Intravenous digital subtraction angiography and duplex ultrasonography in postoperative assessment of carotid endarterectomy

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Seventy-four consecutive patients who had undergone carotid endarterectomy procedures were examined with intravenous digital subtraction angiography (IV-DSA) and duplex ultrasonography (DUS) at intervals ranging from 1 to 14 months postoperatively. Ninety-one percent of the DUS and 74% of the DSA images were of diagnostic quality. The two modalities agreed in the assessment of the endarterectomy appearance in 84% of the arteries, with 85% showing no evidence of significant residual disease. There were no arteries with severe restenosis or complete occlusion. In the 10 vessels in which the two modalities disagreed on disease assessment, the IV-DSA images were often degraded by artifact or vessel overlap leading to underestimation of disease. The authors conclude that DUS is the examination of choice for routine follow-up studies of carotid endarterectomy.

**KEY WORDS** carotid endarterectomy • digital subtraction angiography • ultrasonography • postoperative radiography

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Carotid endarterectomy has become the treatment of choice for many patients with severe atherosclerotic disease of the carotid bifurcation. The long-term clinical results of the procedure have been good; however, the recorded incidence of restenosis or reocclusion has been variable, ranging from 1.9% to 19%. Clinical examination is often not accurate in detecting recurrent disease at the endarterectomy site.

Conventional angiography would be the ideal radiographic modality with which to follow these patients; however, the known associated risk and morbidity precludes its use in asymptomatic patients. Routine follow-up assessment of carotid endarterectomy is therefore not commonly performed. The development of the newer vascular imaging modalities, namely, intravenous digital subtraction angiography (IV-DSA) and duplex ultrasonography (DUS), has provided a safer less invasive alternative to conventional angiography in these patients. Several studies have been reported on the use of continuous-wave Doppler ultrasonography, DUS, and IV-DSA alone and in comparison with conventional angiography to follow endarterectomy patients. In this study, the objective was to compare IV-DSA and DUS in the same patient in terms of image quality and diagnostic accuracy to determine which of these relatively noninvasive techniques would be the better method with which to follow endarterectomy patients.

**Clinical Material and Methods**

Seventy-four consecutive patients who had undergone a carotid endarterectomy at our institution were imaged with DUS and IV-DSA approximately 2 to 3 months following their surgery. The examinations were performed by different physicians on the same day and were initially interpreted independently.

The DUS scanner was a 7.5 or 10-MHz real-time B-mode transducer with a 3-MHz pulsed, range-gated Doppler transducer installed in a single head. The examinations were performed in the standard manner on a commercially available Machlett unit using central 30- to 40-cc injections of Renografin 76. At least two oblique views of the carotid bifurcations at 90° to each...
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Fig. 1. Imaging in a patient 2 months after a right carotid endarterectomy. Left: A good-quality intravenous digital subtraction angiogram, left posterior oblique projection, showing a satisfactory appearance of the right carotid endarterectomy with no evidence of restenosis. Minimal artifact is present with some overlapping of the right vertebral artery on the endarterectomy (arrow). Right: An excellent-quality duplex ultrasound image, sagittal view, showing mild plaque on the posterior wall of the carotid bifurcation (arrow).

other were obtained in all patients whenever possible. Selected hard-copy images were made from the video-screen and were used for the final assessment.

The DUS and IV-DSA hard-copy images were then independently assessed and compared for quality of visualization and the presence or absence of disease. Quality of visualization was assessed using a three-category scale. These categories were: 1) excellent, in which there was clear definition of arterial walls and minimal or no artifacts, with good contrast density in two views at right angles with the IV-DSA; 2) good, in which definition and contrast density were satisfactory and artifacts were present but diagnostic information was available; and 3) poor, in which the vessel either was not visualized or was seen at marginally diagnostic levels. Postoperative endarterectomy status was graded as: normal; mild restenosis (less than 40%); moderate restenosis (40% to 59%); severe restenosis (60% to 99%); or occluded. The presence or absence of common carotid artery disease was also assessed.

Results

Eighty-one endarterectomies were evaluated in 74 patients. In 13 arteries IV-DSA studies were not available and in four arteries DUS was not performed. There were therefore 64 arteries in which both studies were performed. All examinations were performed approximately 2 to 3 months postoperatively (range 1 to 14 months). The quality of visualization is summarized in Table 1. It can be seen that 26% of the IV-DSA images and 9% of the ultrasound images were of poor quality and therefore of minimal diagnostic value; 30% of the IV-DSA and 35% of the ultrasound images were of excellent quality, but of more importance, 91% of the ultrasound images were of adequate diagnostic quality compared to 74% of the IV-DSA images.

The postoperative appearance of the endarterectomies as evaluated by each modality is summarized in Table 2. It can be seen that IV-DSA and DUS agreed exactly in the assessment of disease category in 54 (84%) arteries with 39 (61%) showing no evidence of residual stenosis. Ten arteries (16%) demonstrated only mild disease at the endarterectomy site. There were no arteries with severe restenosis or complete occlusion. In three of the normal endarterectomies, both modalities identified disease of the common carotid artery proximal to the site of surgery. In one vessel, both methods detected a severe innominate artery stenosis that led to slow flow in the right internal carotid artery. In two patients, the studies were of poor quality and the endarterectomy was observed to be open but no further information was available.

There were 10 cases in which the two imaging modalities disagreed. In two vessels graded normal by ultrasound the IV-DSA identified disease, mild in one and moderate in the other; however, both of the IV-DSA studies were of poor quality. Duplex ultrasound identified three cases of mild or moderate disease in vessels graded normal by the IV-DSA (Fig. 1). There was one case assessed as mild disease by the IV-DSA and moderate by DUS, and the ultrasound also identified common carotid artery disease in two vessels assessed as completely normal by IV-DSA (Fig. 2). In one patient with a very deep, tortuous carotid artery, the ultrasound was of poor quality and the endarterectomy was seen to be patent but no assessment of restenosis
FIG. 2. Imaging in a patient 3 months after a left carotid endarterectomy. *Left*: An excellent-quality intravenous digital subtraction angiogram, right posterior oblique projection, showing a satisfactory appearance of the left carotid endarterectomy (arrow). The proximal internal carotid artery is not seen as well as the bifurcation. *Right*: A good-quality duplex ultrasound image, sagittal view, of the common carotid artery approximately 1.5 cm below the bifurcation. Moderate restenosis of the distal common carotid artery caused by dense echogenic plaque is seen (arrow).

Discussion

Although the incidence of clinically significant restenosis in endarterectomy patients is low,7 the unreliability of clinical examination in the detection of recurrent disease makes some form of follow-up imaging desirable. The risks and complications of conventional cerebral angiography are also low;6 however, this invasive procedure is probably not indicated for follow-up examinations in asymptomatic patients. The development of relatively noninvasive vascular imaging techniques such as IV-DSA and DUS has made routine follow-up studies available for these patients.

Several authors have shown that IV-DSA and DUS are comparable to conventional angiography in the diagnosis of atherosclerotic disease at the carotid bifurcations and that the sensitivities and specificities of these two modalities in comparison to conventional angiography are similar in cooperative patients.5,15,17 In this study, we were interested in how the two noninvasive modalities compared in the assessment of carotid endarterectomies and whether either offered advantages over the other.

Previous papers have evaluated the use of the less invasive modalities for carotid endarterectomy follow-up studies. Early series with Doppler ultrasound imaging alone identified recurrent stenoses in 9% to 12% of endarterectomy patients. Acher, et al.,2 used continuous-wave Doppler ultrasonography and IV-DSA to assess 47 endarterectomies, and both modalities identified a 9% restenosis rate. The authors considered that the two techniques were comparable in the identification of significant disease; however, they believed that IV-
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FIG. 3. Imaging in a patient 1 year after a left carotid endarterectomy. Left: A good-quality intravenous digital subtraction angiogram, left posterior oblique projection. There is a moderate restenosis of the carotid bifurcation (arrow). An apparent tight stenosis of the proximal internal carotid artery is simulated by artifact. Right: A good-quality duplex ultrasound image, sagittal view, showing atherosclerotic plaque on the posterior wall of the carotid bifurcation (arrow).

DSA was better for detecting minor intimal irregularities and ulcers. High-resolution B-mode ultrasound was not used in this study. Hertzler, et al.,

performed IV-DSA in 214 endarterectomy patients within the 1st week following surgery; 98% of the studies were of diagnostic quality and 94% showed no abnormality. A 1.9% incidence of postoperative internal carotid artery occlusion was observed.

Zierler, et al.,

used DUS alone in 89 endarterectomies and found a 19% restenosis rate. Eleven patients subsequently underwent conventional angiography and the DUS agreed with the angiograms in 10 patients assessed on a four-category stenosis scale. Roederer, et al.,

performed DUS and conventional angiography in 44 endarterectomy patients and demonstrated a 94% accuracy for DUS where stenosis was greater than 50%.

Our results indicate that IV-DSA and DUS agree in the assessment of endarterectomy status in a high percentage of cases (84%). A further 6% of cases are within one category of disease assessment. It would therefore seem that the choice of which test to use in the follow-up examination of endarterectomy patients should depend on factors other than the diagnostic accuracy, which seem to be comparable.

In our experience, 91% of the DUS images were of good diagnostic quality compared to only 74% of the IV-DSA images. The incidence of nondiagnostic images with IV-DSA may be higher than initially reported, and Hoffman, et al.,

found that only 26% of carotid bifurcations in patients being investigated for atherosclerotic disease were seen satisfactorily in two orthogonal views. The high incidence of swallowing and misregistration artifact, vessel overlap, and poor contrast concentration in elderly patients all contributed to the large number of unsatisfactory studies. These factors were all evident in many of our patients. In those cases in which the IV-DSA and DUS disagreed, the digital images were often degraded by motion artifact or vessel overlap, leading to an underestimation of recurrent disease.

Intravenous-DSA is not a benign procedure and carries a low but appreciable morbidity rate.

These risks relate to the placement of central venous catheters and administration of large volumes of contrast material to patients who are often elderly and may have compromised renal or cardiac function. Duplex ultrasound studies are completely non-invasive and can be easily performed and repeated in all but the most ill or uncooperative patients. The DUS images do, however, have a relatively limited field of view, and imaging of the proximal internal carotid artery and the intracranial vessels is not possible. Occasionally, deep, tortuous carotid bifurcations may be difficult to image. In the immediate postoperative period, the presence of band-

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* CCA = common carotid artery.
aging and suture material on the skin limits access for the ultrasound probe; however, careful positioning may allow diagnostic information to be obtained. These patients will usually be symptomatic, and conventional angiography is often required to provide the high-quality images to determine the need for reoperation.

The combination of high-resolution B-mode scanning for pictorial information and continuous-wave Doppler ultrasonography for flow data provides a diagnostic accuracy equal to IV-DSA and comparable to conventional angiography in a high proportion of patients. In our experience, the combination of convenience, safety, and diagnostic accuracy makes DUS the examination of choice for routine carotid endarterectomy follow-up studies.

References

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