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Evaluation of Cerebral Hemispheric Contrast Transit with Intravenous Digital Subtraction Angiography

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Thirty-six patients with varying degrees of stenosis of one internal carotid artery were studied using intravenous digital subtraction angiography, assessing relative hemispheric washin and washout of contrast medium. Ipsilateral delayed contrast transit was seen in 16 of 18 patients with a 70% or greater carotid artery stenosis. Decreased hemispheric peak contrast density was also seen in most of these patients. With further improvements in the computer program and faster imaging rates, intravenous digital subtraction angiography has the capability of providing valuable physiologic data along with anatomic information in patients with suspected cerebral ischemia.

In an attempt to identify or quantify changes in cerebral perfusion in patients with transient ischemic attacks (TIAs), studies of cerebrovascular transit times have been performed in nuclear medicine with radionuclide angiography, using either visual or computer-assisted analysis [1, 2]. Similar principles have been used with rapid, sequential (dynamic) computed tomographic (CT) scanning of the brain after intravenous bolus infusion of iodinated contrast medium [3, 4], taking advantage of the more precise intracranial anatomic detail of CT. However, neither technique provides what many consider to be the most important information, namely, the morphology of the arteries in the neck and head. This information can only be supplied by cervicocerebral angiography. However, angiography carries a small but definite risk and a significant expense and generally is not used as a screening examination.

The recent advent of intravenous digital subtraction angiography (DSA) has provided a new, safe, and relatively simple means of assessing, on an outpatient basis, the anatomy of the aortic arch and great vessel origins, the common and internal carotid arteries, the vertebral arteries, and the major intracranial arteries [5, 6]. It can be used as a screening procedure and in many instances has replaced conventional angiography as the definitive preoperative examination in patients with TIAs. Since an intravenous injection simultaneously delivers contrast material to all the vessels leading to the brain, intravenous DSA should also be able to provide physiologic transit time information similar to radionuclide angiography. The objective of this preliminary study was to determine if intravenous DSA can demonstrate changes in contrast transit on the side of a carotid stenosis.

Subjects and Methods

We studied 36 consecutive patients with a 50% or greater diameter stenosis of one common and/or internal carotid artery and with minimal or no stenosis on the opposite side with intravenous DSA. Our intravenous technique has been described [6]. Images were obtained with a specially designed system using an image intensifier with 14, 10, and 6 inch (35.6, 25.4, and 15.2 cm) field capabilities. The initial arch aortogram covered a field from the aortic arch to just beyond the common carotid artery bifurcations. Subsequent oblique views of the neck, to demonstrate the common carotid bifurcations optimally, included the distal common carotid arteries and bifurcations, as well as the entire internal carotid arteries, including their cavernous segments. The vertebral arteries also were generally seen in their entirety. The final anteroposterior (or posteroanterior) head images were collimated to the skull periphery with a lead template and comprised the distal internal carotid and vertebral arteries and the entire intracranial vasculature, including the peripheral middle cerebral artery territories. Images were obtained at a rate of one/sec with a 512 × 512 matrix and at two/sec with a 512 × 256 matrix.

The digital head images were acquired in a linear mode and could be amplified in either a linear or logarithmic fashion. Logarithmic amplification was generally optimal for demonstrating vessels passing through the dense skull base, but the linear mode was often superior in areas of more uniform background density, such as the peripheral cerebral vascular territories. The relative washin and washout of contrast material in the distal internal carotid arteries and middle cerebral artery territories were evaluated by visual examination, from initial opacification through the venous phase. More recently, in an attempt to increase the sensitivity of the study in cases with subtle differences on visual inspection, time-density curves have been derived from computer-defined regions of interest obtained from identical areas in each middle cerebral artery territory. We are currently improving the program to allow the examiner more flexibility in defining the contours of the regions of interest.

Results

Eighteen patients had a measured 70% or greater diameter stenosis of one distal common or proximal internal carotid artery at intravenous DSA. Sixteen of these showed a delay of contrast transit distal to the stenosis compared with the unaffected side, but three could not be studied beyond the arterial phase because of image-degrading motion artifacts. The other 13 patients showed a relative delay in washin and washout of contrast material in the middle cerebral artery territory on the side of stenosis, even though there was a variable degree of demonstrable collateral circulation through the circle of Willis. Three patients had computer-generated time-density curves that confirmed the contrast delay and also

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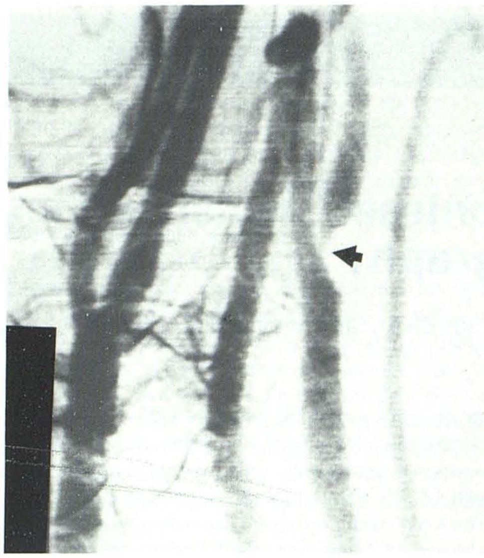

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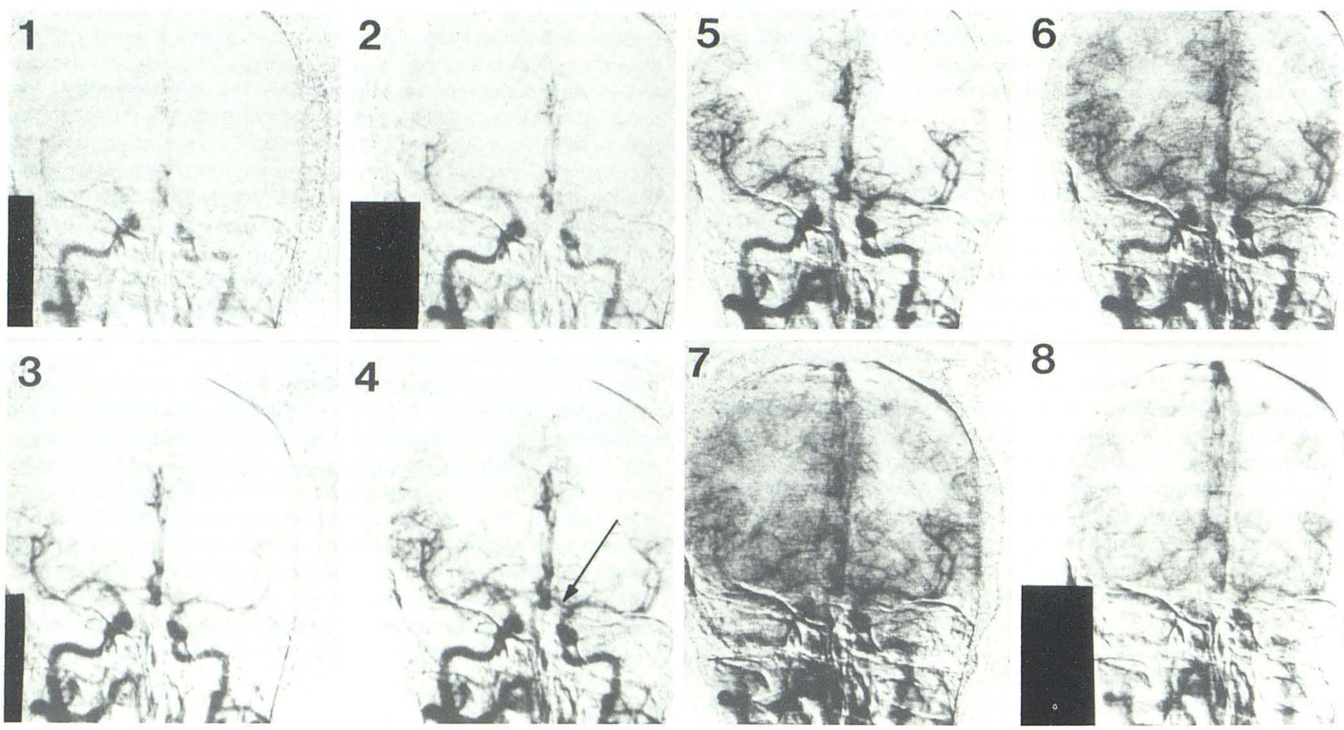

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Fig. 1.—Case 1. **A**, Oblique view of neck. A high-grade stenosis of left internal carotid artery origin (*arrow*). **B**, Serial one/sec images show relative delay in both opacification and clearing of left internal carotid and left middle cerebral arteries, and decreased contrast density in left convexity region compared with right. Note lack of collateral flow to left middle cerebral artery. Left posterior cerebral artery (*arrow*) should not be mistaken for A1 segment, which presumably is hypoplastic.

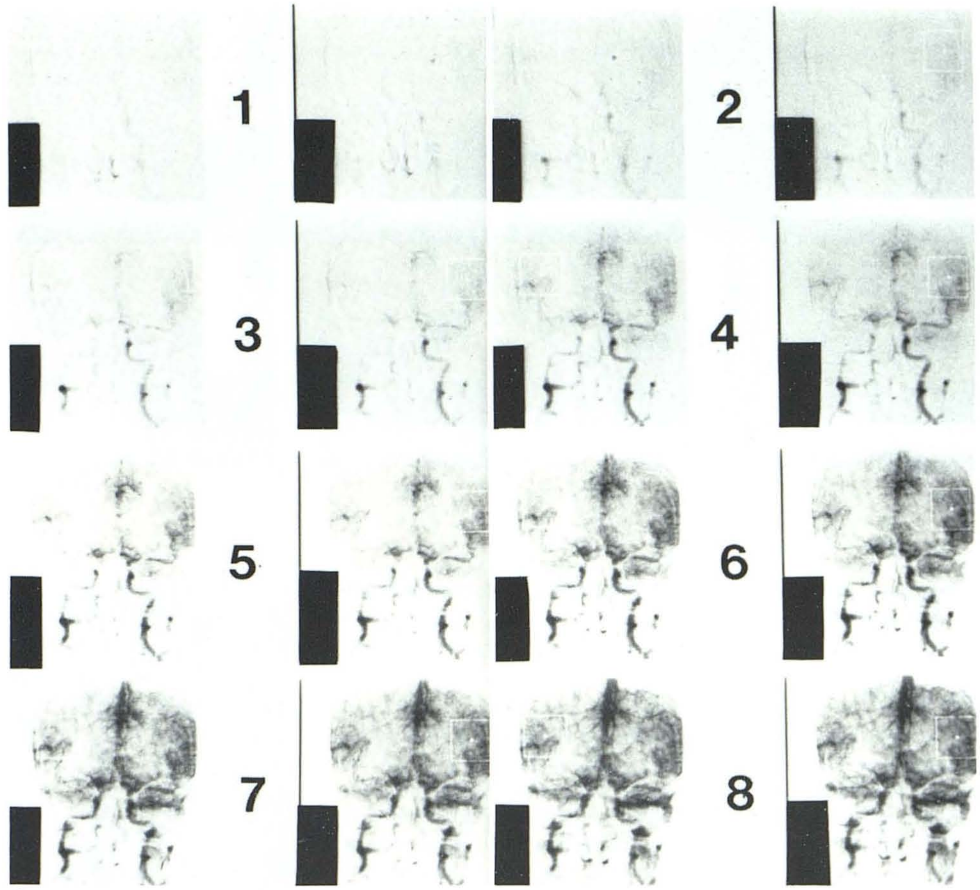
showed a decrease in peak contrast density compared with the unaffected side. A fourth case showed a delay but an increase in peak contrast density on the side of the stenosis. Only one of the 18 cases with less than 70% stenosis (a measured 66%) showed an observable, albeit very subtle, relative delay in contrast transit, confirmed by computer-generated time-density curves.

Since nearly all patients were studied for transient cerebral ischemia, and because of the limited numbers in this preliminary report, no good correlation was found between the degree of delayed transit or the decrease in peak contrast density and clinical symptoms. In fact, one of the most clear-cut examples of delayed washin and washout on the side of stenosis occurred in an asymptomatic patient.

Representative Case Reports

Case 1

A 70-year-old man noted a bruit in the left neck while lying in bed at night. He gave no history of TIAs or other evidence of cerebrovascular insufficiency. An abnormal left oculoplethysmogram led to intravenous DSA, which demonstrated a high-grade stenosis at the



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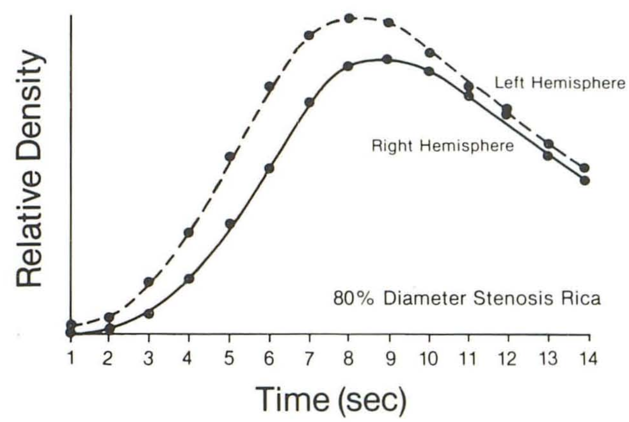

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Fig. 2.—Case 2. **A**, Serial paired images show technique of obtaining regions of interest from right (left of pair) and left (right of pair) middle cerebral artery territories for time-density measurements. Visual inspection alone shows delay in contrast transit and decreased peak cortical "stain" on right. **B**, Time-density curves derived from **A** show delay as well as lower peak on right.

origin of the left internal carotid artery (fig. 1A). Delayed opacification and clearing of the left internal carotid and left middle cerebral artery were demonstrated on serial head images (figs. 1B and 1C). The study also provided additional important intracranial anatomic information by revealing a very hypoplastic proximal left anterior cerebral artery, which prevented significant right-to-left collateral circulation into the proximal middle cerebral artery. Although conjectural, it could be argued that this patient was at a higher risk for infarction because of this variation in the circle of Willis. Left carotid endarterectomy was performed without incident.

Case 2

A 65-year-old man who had undergone a recent left carotid endarterectomy was seen after 1 day of several attacks of left body weakness and numbness. A focal stenosis at the right internal carotid artery origin was believed to be present but was difficult to define with intravenous DSA due to vertebral artery superimposition. However, serial head images clearly showed a relative delay of contrast flow on the right (fig. 2A), and subsequent computer-generated time-density measurements showed both a delay and a

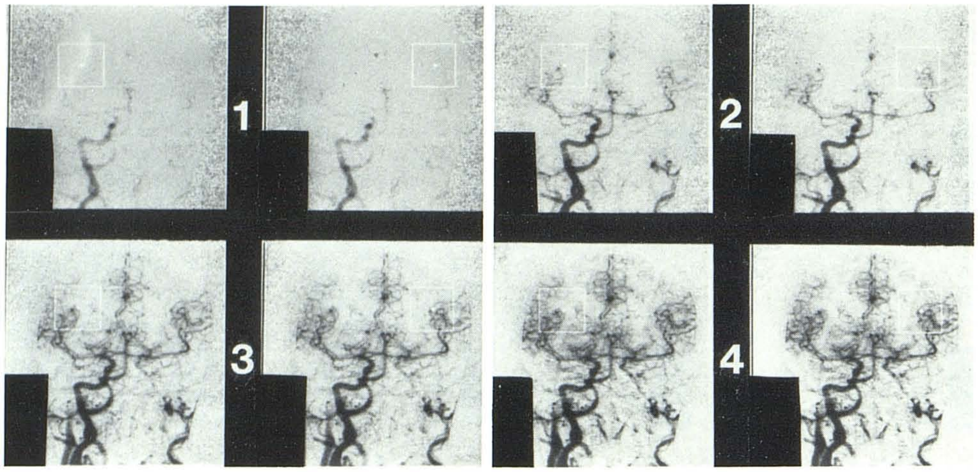

Fig. 3.—75-year-old man with clinically suspected vertebrobasilar insufficiency. Four serial paired images show left internal carotid and left vertebral artery occlusion. Visual inspection shows simultaneous opacification of middle cerebral arteries but slightly less density over left midconvexity (image 4). Computer-generated time-density curves were identical. More adjustable regions of interest conforming to middle cerebral territories would probably provide more accurate data.

slightly lower peak density (fig. 2B). The patient underwent uneventful right carotid endarterectomy.

Discussion

It is clear that this technique does not evaluate cerebral blood flow but only compares transit of contrast material through the internal carotid arteries and the major arteries and veins of the two cerebral hemispheres. Also, delayed opacification does not necessarily reflect reduced flow, since normal flow to an organ may be delayed if it must arrive by a circuitous route. For example, with common carotid artery occlusion, the internal carotid artery may remain patent, receiving excellent external-to-internal collateral flow at the level of the common carotid artery bifurcation. The dynamic intravenous DSA study will show a delayed opacification of the internal carotid artery and hemispheric arteries and veins on the side of occlusion, even though the overall flow through that internal carotid artery is not reduced. Nevertheless, we believe this technique can provide clinically useful hemodynamic information in patients with carotid artery stenosis. We already have seen several cases in which the severity of a carotid stenosis, which was difficult to grade anatomically on the DSA study of the neck, was clarified by the transit study. At this time, intravenous DSA is not as sensitive as radionuclide angiography, which can demonstrate a delay in hemispheric perfusion even with 50% carotid stenosis [2]. More rapid imaging (four to six frames/sec) will undoubtedly increase the sensitivity of this technique.

Intravenous DSA has the additional advantage of being able to define the pattern and degree of interhemispheric cross circulation. As shown in case 1, it is hoped that this information may help identify those patients with carotid stenosis who are at greatest risk for stroke. However, considerable further investigation is necessary. Even in this preliminary series, we have noted a much higher frequency of symmetric, "compensated," hemispheric contrast flow in patients with unilateral carotid occlusion (fig. 3) than in those with high-grade stenosis, who almost invariably show a delay of arterial filling and clearing on the side of the stenosis. As reported by Awad et al. [7], symmetric hemispheric opacification does not necessarily imply normal hemispheric perfusion. A symmetric pattern can be seen in patients with abnormal xenon-133 inhalation cerebral blood flow studies. We are currently comparing the results of our intravenous DSA transit time studies with xenon inhalation studies in patients with unilateral carotid stenosis.

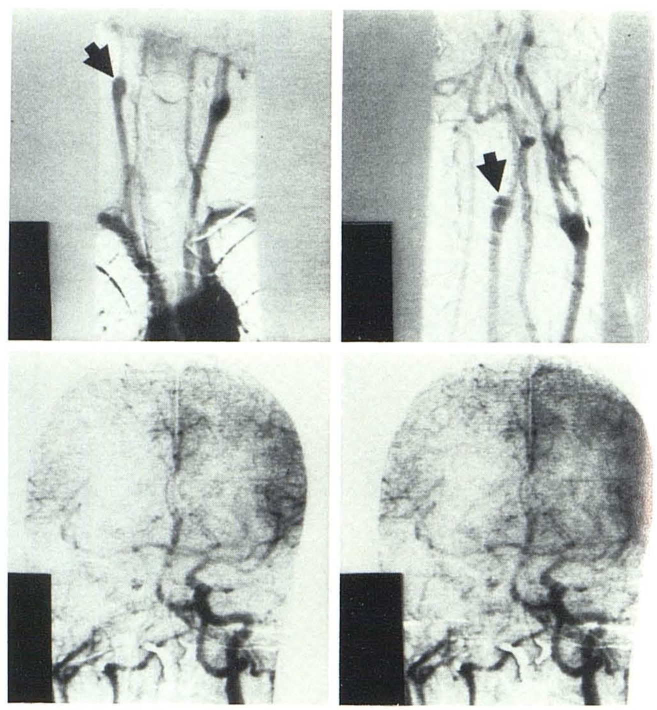

Fig. 4.—65-year-old man after a right cerebral infarct 3 weeks before with residual left hemiparesis. Upper images show occlusion of right internal carotid artery (*arrows*). Lower images show some collateral flow to right middle cerebral artery but markedly decreased convexity "stain" compared with the left.

We are not certain if the relatively lower peak contrast density on the side of stenosis seen in several of our patients reflects decreased hemispheric perfusion. Although this phenomenon is usu- usually seen most strikingly in patients with a completed stroke (fig. 4), it can also be demonstrated in patients with TIAs (fig. 2A) and was even seen in one asymptomatic patient (Figs. 1B and 1C).

With further refinements in technology and technique, it is our hope that a single intravenous DSA examination may in most cases provide sufficient morphologic and hemodynamic information needed in the radiologic workup of the patient with unilateral TIAs, decreasing the need for some "noninvasive" examinations and, more significantly, reducing the need for "invasive" cerebral angiography. It must be emphasized that the success of this technique heavily depends on the dedication of all concerned to obtain the highest quality studies possible, with intimate physician involvement in the conduct and interpretation of the procedures. Good or excellent anatomic studies of the cervical and cerebral vessels and useful dynamic information were obtained in 90% of the cases in our preliminary series.

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