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Limitations in the Interpretation of Intravenous Carotid Digital Subtraction Angiography

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To evaluate the limitations of intravenous carotid digital subtraction angiography (DSA) in the diagnosis of carotid disease, studies of 130 patients were reviewed. Factors that resulted in a nondiagnostic study included: (1) misregistration larynx artifact overlying the carotid bifurcation; (2) external carotid or vertebral artery overlying the internal carotid artery; and (3) poor arterial contrast density secondary to poor cardiac function. As a result of these limitations, the ideal of adequate demonstration of both carotid bifurcations in two opposite oblique projections or an oblique and anteroposterior projection was achieved in only 34 patients (26%). Of 126 carotid bifurcations that were seen adequately in two or more different projections, 19 (15%) showed an abnormality in one projection but appeared normal in another. These abnormalities would not have been detected had the vessel been visualized only in the spuriously normal-appearing projection. These and other limitations of intravenous DSA, such as contrast load and morbidity, are discussed.

Digital subtraction angiography (DSA) has become popular for screening patients for occlusive disease of the brachiocephalic vessels [1–5]. Avoidance of arterial catheterization and performance on an outpatient basis account for the widespread acceptance of DSA. Recent reports have indicated that clinical decisions regarding operative or nonoperative treatment can be made on the basis of these images in 80% of cases [1]. Furthermore, it has been stated that DSA may often obviate conventional aortic arch angiography [2]. However, we caution that unless strict criteria are applied, carotid DSA studies may be interpreted with a degree of confidence not warranted by the quality or completeness of available information. Moreover, although the incidence of significant complications is low, the procedure is not without risk and the associated morbidity has received little mention.

Materials and Methods

A commercially available Philips DVI-I, Lot 2, was used with a 0.7 mm focal spot and 6, 10, and 14 inch (15.2, 25.4, and 35.6 cm) image intensifier modes. Exposure factors were determined by video peak detector and were generally 100–200 mA and 65–75 kVp. The video signal was stored in a 512 × 256 × 8 matrix. Imaging was performed using the serial mode at an acquisition rate of one frame/sec, averaging eight frames.

All patients were instructed to consume about 1 L of fluid beginning the previous night and up to several hours before the procedure. With the Seldinger technique, a 5.0 French straight or a 5.5 French pigtail catheter was placed in the superior vena cava via an antecubital vein. For those patients in whom an arm vein could not be catheterized, the catheter was inserted into the inferior vena cava via a femoral vein. For each projection, 40 ml of Vascoray (Mallinckrodt) was injected at 20 ml/sec. Exposures were initiated 4–5 sec after contrast injection. Our routine evaluation consisted of four projections: 45°–55° right posterior oblique (RPO) and left posterior oblique (LPO) of neck; 55° RPO of aortic arch; and Towne view of intracranial circulation. Additional steeper oblique or anteroposterior (AP) views of the neck on the side of interest were obtained frequently. Postprocessing

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was routinely performed to optimize the image before a film copy was made.

We retrospectively reviewed DSA examinations performed on 130 patients to determine the adequacy of visualization of the carotid bifurcations. The patients were 28–85 years old (mean, 64 years). The studies were performed during a 7½ month period and included our early experience. Each case was examined by three reviewers. We recorded the number of projections in which each carotid bifurcation was visualized adequately or inadequately. The reasons for inadequate visualization included: (1) patient movement, coughing, or swallowing with resultant overlying misregistration larynx artifact; (2) external carotid artery or vertebral artery overlying the internal carotid artery; and (3) poor arterial contrast density attributed to poor cardiac function. The arterial contrast density was graded as good, fair, or poor for each study. In particular, we noted those carotid arteries in which an abnormality (stenosis, ulceration, or atherosclerotic plaque) was seen in one projection with the other projection(s) appearing normal.

Results

The arterial contrast density of the examination was good in 55 patients (42%), fair in 57 (44%), and poor in 18 (14%). The average age of patients with good examinations was 60; fair examinations, 66; and poor examinations, 71 years.

The total number of patients in whom each of the carotid bifurcations was adequately visualized in more than one projection (either two opposite oblique views or an oblique and an AP view) was 34 (26%). Of the total of 260 bifurcations, 21 were not seen adequately in any projection, 113 were seen adequately in only one projection, and 126 were seen adequately in more than one projection (either two opposite oblique views or an oblique and AP view) (table 1, fig. 1). Of the 113 bifurcations seen in only one projection, 25 had a demonstrable lesion and 88 appeared normal.

Nineteen internal carotid arteries appeared normal in at least one projection, but were demonstrated to have a lesion in a different projection (table 1, figs. 2–4).

Of the 130 patients, two views of the carotid bifurcations were obtained in 85; two views plus an AP and/or oblique view were obtained in 44; and only one view was obtained in one. Those projections that visualized one or both internal carotid arteries inadequately are summarized in table 1. In addition to the reasons listed, 18 patients (36 carotid arteries) had poor arterial contrast density attributable to poor cardiac function.

There were significant complications in two patients. In both, cardiac perforation by the catheter occurred with intrapericardial injection of contrast material. One case involved a 61-year-old man with Ehlers-Danlos syndrome for whom DSA was requested because of an aortic dissection after an aortic arch arteriogram several years before. In this case, the catheter was inserted in the high inferior vena cava. The second perforation was in a 70-year-old woman with no known arteritis or connective tissue disorder in whom the catheter was placed in the right atrium. Both patients experienced substernal chest pain after the injection, but neither suffered pericardial tamponade and each recovered without interventional therapy. In both cases a straight Teflon catheter was used. No other perforations occurred after pigtail catheters were substituted for straight catheters.

TABLE 1: **DSA Visualization of Carotid Arteries**

Features of Carotid Visualization	No. (%)		
	Right Carotid	Left Carotid	Totals
Projections with adequately visualized bifurcations (n = 260):			
None	11	10	21 (8)
One	53	60	113 (43)
More than one	66	60	126 (49)
Abnormal arteries appearing normal in one projection (n = 19):			
Stenosis	5	4	9
Ulceration	1	2	3
Plaque	3	4	7
Reasons for inadequately visualized bifurcations (of 305 projections):			
Overlapped origins of ICA and ECA	64 (21)	59 (19)	123 (40)
Misregistration larynx artifact	33 (11)	32 (11)	65 (22)
Overlapped ICA and vertebral artery	5 (2)	12 (4)	17 (6)

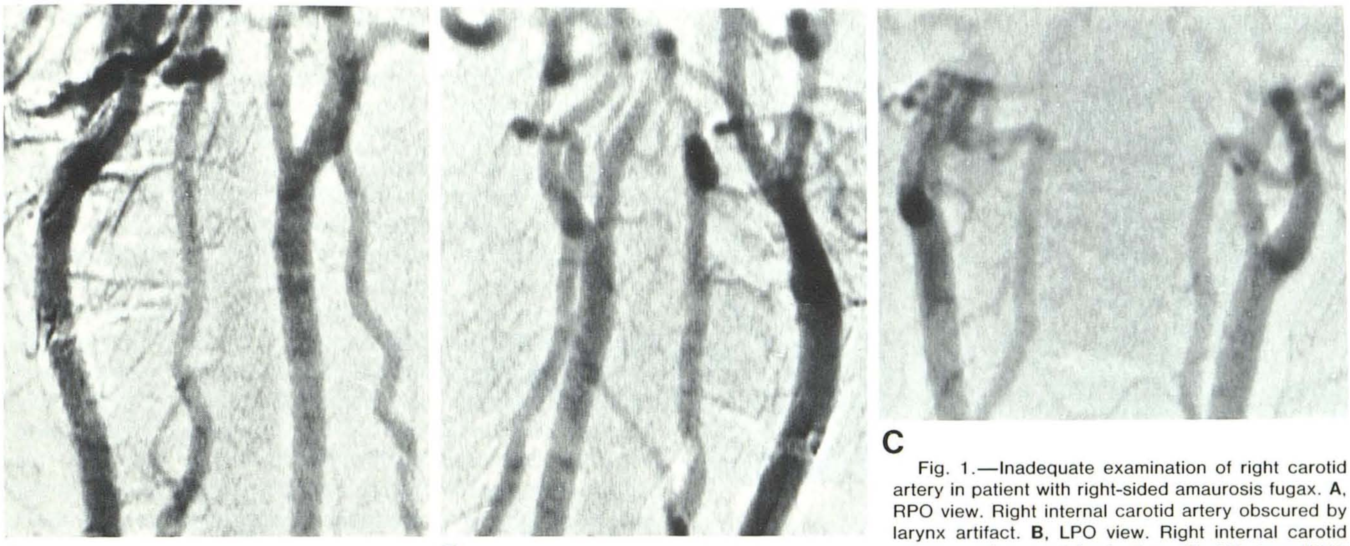
Note.—ICA = internal carotid artery; ECA = external carotid artery.

In addition, four patients encountered less serious complications. These included: (1) a moderately severe contrast reaction requiring premature termination of the study and the administration of epinephrine and steroids; (2) severe nausea and vomiting after the examination requiring antiemetic medications; (3) abdominal pain after the examination requiring observation for several hours; and (4) weakness with orthostatic hypotension requiring that the patient return to the emergency room for intravenous hydration several hours after the study. The hypotension was attributed to hypovolemia from diuresis after the intravenous contrast load and nausea that precluded oral hydration. Because most of the patients in this study were outpatient referrals, we were unable to obtain routine follow-up of renal function.

Discussion

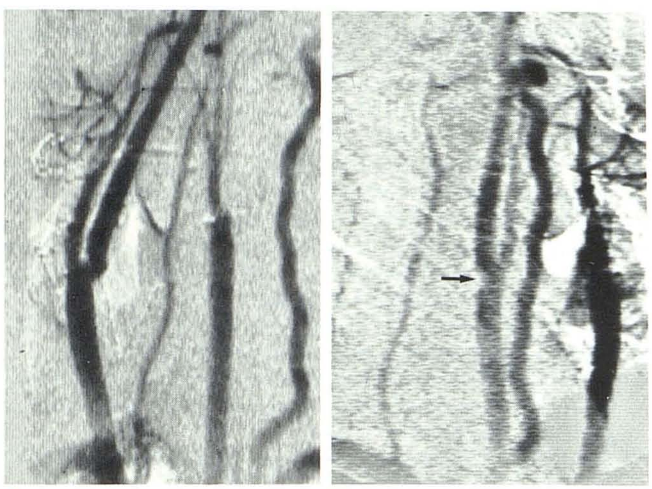
If both 45°–55° oblique projections of the neck did not visualize the carotid bifurcations adequately, then an additional steeper oblique and/or an AP view was obtained. Although more carotids might have been visualized in more than one projection if additional projections in different obliquities had been obtained, we were initially reluctant to subject patients routinely to more than four views of the carotid bifurcation because of the additional contrast load. This was particularly true when the bifurcation corresponding to the side of symptoms had already been visualized adequately.

Those patients who had difficulty refraining from swallowing were asked to bite on a tongue blade or exhale through pursed lips or a straw during the injection. These maneuvers were of equivocal value. In patients with poor cardiac function, attempts were made to increase the heart rate by



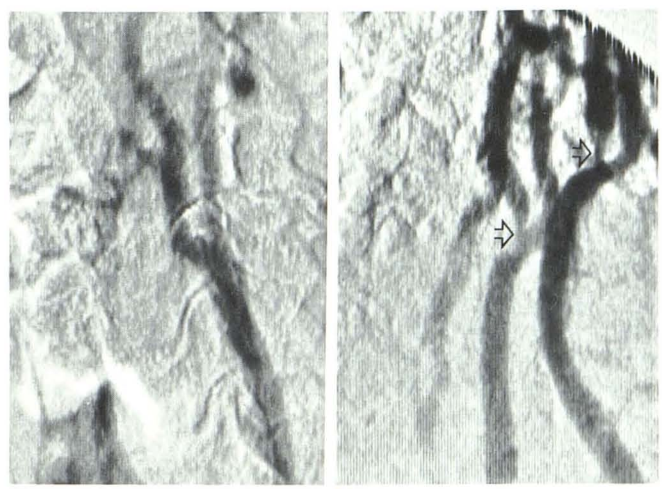
A B C

Fig. 1.—Inadequate examination of right carotid artery in patient with right-sided amaurosis fugax. **A**, RPO view. Right internal carotid artery obscured by larynx artifact. **B**, LPO view. Right internal carotid artery overlaps vertebral artery. **C**, AP view. Right internal carotid artery overlaps external carotid artery.



A B

Fig. 2.—Right carotid plaque seen in one view only. **A**, RPO view. Occluded left internal carotid artery, but right common carotid artery appears normal. **B**, LPO view shows plaque with mild stenosis of right common carotid artery (*arrow*).



A B

Fig. 3.—Necessity for two views of each carotid artery. **A**, RPO view. No obvious lesion of left carotid bifurcation. Right carotid cannot be evaluated. **B**, LPO view. High-grade stenosis of both left and right internal carotid arteries (*arrows*).

isometric exercise; that is, pushing against fixed resistance. In a number of patients, this resulted in a transient increase in heart rate and cardiac output with improved arterial contrast density.

Our data demonstrate the importance of visualizing a vessel adequately in more than one projection and the hazards implicit in assuming a vessel is normal when it is seen in only one projection. Of the 126 carotid bifurcations seen adequately in more than one projection, 19 (15%) showed an abnormality in one projection but appeared normal in another. These abnormalities would not have been detected had the vessel been visualized only in the spuriously normal-appearing projection.

Of the 113 bifurcations seen adequately in only one projection, 88 showed no abnormality and therefore cannot be considered truly diagnostic. When these 88 are added to the 21 bifurcations that were not seen adequately in any projection, there are 109 (42%) of the total 260 carotid bifurcations for which DSA was nondiagnostic.

Intravenous DSA is generally considered to be a procedure with little morbidity. In addition to the complications described above, a number of our patients experienced less significant adverse effects after the study. These included generalized weakness, headache, and light-headedness without orthostatic blood pressure or pulse changes. These were seen most often in elderly patients and often required

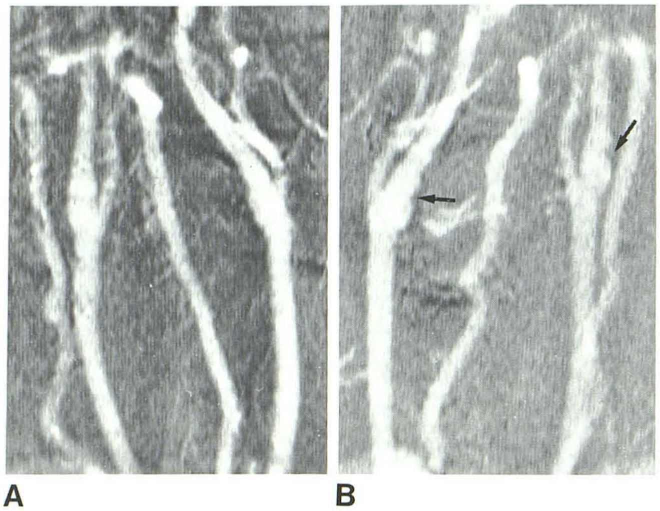


Fig. 4.—Necessity for two views of each carotid artery. **A**, LPO view. Normal bifurcations bilaterally. **B**, RPO view. Irregular atherosclerotic plaque and possible ulcerations involving both internal carotid arteries (*arrows*).

that the patient remain in the radiology department for a short period of observation.

Intravenous DSA has been advocated for examining aged patients or those with generalized vascular disease in whom conventional angiography might have greater morbidity [1]. However, this is the same group of patients most likely to have impaired cardiac function with resultant poor arterial contrast density on DSA. Note that the mean age of patients with poor arterial contrast studies was 71 years versus 60 for those with high arterial contrast studies. Also, the elderly patient is often less able to cooperate so that swallowing and gross motion artifacts are more likely.

The contrast dose administered for DSA is greater than that used for conventional arch aortography. Our routine DSA evaluation involves a minimum of 160 ml and up to 240 ml of contrast material. This compares with about 120 ml of contrast material used in conventional arch aortography. To the extent that increasing the contrast dose contributes to the impairment of renal function, the patient is at greater risk with DSA than with conventional arteriography. In addition, many outpatients referred for DSA have no documentation of prior assessment of renal function.

An inherent limitation of DSA is its inability to isolate specific parts of the vascular system, which is readily accomplished with selective arteriography. Previous studies have correlated DSA with selective carotid arteriography [3]. However, the optimal carotid DSA will be comparable to an arch aortogram rather than a selective carotid study. It shares the limitation of an arch study, the most significant of which is absence of a true lateral view of the carotid bifurcation. The importance of this view in visualizing the posterior wall of the bifurcation has been emphasized [6, 7].

We expect that newer technologic refinements, such as energy subtraction and temporal band-pass filtration, will suppress some forms of motion artifact in DSA [8–12]. However, vessel overlap remains a significant drawback, and in our study was the most frequent cause of inadequate visualization of the carotid bifurcation.

To conclude, intravenous carotid DSA is rapidly gaining clinical use as a screening test for extracranial carotid occlusive disease. Although it is a useful procedure, it has inherent limitations. These include: (1) A significant number of carotid artery lesions will be missed if the vessel is well visualized in only one projection. (2) In order to adequately visualize each bifurcation in two opposite oblique views, multiple injections in each obliquity may be required. This can result in the administration of large volumes of contrast material, which may compromise renal function in the elderly patient.

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