Digital Subtraction Angiography with Intravenous Injection: Assessment of 1,000 Carotid Bifurcations

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Digital Subtraction Angiography with Intravenous Injection: Assessment of 1,000 Carotid Bifurcations

Gary W. Wood¹,² Robert R. Lukin¹ Thomas A. Tomsick¹ A. Alan Chambers¹

Digital subtraction angiography (DSA) with intravenous contrast injection was performed on 500 consecutive adult patients and evaluated for image quality of the carotid artery bifurcations. Diagnostic quality examinations were obtained in 974 common, 925 internal, and 904 external carotid artery segments. Sixty-two patients had standard carotid arteriography around the same time as DSA. Agreement of standard arteriograms with diagnostic quality DSA examinations was noted in 97 of 98 common, 94 of 95 internal, and 79 of 91 external carotid artery segments. All cases of complete carotid occlusion (14 of 14) were correctly interpreted by DSA. To identify a population with clinically significant stenosis, a 60% or greater reduction in diameter of the internal carotid was defined as a positive examination. Applying this criterion, the sensitivity, specificity, and accuracy of DSA as compared with standard arteriography was about 94%.

Several clinical trials of digital subtraction angiography (DSA) with intravenous contrast injection have been published setting preliminary indications for its use [1–5]. Clinical acceptance of this technique has been enthusiastic and many anticipate results of DSA to rival those of selective contrast arteriography. This study was designed to determine the following: (1) the frequency with which a diagnostic quality examination of the carotid bifurcation for vascular occlusive disease can be obtained with DSA; (2) the accuracy of DSA in determining the degree of carotid stenosis using selective arterial angiography as the standard; and (3) the utility of DSA in defining a population with substantial carotid occlusive disease.

Subjects and Methods

The study population comprised the first 500 patients referred to the University of Cincinnati Medical Center for carotid DSA during a 19 month period. Of these, 62 also had standard carotid arteriography near the time of the digital examination. This yielded 96 carotid bifurcations examined by both methods; no patient had both examinations for correlative purposes alone. Typically patients were 50–80 years old and about two-thirds of all cases were outpatients. Indications for DSA included asymptomatic carotid bruits; clinically evident ischemic symptoms; nonspecific, possibly ischemic, symptoms; postsurgical follow-up, and contraindications for direct arteriography.

A commercially available digital vascular imaging system (Philips) was used for all DSA examinations, and a prototype system has undergone clinical testing at the University of Wisconsin, Madison, and operational characteristics have been described [6]. Serial imaging at one frame/sec with four summations/frame was used for neck examinations using radiographic technique of 55–75 kVp and 200–300 mA. The system employs a dual mode 5 or 9 inch (12.7 or 22.9 cm) cesium-iodide image intensifier with a Plumbicon camera. Digital conversion and processing occur instantly with real-time display and postprocessing ability on a 256 × 512 matrix with resolution of 8 bits. Performance specifications include 1% contrast resolution and a 650:1 system signal:noise ratio.

A 16 gauge, 30.5 cm, straight, end-hole catheter (Intracath, Deseret), placed in the
basilic or cephalic vein, was used for about 75% of the injections. Fluoroscopic contrast testing of catheter placement was performed to avoid injection into inadequate or banch veins. In three or four patients with small or tortuous veins, contrast extravasation in the soft tissues of the arm resulted in local pain without lasting complication. Early in our experience, many examinations were performed through an end- and multi-hole 5 French straight Teflon catheter positioned in the superior vena cava, but this method was abandoned after eight instances of mediastinal contrast extravasation. Occasional use of pigtail catheters in the superior vena cava and catheter placement in the inferior vena cava via the femoral route was made without observed complication. Typical injection rates of 8–12 ml/sec of MD-76 (Mallinckrodt) diatrizoate meglumine and diatrizoate sodium, 370 mg iodine/ml) were used for a total volume of 35–50 ml of contrast material followed by a 20–30 ml 5% dextrose in water bolus flush. All examinations were physician-controlled. Typically three, but from one to five, angiographic sequences in various oblique projections were used per patient.

Each DSA was subsequently interpreted by one of three experienced neuroradiologists (R. R. L., T. A. T., or A. A. C.). In questionable instances, one or both of the other staff neuroradiologists were consulted for a consensus opinion. Subjective image quality was assessed for each common, internal, and external carotid artery segment at the bifurcation. Excellent, diagnostic or unsatisfactory ratings were assigned on the basis of artery projection, contrast and spatial resolution, artifacts, and image correlation among various oblique views (fig. 1). Subsequently, percentage stenosis was measured relative to the normal or projected normal artery lumen. An unsatisfactory rating was given when the arterial segment was overlapped or obscured on all images. Excellent and diagnostic examinations were interpreted for degree of arterial stenosis. Unsatisfactory examinations were recorded as to patency, but no assessment of stenosis was attempted.

Consistency with other reports was desired at the study outset, and the methods of Chilcote et al. [3] were chosen for grading arterial stenosis and determining angiographic correlation. Arterial stenosis of each bifurcation element was classified into the following categories: 0 = normal; 1 = minimal stenosis (1%–20%); 2 = mild stenosis (20%–40%); 3 = moderate stenosis (40%–60%); 4 = moderate to marked stenosis (60%–80%); 5 = marked stenosis (80%–99%); and 6 = occluded (100%). DSA was considered correct if the category assigned agreed with standard arteriography.

To identify a population of patients with clinically significant carotid stenosis, DSA was considered positive if the internal carotid artery segment stenosis was equal to or greater than 60% (category 4) [7–9]. Sensitivity, specificity, and accuracy were determined relative to standard arteriography.

**Results**

DSA examinations of at least diagnostic quality were obtained in 974 (97%) common, 925 (93%) internal, and 904 (90%) external carotid artery segments at the bifurcation (table 1). In no case was the internal carotid artery satisfactorily imaged when the common carotid was not.

The estimation of degree of arterial stenosis with excellent or diagnostic DSA examinations agreed with standard arteriography in 97 of 98 common, 94 of 95 internal, and 79 of

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**TABLE 1:** Quality of Demonstration by DSA of Carotid Bifurcation Artery Segment

<table>
<thead>
<tr>
<th>Segment of Carotid Artery Bifurcation</th>
<th>No. Arteries</th>
<th>Excellent</th>
<th>Diagnostic</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common</td>
<td>455</td>
<td>619</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>474</td>
<td>430</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>Internal</td>
<td>482</td>
<td>443</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

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*Fig. 1.—DSA quality criteria. A, Excellent visualization of carotid bifurcation. B, Diagnostic visualization of carotid bifurcation. Misregistration artifact from hyoid bone motion (arrow). C, Inadequate visualization due to patient motion.*
91 external carotid artery segments at the bifurcation. DSA overestimated arterial stenosis by two grades in each of two cases of common and internal carotid artery stenosis. Exact correlation of DSA with standard arteriography was observed in all grade 5 (80%–99% stenosis) and grade 6 (complete occlusion) lesions (figs. 2 and 3).

Table 2 presents the comparison of internal carotid DSA with standard arteriograms in the same fashion as Chilcote et al. [3]. No stenosis was greater in the common than the corresponding internal carotid artery segment.

Standard arteriography was used to define the positive and negative patient populations for carotid occlusive disease at the 60% or greater level of stenosis. DSA identified

TABLE 2: Stenosis of Internal Carotid Arteries Judged Excellent or Diagnostic by DSA Correlated with Standard Arteriography

<table>
<thead>
<tr>
<th>Stenosis by Standard Arteriography</th>
<th>No. Arteries with Stenosis by DSA (n = 95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, Normal</td>
<td>11</td>
</tr>
<tr>
<td>1, 1%–20%</td>
<td>10</td>
</tr>
<tr>
<td>2, 20%–40%</td>
<td>11</td>
</tr>
<tr>
<td>3, 40%–60%</td>
<td>2</td>
</tr>
<tr>
<td>4, 60%–80%</td>
<td>2</td>
</tr>
<tr>
<td>5, 80%–99%</td>
<td>9</td>
</tr>
<tr>
<td>6, Occluded</td>
<td>14</td>
</tr>
</tbody>
</table>

* DSA overestimation by two grades of arterial stenosis.
† DSA overestimation by one grade of internal carotid stenosis. DSA overestimation of a lesser grade common carotid stenosis by two grades occurred in this patient.

Fig. 2.—Evaluation for carotid bruit. A, DSA shows high-grade (80%) stenosis of proximal internal carotid artery. B, Selective common carotid arteriogram of same patient.

Fig. 3.—A, DSA shows right internal carotid occlusion (arrow) and significant stenosis of left internal carotid artery. Selective right (B) and left (C) common carotid arteriograms.
28 of 30 true-positives (≥60% stenosis) and 61 of 65 true-negatives (<60% stenosis) for a sensitivity of 93%, specificity of 94%, and accuracy of 94%. These percentages would increase slightly if a clinically significant stenosis were defined as 40% or greater.

We have now obtained 2,000 digital angiograms at Cincinnati General Hospital. There have been no known related mortalities. Those cases of contrast extravasation have resulted in local pain of minutes to hours without lasting sequelae. We know of one case each of the following related to contrast administration: exacerbation of preexisting renal insufficiency, congestive heart failure, and myocardial infarction 6 hr after the procedure in a patient with a history of infarct. We have encountered a somewhat disturbing incidence of anginal attacks closely related to contrast injection (perhaps 5%–10% of patients with known preexisting angina). Urticaria, nausea, and vomiting occur at about the same rate as in intravenous urography. At present, patients with renal insufficiency, diabetes, or known atherosclerotic heart disease are carefully evaluated as to their indications for the procedure. Most patients tolerate the procedure well (two-thirds are outpatients) and many patients have stated that having also experienced standard arteriography, they greatly prefer the digital intravenous examination.

Discussion

Results of this study compare favorably with previous reports regarding the accuracy of DSA in defining carotid artery stenosis [1, 2]. High sensitivity, specificity, and accuracy characterize DSA in identifying patients with significant carotid occlusive disease.

In our series, an accurate assessment of internal carotid stenosis at the bifurcation was obtained with DSA in more than 90% of individual artery evaluations. Examinations were performed in a representative clinical practice situation with an occasional uncooperative patient accounting for most of our unsatisfactory examinations. These were mainly due to patient motion and swallowing artifacts. Only two patients were deferred because of their inability to cooperate, and in only one were we unable to place a venous catheter properly. This latter patient was a bilateral, above-the-knee amputee with poor arm veins and multiple femoral scars from previous vascular graft placements. Problems such as venous reflux and vessel overlap were usually solved by varying oblique projections.

Contrast resolution was only rarely insufficient for diag-
nostic carotid bifurcation imaging. In two patients this occurred with very sluggish venoarterial circulation, despite a superior cava catheter and 12 ml/sec injection rate. Insufficient contrast at the carotid bifurcation has not been a problem with peripheral injection sites. We have performed diagnostic DSA with as low as 7 ml/sec injection rates (fig. 4). From the point of view of patient convenience and laboratory throughput, a peripheral injection site is preferred to the centrally placed catheter. Some technical facility is necessary, however, particularly in patients with inadequate veins. In other applications a more compact central bolus contrast injection may be beneficial.

Important to maximizing information is viewing of the entire serial angiographic sequence and the ability to post-process and remask images during the procedure. We frequently return to the video disk or tape for reprocessing and reviewing during final examination interpretation.

We often noted satisfactory DSA imaging of carotid ulceration and intracranial artery segments during this study, although our experience in these areas has been inconsistent to date (figs. 5 and 6). In anticipation of this, we excluded analysis of angiographic features other than carotid bifurcation stenosis for the purposes of this study.

REFERENCES