Intravenous DSA and duplex sonography as screening examinations for carotid disease: comparison in 102 vessels.

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Intravenous DSA and Duplex Sonography as Screening Examinations for Carotid Disease:

Comparison in 102 Vessels

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Duplex sonography and intravenous digital subtraction angiography (DSA) were compared in 102 carotid bifurcations in 51 patients. Sonograms were adequate in 87 (85%) vessels and angiograms were adequate on at least one view in 86 (84%) vessels. An adequate image was obtained by one or the other method in all but two vessels (98%). Although most vessels were seen well on one view only on DSA, agreement with sonography was exact in 73% of compared vessels and acceptable in 96%. Furthermore, no difference was found in the rate of agreement with sonography for vessels seen well by DSA on two or more views compared with those seen well on one view only. It was concluded that DSA and sonography are comparable screening methods for carotid disease and that a suboptimal study by either can usually be compensated for by performance of the other.

Duplex sonography and intravenous digital subtraction angiography (DSA) are now widely used as screening tests for the evaluation of the extracranial cerebral vessels in patients with suspected cerebrovascular disease. The details of the performance, capabilities, and limitations of each method are well described in the literature as is their acceptable accuracy in the assessment of carotid disease relative to conventional angiography [1–13]. Little information is available, however, directly comparing the two methods for technical adequacy and the extent of agreement in estimates of disease. We compared the DSA and sonographic findings in 102 carotid bifurcations in 51 patients with suspected cerebrovascular disease.

Subjects and Methods

At our hospital intravenous DSA or sonography is used as a screening test for lesions of the carotid bifurcations in patients with suspected cerebrovascular disease. The most common indications for either test are definite or atypical symptoms of cerebrovascular disease, asymptomatic neck bruits, or a history of coronary or peripheral vascular disease. Intraarterial DSA or conventional angiography is the preferred technique in patients with typical histories of cerebral hemispheric or ocular ischemic episodes, and in preoperative evaluations before carotid endarterectomy. The patients entering this study were 51 consecutive subjects referred for intravenous DSA. For the purpose of the study sonography was performed on all these subjects before or soon after DSA. The examinations were undertaken without knowledge of the results of the corresponding study in each case.

DSA was performed using a Technicare DR 960 system added to a Siemens Gigantus Optomatic 100 kW generator, selectable 6 or 9 inch (15.2 or 22.9 cm) image intensifier, and Video-Med 3 TV system. The central processing unit was controlled by a DEC 11-34 computer using a 512 × 512 image display matrix and 160 megabyte disk storage. After sterile preparation, an 8 in 16 gauge intracatheter was inserted into an antecubital vein. Twenty-five ml of 5% dextrose was layered over 40 ml Renografin-76 (Squibb, Princeton, NJ) and injected at 12 ml/sec. Exposures commenced 4 sec after injection of contrast material began. The image sequence was usually recorded at a frame rate of 1.25 exposures/sec at 70 kVp and 32 mAs. Views obtained routinely were 45°–55° right (RPO) and left (LPO) posterior oblique projections of the neck, 55° RPO of the aortic arch, and Towne view of the intracranial

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circulation. In addition, anteroposterior or steep oblique projections on the side of interest were obtained in some instances. The maximum number of injections was five.

Duplex sonographic examinations were performed with a Biosound high-resolution real-time scanner. This has a midrange frequency of 8 MHz, and the sound beam is directed at a parabolic mirror to produce a rectangular field of view 3 cm long and 4 cm deep. Axial resolution is less than 0.3 mm and lateral resolution 0.5 mm. The system has integral-range, gated, pulsed Doppler with a 1 mm volume sampler, which can be adjusted to interrogate sites of interest in imaged vessels. Our technique for B-mode imaging has been reported [5]. Recent improvement in the pulsed Doppler of the instrument has increased its usefulness in diagnosis on the basis of audible recognition of abnormalities in the recorded signal. These include increased velocity and turbulence in association with stenotic lesions and absence of flow in occlusions. Our instrument does not have Doppler spectral analysis capability.

Comparison between DSA and sonographic studies on each side was confined to the supraclavicular part of the common carotid artery and the internal carotid artery for at least 3 cm beyond its origin. DSA examinations were categorized according to whether this vascular segment was shown adequately on more than one view, shown adequately on one view only, or not shown adequately on any view. Designation of an image as adequate on any given view was based on excellent or good arterial contrast density and absence of degradation by misregistration artifacts, vessel overlap, or patient movement. Sonographic examinations were categorized as adequate or inadequate. An adequate study was one in which B-mode imaging showed well defined vessel walls with good gray-scale resolution and a lumen unobscured by substantial artifacts. The Doppler part of the study was considered satisfactory when adequate signals were obtained from all parts of the image vessel lumen, including that distal to a diseased segment. The exceptions to this were those occasions when absent signals, in association with consistent findings on B-mode imaging, were interpreted as complete occlusions. Stenotic lesions were classified into categories based on the division of the lumen diameter into intervals of 25% for both DSA and sonography. For the purpose of this study agreement to within one category was regarded as acceptably close correspondence in estimates of disease.

A stenosis seen on DSA was measured by comparing the lumen diameter in the diseased segment with that of the vessel lumen distal to the lesion. Calipers were used to obtain measurements directly from the angiographic films. For sonography, measurements of stenoses and the diameter of the normal vessels distal to the diseased areas were obtained directly from the television monitor by means of an electronic graticule superimposed on the gray-scale image. Longitudinal and transverse images were obtained, and assessment of a stenosis was made from that projection that best displayed the residual lumen in a diseased area. Doppler assessments of stenoses were based on the quality of the audible signals in diseased areas and the presence of poststenotic turbulence [14]. Stenoses were considered minor if abnormal flow velocity and corresponding frequency shifts were minimal and occurred only during systole. Lesions were considered hemodynamically significant (≥50% diameter reduction) if increased flow velocities were obvious and occurred during diastole as well as systole. Flow-restricting lesions of critical severity (75% or greater reduction in lumen diameter) were diagnosed when very high frequency "hissing" signals were heard in both systole and diastole, especially during systole. Obvious turbulence heard beyond a stenosis was considered a sign of a hemodynamically significant lesion. Turbulence heard over a long distance beyond a stenotic site was considered indicative of severe stenosis, that is, >75% diameter reduction. Diagnosis of occlusion on sonography was based on

TABLE 1: **Usefulness of Digital Subtraction Angiography and Sonography in the Evaluation of Cerebrovascular Disease**

Study: Technical Quality	No. (%) of Vessels (*n* = 102)
Digital subtraction angiography:	
Adequate on more than one projection	34 (33)
Adequate on one projection only	52 (51)
Adequate on one or more projections	86 (84)
Indequate on all projections	16 (16)
Sonography:	
Adequate	87 (85)
Inadequate	15 (15)
Sonography *or* digital subtraction angiography adequate on at least one view	100 (98)
Sonography *and* digital subtraction angiography adequate on at least one view	73 (72)

TABLE 2: **Reasons for Inadequate DSA or Sonographic Studies in the Evaluation of Suspected Cerebrovascular Disease**

Technical Quality: Reason	No. of Vessels (*n* = 102)
DSA inadequate on all views:	
Vessel overlap all views	9
Vessel overlap and misregistration artifacts	4
Poor arterial contrast density	2
Artifacts on all views	1
Total	16
DSA adequate on one view only:	
Vessel overlap artifacts	39
Artifacts alone	11
Patient movement	2
Total	52
Sonography:	
High bifurcation of the common carotid artery and/or thick neck	7
Poorly shown lumen due to calcification or soft plaque	5
Poorly shown lumen on B-mode but adequate Doppler signals	3
Total	15

Note.—DSA = digital subtraction angiography.

TABLE 3: **Degree of Stenosis in 73 Carotid Bifurcations in Which DSA and Sonographic Studies Were Adequate**

Degree of Stenosis on Sonography	Degree of Stenosis on DSA					
	Normal	0–25%	25%–50%	50%–75%	75%–99%	Occluded
Normal	25	...	...	...	1	...
0–25%	13	12	...	...	...	...
25%–50%	...	3	3	...	...	...
50%–75%	...	1	1	7	...	...
75%–99%	...	...	1	...	4	...
Occluded	...	...	...	...	...	2

Note.—There was agreement by category in 53 vessels (73%) and agreement to within one category in 70 (96%). DSA = digital subtraction angiography.

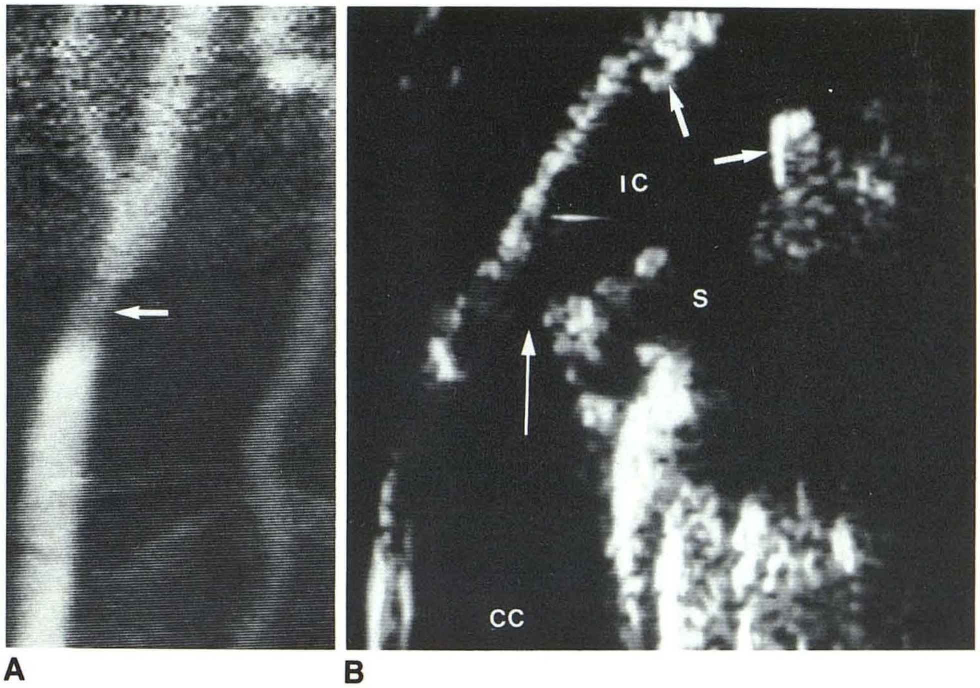


Fig. 1.—**A**, DSA. Localized lesion of distal common carotid artery (*arrow*) was considered to be in 75%–99% range of diameter reduction. **B**, Sonogram. Marked localized narrowing of distal common carotid artery (*long arrow*). Doppler signals at this site were increased in duration and pitch and associated with loud turbulence. More distal plaque (*short arrows*) on B-mode images was not appreciated on DSA. CC = common carotid artery; IC = internal carotid artery; S = acoustic shadowing. Skin line is on reader's left.

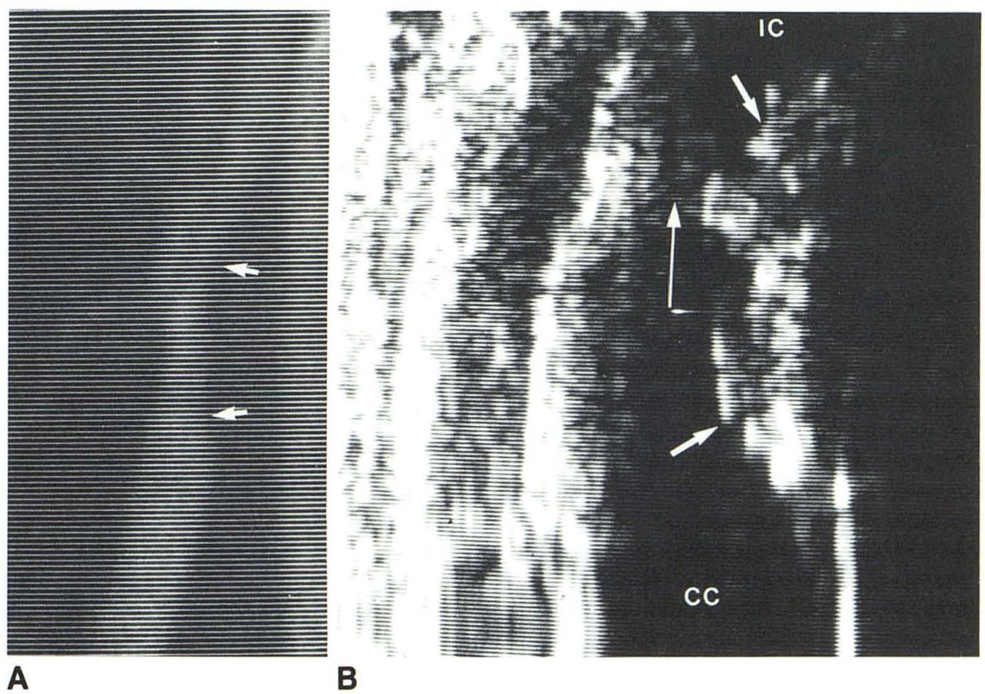
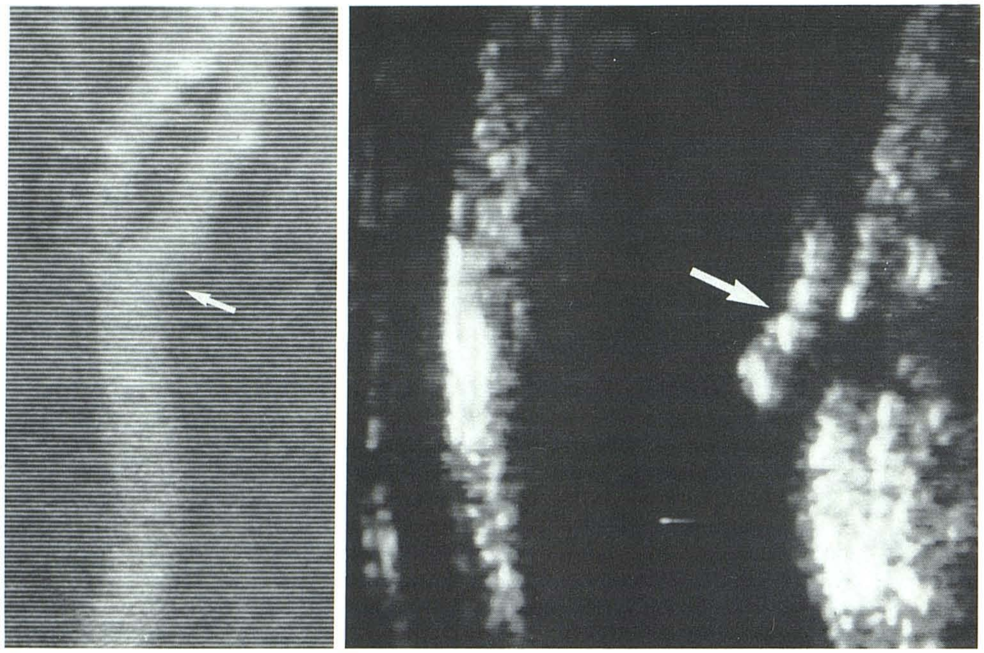


Fig. 2.—**A**, DSA. Minimal deformity of contour of proximal internal carotid artery (*arrow*). **B**, Sonogram of proximal internal carotid artery. Obvious, though small, atheromatous plaque (*arrow*). Skin line is on reader's left.

depiction of a nonpulsatile vessel containing echogenic material from which no Doppler signals could be obtained. The confidence with which occlusion was interpreted from absent Doppler signals increased if signals were obtained from the contiguous external carotid artery at the same level in the neck.

In all sonographic evaluations, assessment of the severity of disease was based on a combination of data from B-mode imaging and Doppler sampling. Since it is well recognized that poorly echogenic plaque may be undetected by sonography and result in underestimation of stenoses, discrepancies between imaging and Doppler assessments were resolved in favor of Doppler. We did not attempt to compare DSA and sonography for detection of plaque ulceration. Except for gross ulceration we believe both methods to be inherently inaccurate for this determination.



A B

Fig. 3.—**A**, DSA. Narrowing of distal common and internal carotid arteries by long plaque (*arrows*). Associated stenosis was considered to be in 50%–75% range of diameter reduction. **B**, Sonogram. Plaque (*short arrows*) and localized region of severe stenosis within diseased segment (*long arrow*). Doppler signals at this site were consistent with severe stenosis (>75% diameter reduction). CC = common carotid artery; IC = internal carotid artery. Skin line is on reader's left.

Results

One hundred two carotid bifurcations were studied in 51 patients with suspected cerebrovascular disease. The technical quality of examinations for all vessels is categorized in table 1, and the reasons for suboptimal or uninterpretable examinations are listed in table 2. Eighty-six (84%) vessels were adequately shown by DSA on at least one projection, 34 (33%) on two or more projections, and 52 (51%) on one projection only. Only 11 (22%) of the 51 patients had both carotid bifurcations adequately shown by DSA on more than one projection. Sonographic studies were technicially adequate in 87 (85%) vessels. If it is assumed that technically satisfactory DSA studies include those in which vessels are seen well on only one view, then either DSA or sonography was satisfactory in 100 (98%) vessels. Estimates of disease severity were compared in 73 vessels in which both sonography and DSA were adequate on at least one view (table 3). In 53 (73%) there was exact agreement by category and agreement to within one category in 70 (96%) (figs. 1–3). The frequency of agreement by category was 73% for vessels shown well by DSA on at least two views and 70% for vessels shown well by DSA on one view only. This difference is not statistically significant ($p < 0.01$).

In 18 of the 19 vessels in which there was lack of correspondence in estimates of disease, the sonographic estimate exceeded that on DSA. In most of these, relatively minor lesions were well shown on sonography when DSA was normal or showed only slight irregularity of vessel contour (fig. 2). In one vessel DSA showed a distal intimal carotid lesion that was missed on sonography.

Conventional selective angiography or intraarterial DSA was undertaken in seven patients in whom intravenous DSA was inadequate on one or both sides. Sonograms were adequate in 12 of the vessels and inadequate in two. In nine of the 12 adequate studies sonography correlated closely with the angiographic findings. In the other three, relatively minor lesions seen well on sonography were not detected on angiography.

Discussion

A problem common to DSA and sonography is the technically inadequate examination, which in this series occurred in 15% of vessels on sonography and in 16% on DSA. In only 2% of vessels, however, were both studies entirely inadequate, and in this regard they are complementary: An inadequate study by one can be compensated by performance of the other. The need for conventional angiography in patients with suboptimal DSA studies thus might be avoided.

Numerous reports have compared sonography and DSA with conventional angiography and shown both to be adequate screening methods in the assessment of carotid disease [1–13]. A shortcoming of our study is that in most patients we were unable to compare results with conventional angiography. There are inherent difficulties, however, in the use of conventional angiography as a gold standard. Thiele et al. [15] measured intrareader and interreader variability among experienced radiologists in the interpretation of high-quality carotid arteriograms and concluded that their use as a means of assessing the sensitivity of noninvasive methods should be seriously questioned. Agreement between observers for detection of normal vessels was only 56.5% and for estimating stenoses of more than 50% diameter reduction, 85.4%. Similar observations and conclusions were made by Cranley [16]. In his study of interobserver agreement in interpretation of carotid angiograms it was necessary to have a 35% point spread in order to include more than 90% of the interpretations. For these reasons it is important to know how closely sonography and DSA agree as well as how well they compare individually to arteriography. The closeness of this agreement, measured in a number of patients, is an indirect but meaningful indication of the accuracy of the tests [17]. In this series, there was acceptable agreement in estimates of disease between DSA and sonography in most vessels: 73% agreed exactly by category and 96% agreed to within one category (fig. 1).

In studies that have examined the utility of DSA, a single unobscured view of the vessels is usually considered adequate for diagnosis [9]. Theoretically, however, a lesion may be undetected if only one adequate view of the vessel is obtained [18]. Since angiography profiles the lumen, eccentric plaque may be undetected unless positioned tangential to the x-ray beam. Only 22% of our patients had both carotid bifurcations adequately seen by DSA on more than one view; this is similar to an incidence of 26% in the series of Hoffman et al. [18]. Despite this, we found no significant difference in the frequency of agreement by category for vessels seen well by DSA on at least two views compared with those seen well on one view only. This is because only minor lesions are likely to be missed by poor profiling. Larger lesions span a greater proportion of the vessel circumference and will be detected in any view on DSA. Incomplete profiling of lesions may lead to some discrepancies in estimates of disease in comparison with sonography, but they are seldom great enough to lead to assignment to different categories by the two methods (based on 25% increments of vessel diameter). Those discrepancies that did occur were mostly related to minor lesions seen well on sonography but undetected or relatively inapparent on DSA. Sonography shows plaque more readily because it depicts the structure of the vessel wall as well as the lumen (figs. 2 and 3). With a technically optimal study, lesions are immediately apparent to the observer, who can be assured that what is seen is an accurate depiction of disease (fig. 2). This is in keeping with our own previous experience [5] and that in other reports [2, 4, 8], which have shown greater sensitivity of sonography in detection of disease compared with conventional angiography, especially for minor lesions.

In one vessel in our series the estimate of severity of disease on DSA exceeded that on sonography. DSA showed a distal internal carotid lesion of the neck that was not detected on sonography. Failure of sonography to detect distal lesions is a shortcoming not shared by DSA and may be related to a high bifurcation of the common carotid artery or marked vessel tortuosity. Even in the absence of these factors, however, a high cervical or intracranial lesion of the internal carotid artery may not be detected by sonography. For this reason some authors continue to recommend that oculoplethysmography and orbital Doppler studies be performed in addition to direct examination of the carotid bifurcation by duplex sonography. [19]. Discrepancy between results of these tests and duplex sonography would be suspicious of a distal lesion.

In conclusion, our results suggest that DSA and sonography have comparable utility in screening for carotid disease, based on the frequency of technically adequate examinations and correspondence of estimates of disease severity. Since sonography is noninvasive, cheaper, quicker to perform, and easily repeatable, we believe it to be the preferred screening technique. The use of DSA as a screening test could be reserved for patients having technically inadequate or suboptimal sonograms.

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