Intravenous DSA of Extracranial Carotid Lesions: Comparison with Other Techniques and Specimens

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Intravenous DSA of Extracranial Carotid Lesions:
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Intravenous digital subtraction arteriography (DSA) was performed in 306 patients with suspected ischemic cerebrovascular disease. Forty-eight carotid endarterectomies were performed in 43 of these patients. The percentage stenosis as determined on the intravenous DSA examination concurred (±10%) with the surgical findings in 83.3%. There were 12.5% undercalls (false-negatives) and 4.3% overcalls (false-positives). Of the false-negative and false-positive examinations only three would have affected the clinical management of the patient, yielding an overall sensitivity of 93.7%. Nine surgical lesions had both intravenous DSA and conventional arteriography. Intravenous DSA was correct in six and arteriography in seven of these lesions. There were four surgically confirmed ulcerations. Two were evaluated by intravenous DSA alone. Two had intravenous DSA and arteriography. The latter showed both ulcers; the former, only one. Thirty-seven surgical lesions had both intravenous DSA and high-resolution real-time sonographic imaging. Sonography agreed in 67.5% and intravenous DSA in 83.7% of these lesions. When an abnormal supraorbital Doppler or an abnormal oculopneumoplethysmography/Gee examination is added to the sonographic examination, an overall sensitivity of 93% was obtained in detecting a surgical lesion (stenosis greater than 50%).

Intravenous digital subtraction arteriography (DSA) has become increasingly popular in the evaluation of patients with suspected ischemic cerebrovascular disease [1–5]. Originally conceived as a screening procedure [6–8], it has become the final diagnostic examination in some patients, often replacing the conventional arteriogram. We reviewed the experience of the Section of Neuroradiology, the Noninvasive Vascular Disease Laboratory, and the Department of Thoracic Surgery with intravenous DSA during the first year after its introduction at Mount Sinai Medical Center. Specifically, the accuracy of intravenous DSA in detecting the degree of common carotid bifurcation and adjacent internal carotid artery stenosis is reported using surgical findings as the standard. Comparison with arteriography, B-mode sonography, supraorbital Doppler, and oculopneumoplethysmography (OPG) was also undertaken [9].

Materials and Methods

Three hundred six patients with suspected ischemic cerebrovascular disease were referred to Mount Sinai Medical Center for intravenous DSA between October 1981 and September 1982. The patients were 39–92 years old (mean, 70 years; mode, 72). About 75% were outpatients. During the first weeks after introduction of intravenous DSA in our institution, surgical lesions were confirmed by arteriography. This included a right posterior oblique (RPO) arch projection and biplane views of the common carotid bifurcations and intracranial vasculature after selective injection via a femorocerebral catheter. However, the intravenous DSA examination rapidly gained wide acceptance by our referring vascular surgeons, and as a result, arteriography was not performed routinely. Only 21 (7%) of the 306 patients undergoing intravenous DSA had arteriography. An arteriogram was considered necessary if the intravenous DSA examination was of poor quality (10 patients), partly nondiagnostic

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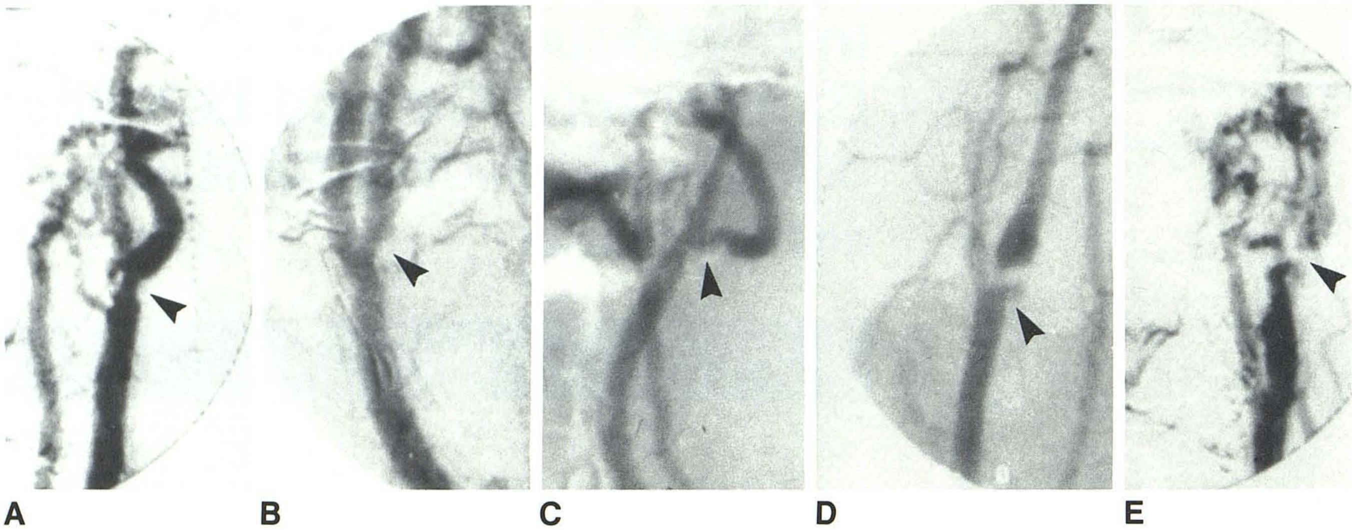

Fig. 1.—Five different common carotid bifurcations with surgically proven stenosis (*arrowheads*) of 50%–59% (**A**), 60%–69% (**B**), 70%–79% (**C**), 80%–89% (**D**) (*arrowhead* indicates ulceration), and 90%–99% (**E**).

TABLE 1: **Correlation of Intravenous DSA with Surgical Findings in Carotid Artery Stenosis**

% Stenosis at Surgery	No. of Arteries	DSA Findings Relative to Surgery (%)		
		Consistent	Undercall	Overcall
100	3	1	2	0
90–99	27	24	3	0
80–89	13	11	1	1
70–79	3	3	0	0
60–69	1	1	0	0
50–59	1	0	0	1
Total	48	40 (83)	6 (13)	2 (4)

Note.—Forty-eight carotid operations were performed in 43 patients. DSA = digital subtraction arteriography.

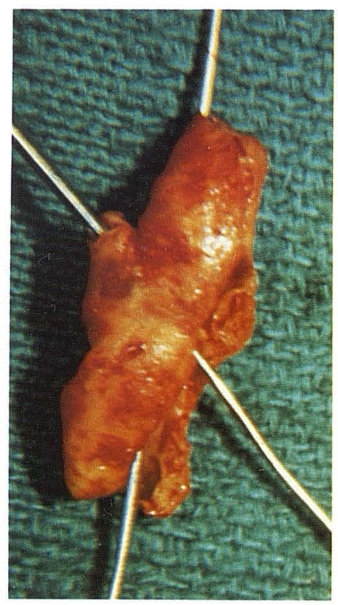

Fig. 2.—Entire plaque removed en bloc with vascular sounds in place. Vertical sound passes through stenotic lumen of common and external carotid arteries. Diagonal sound passes through stenotic lumen of external carotid artery. External diameter of specimen is diameter of original lumen.

(seven patients), nondiagnostic (two patients), or performed to confirm an ulcerative lesion (two patients). A poor-quality examination was one in which there was low contrast density in the extracranial carotid arteries from either poor cardiac output, patient motion, or swallowing artifact. In a partly nondiagnostic examination either the common carotid bifurcation could not be unfolded on one or both sides or there was inadequate visualization of the intracranial vasculature. A completely nondiagnostic examination yielded no information from the intravenous DSA.

The intravenous DSA examinations were performed using a commercially available ADAC digital system with a 512 × 512 matrix. This system was added to our biplane neuroangiography suite. A Eureka x-ray tube with a 0.6/1.2 mm focal spot and a heat capacity of 400,000 U was used at fluoroscopy. This was powered by a Siemens Garantix 1000 mA, 75 kW generator. Technical factors were 102 kV and 32–40 mAs. The films were detected by a Thompson Houston 9/6 inch (15.2/22.9 cm) image tube with a 12:1 grid ratio. Subtracted images were viewed in real time at 1.2 frames/sec and stored in digital mode. Postprocessing with remasking was performed routinely.

Using the 6 inch (15.2 cm) fluoroscopy mode for maximum resolution of the common carotid bifurcations, 40°–50° RPO, left posterior oblique (LPO), and sometimes anteroposterior (AP) projections were obtained. This was followed by 40°–50° RPO projections of the aortic arch and appropriate AP and/or off-lateral views of the intracranial cerebral vasculature using the 9 inch (22.9 cm) fluoroscopic mode. A 5 or 6 French pigtail catheter was inserted into the superior vena cava via an antecubital vein (84% of the patients) or the inferior vena cava via the femoral vein (16% of the patients). Renografin-76 was injected at a rate of 18–22 ml/sec for a total volume of 35 ml/projection. A total examination volume of 140–175 ml was used, depending on the number of projections required to visualize the brachiocephalic arterial system from the aortic arch to the intracranial vasculature.

Forty-eight carotid operations were performed on 43 patients aged 40–89 years (mean, 71; mode, 72 years). The surgical findings were used for the intravenous DSA correlation. A lesion was considered surgical when the intravenous DSA examination of the extracranial

TABLE 2: **Correlation of Intravenous DSA with Arteriography in Carotid Artery Stenosis**

% Stenosis on Arteriography	No. of Lesions	DSA Findings Relative to Arteriography			
		Consistent	Undercall	Overcall	Poorly Visualized
100	9	6	1	0	2
90–99	4	4	0	0	0
80–89	7	4	1	0	2
70–79	4	1	2	0	1
60–69	2	1	0	0	1
50–59	6	4	0	1	1
40–49	0	0	0	0	0
30–39	0	0	0	0	0
20–29	1	1	0	0	0
10–19	2	0	0	2	0
Normal	3	3	0	0	0
Total	38	24	4	3	7

Note.—There were 38 lesions in 21 patients. DSA = digital subtraction arteriography.

TABLE 3: **Correlation of Intravenous DSA and Sonography in 37 Surgical Lesions**

	No. of Lesions
DSA and sonography both:	
Correlate with surgical lesion	21
Undercall surgical lesion	2*
Overcall surgical lesion	0
Subtotal	23
DSA only correlates with surgical lesion:	
Sonography undercalls	9
Sonography overcalls	1
Subtotal	10
Sonography only correlates with surgical lesion:	
DSA undercalls	2
DSA overcalls	2
Subtotal	4
Total	37

Note.—DSA = digital subtraction arteriography.
* Complete occlusion at surgery.

carotid artery on the side suspected of causing the patient's symptoms showed an ulceration [10, 11] or a degree of stenosis greater than 50%–60% [12]. The degree of stenosis in the region of the common carotid bifurcation or the adjacent internal carotid artery was calculated by measuring the diameter of the adjacent normal lumen and subtracting the diameter of the region of the maximum luminal narrowing as determined from the multiple projections. This was divided by the measured diameter of the normal lumen, and the percentage stenosis (degree of stenosis) was calculated.

The intravenous DSA findings (fig. 1) were correlated with the degree of stenosis determined at surgery (table 1). The intravenous DSA findings were considered consistent with the surgical findings if the degree of stenosis was within ±10% of the stenosis determined at endarterectomy. This latter stenosis was determined as follows: At surgery a common carotid–internal carotid artery bypass shunt was temporarily inserted and the region of the arteriosclerotic disease was isolated. At endarterectomy the entire atheromata with stenotic lumen en bloc was excised, using a subendothelial tissue plane for the plane of dissection. The diameter of this luminal cast was measured and considered the normal luminal diameter. The patent lumen of this cast was probed with a vascular sound of known caliber (fig. 2) and the diameter determined. By subtracting the diameter of the patent lumen from the maximum diameter of the atheromatous cast and dividing by this latter diameter, the percentage stenosis (degree of stenosis) was calculated.

The intravenous DSA findings were also correlated (±10%) with the standard arteriograms in the 21 patients (38 carotids) undergoing arteriography (table 2). Nine lesions in eight patients undergoing both examinations had surgery, and the findings were correlated.

A retrospective correlation of the results from the Noninvasive Vascular Laboratory (sonography, supraorbital Doppler, and OPG) with the surgical findings was also done. High-resolution sonograms of the common crotid bifurcations were obtained using a real-time B-scan imager with an 8 MHz transducer and an axial resolution of about 0.3 mm (Biodynamics, biosound imager). The percentage stenosis was visually estimated from cross-sectional images through the area of atheromata. The degree of stenosis was considered to be consistent with that found at surgery if there was ±10% agreement with the surgical findings. Thirty-seven surgical lesions had both intravenous DSA and sonography. These were correlated using the surgical findings as the standard (table 3).

The sensitivity of real-time sonography, OPG, and supraorbital Doppler in the ability to detect a surgical lesion (i.e., greater than 50% stenosis) was evaluated in 40 cerebral lesions in 37 patients (table 4).

OPG was considered abnormal if there was more than a 5 mm mercury difference in the measured ophthalmic artery pressure between the two eyes or if the measured pressure was less than 60%

TABLE 4: **Sensitivity of Noninvasive Tests in Detecting Carotid Lesions of Greater than 50% Stenosis**

Imaging Study	No. Lesions Detected/Total (%)
High-resolution B-scan sonography*	34/40 (85)
Abnormal OPG†	22/38 (58)
Reversal of flow in supraorbital Doppler	17/40 (43)
Abnormal OPG, supraorbital Doppler, or B-scan	37/40 (93)

Note.—There were 40 carotid lesions in 37 patients. OPG = oculopneumoplethysmography.
* Includes three patients not imaged.
† Two patients were not studied.

TABLE 5: **Summary of Incorrect Intravenous DSA Interpretations Relative to Surgery**

DSA Finding: % Stenosis at Surgery	% Stenosis by DSA
False-negative (undercall):	
100	95
100	60
95	80
90	70
90*	40
80	50
False-positive (overcall):	
80	95
50†	65

Note.—DSA = digital subtraction arteriography.
* Arteriography showed 70% stenosis.
† Arteriography showed 50% stenosis.

of the brachial systolic pressure [13]. A supraorbital Doppler evaluation was considered abnormal if there was reversal of flow [14].

Results

Forty-eight carotid artery endarterectomies were performed in 43 patients. Table 1 compares the degree of stenosis on the intravenous DSA examination with that demonstrated at surgery. There was agreement in 40 patients (83.3%) with six (12.5%) undercalls (false-negatives) and two (4.2%) overcalls (false-positives) (table 5).

Twenty-one patients having an intravenous DSA examination also had arteriography. The findings on the intravenous DSA examination were compared with those on arteriography (table 2). As the intravenous DSA examinations in two patients were completely nondiagnostic, only 19 examinations demonstrating 38 carotid bifurcations could be compared. There was agreement (±10%) in 24; underestimations of the lesion in four; and overcalls in three. Seven common carotid bifurcations could not be visualized adequately on the intravenous DSA examination other than to note that there was patency. Nine endarterectomies were performed on common carotids evaluated with intravenous DSA and arteriography. There were seven correlations between intravenous DSA and arteriography, six of which correlated with the surgical findings and one whereby both methods undercalled the lesion equally. In two instances intravenous DSA and arteriography did not correlate. In one case the angiogram correlated with surgery, and in the other both intravenous DSA and angiography undercalled the surgical lesion. However, in this latter instance, the angiogram was more accurate than intravenous DSA.

There were four surgically proven atheromatous ulcers. Two were evaluated with intravenous DSA alone (fig. 1D); two had intravenous DSA and arteriography. In the latter, intravenous DSA demonstrated one of the ulcers while arteriography demonstrated both. Three other ulcerations were identified on the intravenous DSA examination, however; these were treated medically and were not confirmed arteriographically or surgically.

Sonography was correlated with endarterectomy findings in 40 carotid surgeries in 36 patients. There was agreement (±10%) in 25 lesions (62.5%), undercalls (false-negatives) in 11 (27.5%), and overcalls (false-positives) in one (2.5%). In three carotid studies the common carotid bifurcation could not be localized and hence was not assessed.

Thirty-seven surgical lesions had both intravenous DSA and sonographic examinations (table 3). Intravenous DSA and sonography agreed in 23 patients, 21 of which correlated with the surgical findings. Intravenous DSA and sonography disagreed in 14 patients. Intravenous DSA correlated with the surgical lesion in 10 of these, and sonography correlated in four. Therefore, intravenous DSA agreed with surgical findings in 31 (83.7%) and sonography agreed in 25 (67.5%) of the lesions.

Sonography is one of three examinations constituting a noninvasive vascular study. The other two are OPG and supraorbital Doppler. When abnormal, the latter two examinations indicate a degree of stenosis sufficient to decrease flow at some point in the carotid or ophthalmic artery systems. All three examinations were considered together (table 4) and compared with the surgical findings to determine their sensitivity. Sensitivity was defined as a degree of stenosis in the common or internal carotid artery that will decrease the peripheral flow (i.e., greater than 50% diameter stenosis). When the three noninvasive tests were considered together, 37 (93%) of 40 surgical lesions were correctly ascertained.

Three hundred six patients, most of whom were outpatients, underwent intravenous DSA. There were eight complications. Three were minor reactions related to the injection of contrast material (two skin rashes responded to Benadryl and one hyperemesis responded to intravenous fluids). There was one mediastinal extravasation. The patient was observed overnight and then sent home. One patient with preexisting renal disease had exacerbation of the renal failure leading to eventual death. Three patients with preexisting heart disease had exacerbation of their symptoms (two angina attacks and one congestive heart failure).

Discussion

The appropriate clinical strategy for management of patients with ischemic cerebrovascular disease depends on accurate assessment of the atheromatous lesions involving the brachiocephalic vasculature. If intravenous DSA is to provide this type of assessment, an accurate demonstration of the stenotic and/or ulcerative lesions in the regions of the common carotid bifurcations is necessary. Visualization of the origins of the brachiocephalic vessels from the aortic arch and their intracranial ramifications should also be obtained. This requires several different projections and, consequently, several injections of contrast material. A central venous injection of contrast material via a pigtail catheter inserted into the superior or inferior vena cava was used so that a smaller amount of contrast material could be injected (35 ml of Renografin-76 per injection). This obviates layering another volume of D5W over the contrast material for use as a flush, as is the case with a peripheral injection. In addition, a central injection gives a more compact bolus and, hence, more contrast material for better vessel delineation, especially of the smaller intracranial vessels [15].

To properly determine surgical management, accurate delineation of the atheromata is necessary. The patent lumen through either a normal vessel or a region of stenosis is in reality a cross-sectional area. In the latter instance, the cross-sectional area could be very irregular, and its diameter as seen on angiography would depend on the obliquity of the projection. Therefore, the diameter of the region of stenosis was taken as an average on at least two projections and was considered to correlate with the actual stenosis as determined at surgery if there was agreement to within ±10%. This occurred in 83.3% of the carotid surgeries and is slightly lower than that previously reported [14]. This is because of our strict requirement (±10%) for correlation. There were six false-negatives (table 5). Only three of these would have altered the surgical strategy in managing the patient. One

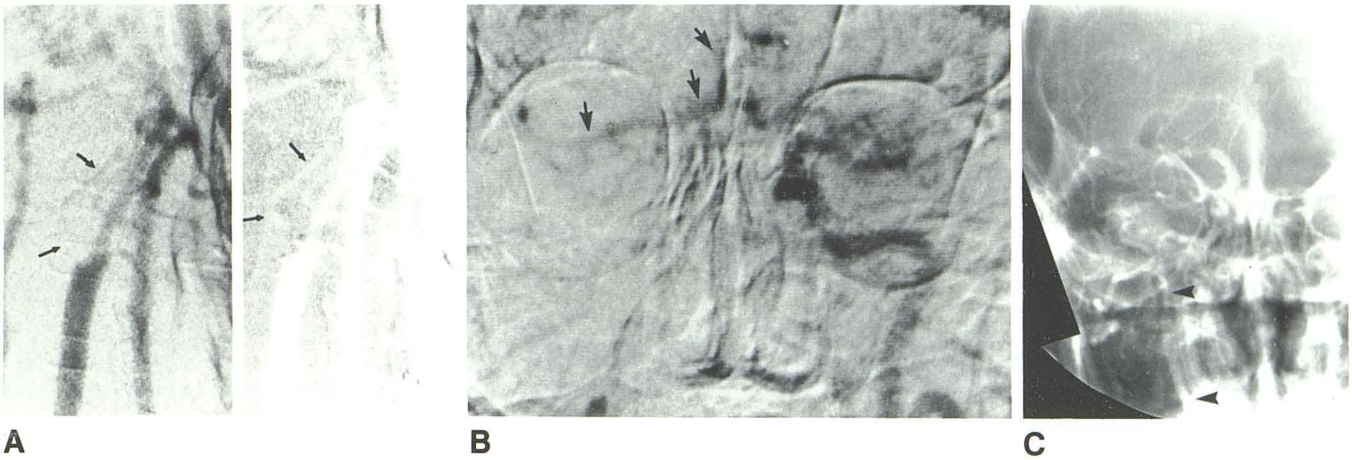

Fig. 3.—76-year-old man with transient ischemic attacks referable to right hemisphere. **A**, Intravenous DSA. High-grade stenosis of right internal carotid artery is demonstrated with thin stream of contrast material (*arrows*) in regular and reverse modes. **B**, Intracranial projection demonstrates filling of right anterior and middle cerebral arteries (*arrows*), apparently from left carotid system via anterior communicating artery. **C**, Frontal projection of selective right common carotid arteriogram demonstrates contrast material in collapsed lumen of right internal carotid artery (*arrowheads*) ascending to fill the intracranial vasculature. Findings were confirmed at surgery.

patient had a 60% stenosis via an ulcerated plaque on intravenous DSA. Eight days later a complete obstruction by a fresh thrombus propagating into the internal carotid artery from the ulceration was present at surgery. This probably occurred after the original intravenous DSA examination. Another patient had a 95% stenosis (interpreted on the intravenous DSA examination). A thin stream [16] of contrast material was thought to extend to the intracranial carotid vasculature. At surgery there was complete obstruction. We have experienced difficulty in differentiating complete obstruction from high-grade stenosis when the site of the lesion has a tapered appearance (fig. 3). We believe this is because the small-diameter column of contrast material in the collapsed lumen distal to the stenosis is beyond the resolution of the digital system. Consequently, the narrowed lumen would not be visualized and would be interpreted as an obstruction.

When an apparent obstruction has a tapered appearance on intravenous DSA, we recommend arteriography to exclude a "poststenotic carotid slim sign" [16]. In the last undercall of significance, a 40% stenosis was demonstrated on intravenous DSA. However, only the LPO projection was successful. The RPO and AP projections were nondiagnostic because of swallowing artifacts and patient motion. Arteriography was performed and demonstrated the surgical nature of the lesion (90% stenosis).

There were two patients with false-positive (overcalls) examinations (table 5). Neither of these changed the surgical strategy.

Consequently, intravenous DSA correctly diagnosed the presence of a surgical lesion in 45 of 48 patients undergoing carotid endarterectomies for an overall sensitivity of 93.7%.

Arteriography was performed in 21 (7%) of the 306 patients undergoing intravenous DSA. A complete arteriogram was not obtained, but only selective injections to visualize the area in question not adequately demonstrated on the intravenous DSA examination (i.e., the common carotid bifurcation, the carotid siphons, patency of the anterior and middle cerebral arteries, etc.). Arteriography was also performed to confirm the presence of ulcerations. Two patients had a completely nondiagnostic intravenous DSA examination from which no information could be abstracted, and these individuals underwent complete arteriography. Although arteriography was performed because of a nondefinitive intravenous DSA examination, there was still agreement (±10%) in 24 (63%) of the 38 carotids evaluated.

High-resolution sonography is another screening method that demonstrates common carotid bifurcation atherosclerotic disease. Forty of the carotid endarterectomies had this procedure. There was agreement (±10%) in 25 (62.5%) of the 40 patients. This is lower than that reported [9, 17] and relates to the strict criterion (±10%) we used for correlation. If a more liberal criterion (±20%) were used, there would be 92% correlation with surgical findings. Heavy calcification in the vessel usually limits the ability of sonography to image a severely stenotic lumen. If a stenosis of 50% or greater is detected by sonography and coupled with an abnormal OPG and an abnormal supraorbital Doppler, a sensitivity of 93% could be achieved in detecting a surgical lesion.

Intravenous DSA is a relatively safe examination, and for the most part is performed on outpatients. Two patients developed skin rashes and one hyperemesis; this is inherent in any intravenous contrast examination. These patients were treated medically and released. The mediastinal extravasation occurred early in our experience when we were using straight catheters. The patient was observed overnight with no further treatment and released the next morning. Since we started using pigtail catheters, we have had no further extravasations.

Many patients with ischemic cerebrovascular disease have preexisting heart disease. This was the situation with our two patients who had angina attacks during the examination and with the one who went into congestive heart failure. Patients with cardiac disease should be well controlled and carefully monitored during the intravenous DSA examination.

Subsequent to our one patient who went into renal failure, we have been carefully evaluating the renal status of patients referred for intravenous DSA. Preexamination BUN and creatinine are measured and the total volume of contrast material and examination technique moderated accordingly. In those patients with abnormal values, the number of projections and, hence, the volume of contrast material limited to those required for the evaluation of the common carotid bifurcations (i.e., RPO, LPO, and, if necessary, AP projections). If a surgical lesion is demonstrated, arch and intracranial views are obtained on another day. The patients are also well hydrated before the examination. Since implementing this protocol, no patients have experienced renal failure nor has the renal status of patients with preexisting renal disease worsened.

Intravenous DSA and high-resolution sonography coupled with supraorbital Doppler and OPG both had a sensitivity in detecting a surgical lesion of about 93%. Inasmuch as the latter examinations do not require intravenous injection of contrast material, they should be the initial screening procedure for patients with suspected ischemic cerebrovascular disease. This is especially recommended in patients without neurologic deficit, that is, patients with asymptomatic carotid bruits [18] or older patients undergoing surgery for unrelated reasons, in whom there may be a transient lowering of blood pressure. Intravenous DSA is more accurate in delineating the atheromatous lesions and is better able to demonstrate the origin of the brachiocephalic vessels from the aortic arch and their intracranial branches. It should be performed in patients with suspected ischemic cerebrovascular disease and a positive sonogram or in patients with central nervous system symptoms, notably transient ischemic attacks. If this latter examination does not yield the information necessary for the decision of the appropriate management strategy, or if an ulcerated lesion is suspected but not demonstrated, then arteriography should be considered.

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