14-year-old drowning victim.

of seizures. The primary drainage from the superior sagittal sinus is by the right transverse sinus with no venous structures observed on the left side. Although asymmetrical transverse sinus drainage is frequently encountered, displacement of the torcular Herophili to the right indicates an abnormality that originated in utero or shortly after birth. The interpretation was a left infratentorial fossa mass that displaced the venous structures to the right. Since the patient had been asymptomatic for 65 years, we concluded that it probably was a large arachnoid cyst. Cisternography confirmed the diagnosis.

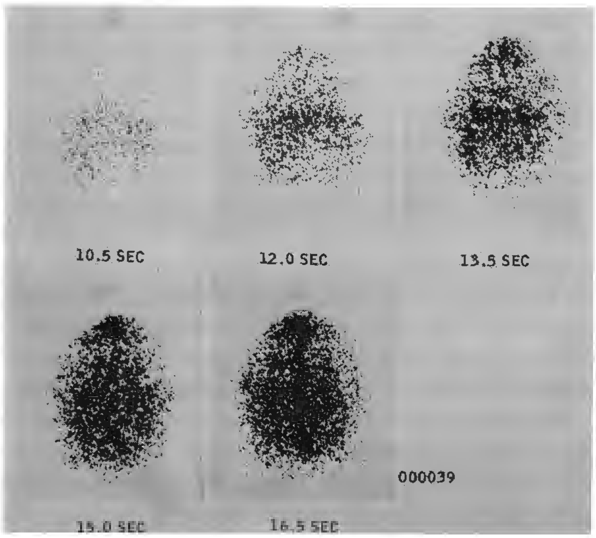


Fig. 5—Nuclear angiography on patient with head trauma.

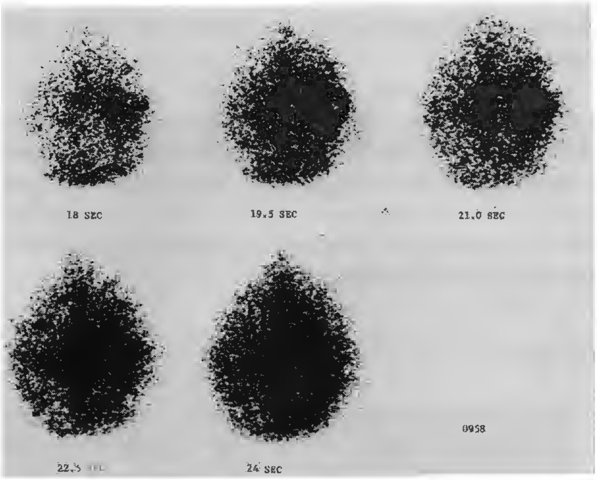


Fig. 6—Diminished flow of left middle cerebral artery in patient with right hemiparesis.

Correlation of the sequential concentration of activity in a lesion with the sequential distribution of activity in the normal brain provides information on the type of pathology. For eight years a young college student had had muscular twitching of the right hand, usually precipitated by physical stress. Static radionuclide images revealed a left cortical lesion, oriented with the rolandic sulcus, in the distribution of the rolandic branch of the left middle cerebral artery. The dynamic study (Fig 3) presented the characteristics of a large rapid arteriovenous shunt. Circumscribed radioactivity was first observed in the left mid-hemisphere nine seconds after administration of the radiopharmaceutical. By the 12-second frame, activity was heavily and focally concentrated

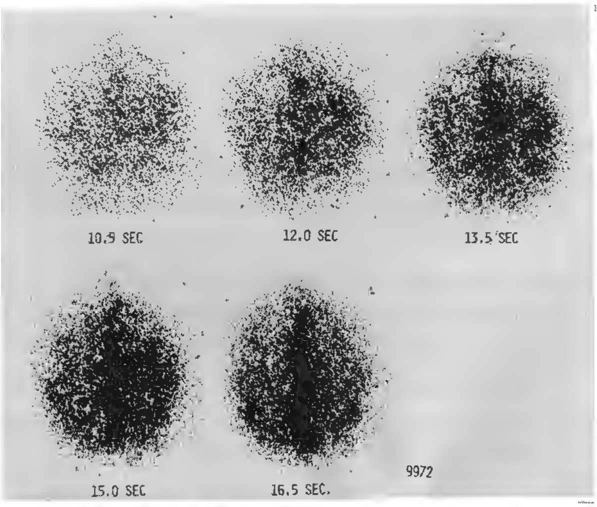


Fig. 7—Diminished flow to left hemisphere in patient with right hemiparesis.

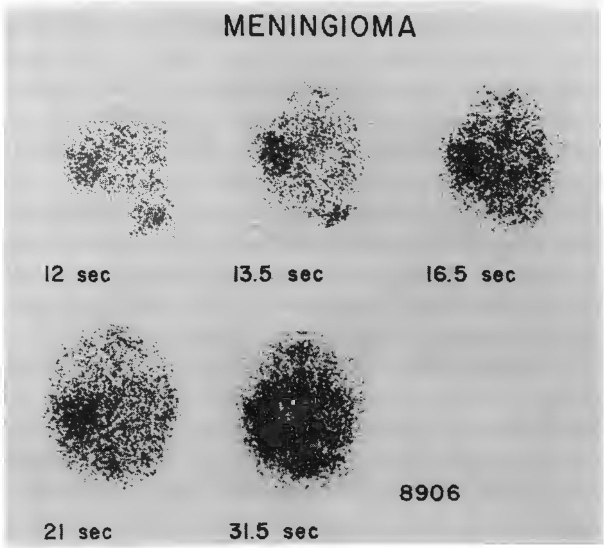


Fig. 8—Dynamic study on patient with suspected arteriovenous malformation.

in the left hemisphere, and early distribution to right cortical area was present.

Within 1½ seconds (13.5-second frame), there was venous drainage through the superior sagittal sinus. Since the 1.5-second interval was too short a period to attribute the venous drainage to the right hemispheric circulation, only a vascular shunt would produce this sequence of events. The diagnosis was a rapid arteriovenous malformation that originated from branches of the left middle cerebral artery and drained into the superior sagittal sinus. Contrast angiography demonstrated the arteriovenous malformation and also revealed that there was a "steal" from the right internal carotid blood supply by way of the anterior communicating artery.

A 14-year-old boy nearly drowned and subsequently developed pneumonia and pulmonary abscesses. He became somnolent, and an electroencephalogram demonstrated diffuse encephalopathy. In the radionuclide angiogram there was no perfusion through the right middle cerebral artery with little evidence of collateral circulation (Fig 4). Angiography revealed obstruction of the internal carotid at the base of the skull. The absence of flow and collateral circulation suggested cerebral edema which was demonstrated by autopsy examination.

Cerebral radionuclide angiography has been particularly helpful in the detection of concussion and contusion with associated vasospasm. For example, a 40-year-old man received head trauma with contusion of the scalp on the left side. The static images demonstrated increased peripheral activity along the left side that could have been a subdural hematoma or superficial scalp trauma. The dynamic study revealed irregular decreased perfusion of the right middle cerebral artery (Fig 5). On the basis of the increased superficial radioactivity on the left and the decreased perfusion on the right, the interpretation was contracoup concussion or contusion with vasospasm. Subsequent follow-up examinations did not demonstrate evidence of subdural hematoma, and the patient recovered completely.

Radionuclide angiography has proven most useful in patients with cerebrovascular diseases. Most of our patients with strokes usually are examined within several days after the onset of symptoms. Although static studies are almost invariably negative, the dynamic studies are usually positive if the site of the infarction is cortical. Figure 6 illustrates diminished flow of the left middle cerebral artery in a patient with a right hemiparesis. In addition to the localization of the decreased blood flow, collateral flow can frequently be evaluated and furnish prognostic information. In this patient there is little evidence of collateral blood flow to the left hemisphere. The probability of his regaining function from this hemisphere is poor, which was borne out by his subsequent course. In contrast, Figure 7 illustrates another patient with a right hemiparesis and decreased flow to the left hemisphere. In the sequential frames there is collateral blood flow to the left hemisphere, and this patient's prognosis is better. We have found a good correlation between the status of collateral blood flow (determined within a week after the stroke) and recovery of function in the affected side.

As stated earlier, increased, decreased, or no change in perfusion does contribute to the differential evidence in the diagnosis of cerebral lesions. For example, a 40-year-old man developed right-sided symptoms over a period of several months. The static images revealed an area of increased activity of the left cerebral hemisphere, limited to the cortex, and correlated with the configuration of the rolandic branch of the left-middle cerebral artery. From the static images the lesion was interpreted as a possible arteriovenous malformation, or as a lesser possibility, a progressive stroke. The dynamic study (Fig 8) demonstrated early concentration of radioactivity in the correct location that persisted through the dynamic sequence and did not "wash out." This evidence suggested a neoplasm, probably an en-plaque meningioma that was found at subsequent surgery.

The position of cerebral radionuclide angiography has been well established. In our experience, 75%–85% of diagnosis from brain imaging is based on the dynamic studies. Improved techniques and continued experience with nuclide angiography can be expected to advance the diagnosis of central nervous system lesions.

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