Limitations of Intravenous Digital Subtraction Angiography

Patrick A. Turski,[1] William J. Zwiebel,[1] Charles M. Strother,[1] Andrew B. Crummy,[1] Gastone G. Celesia,[2] and Joseph F. Sackett[1]

Eighteen digital subtraction angiography (DSA) examinations were retrospectively evaluated for factors that led to their erroneous interpretation. Overlapping vessels obscured pathologic conditions in five cases. In four cases the lesions were not adequately profiled by the DSA projections. Eight lesions were rendered inconspicuous by misregistration artifacts attributable to motion, either from swallowing or from pulsation of vessel walls. One diagnostic error was caused by poor opacification from a degraded contrast bolus secondary to low cardiac output.

Digital subtraction angiography (DSA) permits visualization of vascular structures after intravenous injection of contrast material [1–4]. The method is sensitive, specific, and accurate in its ability to demonstrate pathologic conditions involving the extracranial carotid arteries [5, 6]. The low risk associated with the procedure has resulted in rapid acceptance of the technique for the evaluation of vascular disease. However, there are situations in which interpretation of the DSA examination results in an incorrect diagnosis. The purpose of this investigation was to identify factors that may contribute to diagnostic error.

Materials and Methods

The arteriographic images of patients referred for standard angiography and intravenous DSA between May 1981 and October 1982 were reviewed retrospectively. The patients comprised a select population in which atherosclerotic lesions were common. Eighteen DSA examinations performed on members of this population were found to have been erroneously interpreted. Sixteen diagnostic errors involved lesions of the carotid bifurcation or proximal internal carotid artery, one involved the proximal right common carotid artery, and one involved the left subclavian artery. All DSA examinations reviewed were considered adequate for diagnosis at the time the examination was performed. All lesions studied were atherosclerotic in nature and were classified as either stenoses or surface irregularities, which were considered ulcerations. Stenoses were graded as minimal (0–30%), moderate (30%–70%), or severe (70%–99%). The DSA diagnosis was considered incorrect if subsequent standard angiography changed the grade of the stenosis (e.g., from minimal to moderate) or revealed previously undetected surface irregularities suggesting ulcerations. The DSA examinations that had been erroneously interpreted were then reviewed to identify the causes of the incorrect diagnoses.

The DSA system using a time subtraction algorithm (also called mask mode radiography) has been described in detail elsewhere [1, 3, 4]. Forty ml meglumine diatrizoate (Renografin 76, Squibb) was injected at a rate of 14 ml/sec through a 5.3 French pigtail catheter inserted in the superior vena cava via a brachial vein. The carotid bifurcation was evaluated in left and right posterior oblique projections with angulation of the patient and x-ray tube of approximately 60°. If the initial oblique views were inadequate, anteroposterior or repeat oblique views were obtained. When symptoms were referable to the proximal brachiocephalic vessels, a right posterior oblique view of the aortic arch was obtained. The examination was limited to four injections, thus restricting the number of projections that could be attempted. The size of the image intensifier (15.2 cm or 22.9 cm mode) required that each anatomic region (aortic arch, carotid bifurcations, or intracranial vessels) be examined separately.

Results

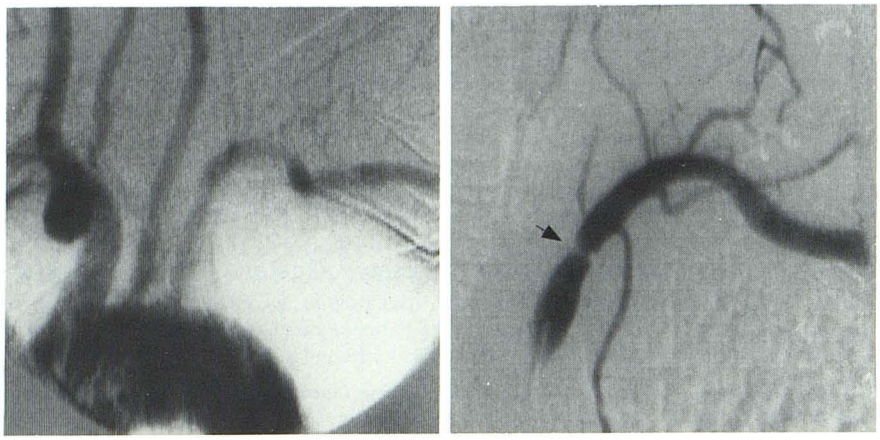
In nine cases DSA led to underestimation of the degree of stenosis by at least one grade when compared with the results of standard angiography. Three of these lesions were weblike plaques, not visualized by DSA, that proved to be severe stenoses (figs. 1 and 2). Conversely, in five cases the DSA examination suggested a more severe stenosis than was demonstrated by standard angiography. In the remaining four cases DSA failed to visualize ulcerated lesions, two of which were confirmed at surgery (fig. 3).

The diagnostic errors and their causes are summarized in table 1. Five stenotic lesions involving the common carotid artery or proximal internal carotid artery were incorrectly assessed because the external carotid artery, vertebral artery, or subclavian artery was superimposed on the lesion. Four lesions (two stenoses, two ulcerations) were not adequately profiled by the standard oblique DSA projections of the carotid bifurcation. Eight lesions were rendered inconspicuous by misregistration artifacts (in two cases, the cause was motion of the larynx and hyoid bone secondary to swallowing by the patient; in six cases, pulsations of the vessel wall resulted in misregistration of calcified atherosclerotic plaque or poor registration of the iodine-containing arterial lumen).

Discussion

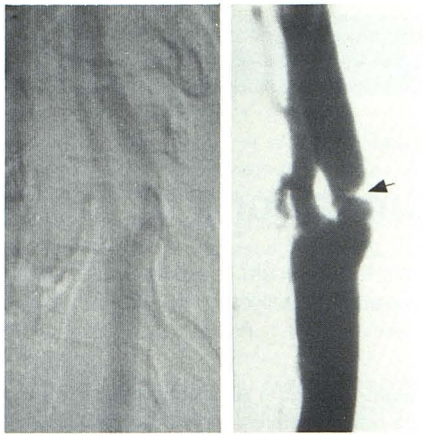
The simultaneous opacification of the carotid arteries and vertebral arteries inherent in the intravenous DSA technique is a difficult problem to overcome. Even when the plane of view is varied, superimposed vessels may be encountered. In our study, errors in diagnosis secondary to vessel overlap were found to have occurred

[1]Department of Radiology, University of Wisconsin Clinical Science Center, 600 Highland Ave., Madison, WI 53792. Address reprint requests to P. A. Turski.
[2]Department of Neurology, University of Wisconsin, Madison, WI, and Neurology Service, Veterans Administration Hospital, Madison, WI.
AJNR 4:271–273, May/June 1983 0195-6108/83/0403-0271 $00.00



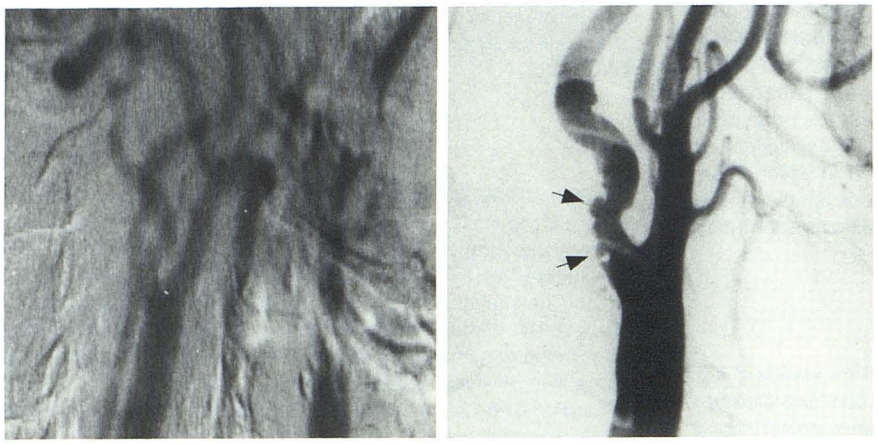
1A 1B

Fig. 1.—**A**, Intravenous DSA of aortic arch. Left subclavian artery appears free of significant stenosis. **B**, Intraarterial DSA reveals high-grade stenosis secondary to vascular web (*arrow*).



2A 2B

Fig. 2.—**A**, Carotid DSA compromised by poor vascular opacification from low cardiac output. Carotid artery appears free of obstruction. **B**, Standard angiography reveals high-grade stenosis secondary to vascular web (*arrow*).



3A 3B

Fig. 3.—**A**, DSA fails to show small ulcerations because of vessel overlap, lack of profile view, and pulsation of vessel wall. **B**, Standard angiography demonstrates multiple small ulcerations.

4

Fig. 4.—Intracranial DSA with incorrect logarithmic amplification results in loss of iodine signal as carotid artery passes through petrous bone.

when variations in the opacification of an underlying vessel were used to determine the presence or absence of lesions. This method is especially unreliable when vascular webs are present.

For optimum assessment of degree of severity, lesions should be seen in profile. The radiographic projection must be designed in such a manner that the x-ray beam is tangent to the vessel wall in question. The most common site for atherosclerotic disease is the posterior wall of the carotid bifurcation [7]. This part of the carotid bifurcation is very difficult to profile with DSA because of superposition of vessels. The inability to obtain a true lateral view of the carotid bifurcation with intravenous DSA may lead to incomplete or incorrect assessment. After reviewing 200 standard arteriograms of the common carotid artery bifurcation, Kasef [8] reported that oblique views adequately show the bifurcation in the majority (62%) of vessels but that a true lateral view was required for a diagnostically adequate display of the bifurcation in the remainder. Unfortunately, the large amount of contrast material that must be administered for DSA limits the number of projections that can be obtained.

Patients have a reflex urge to swallow during the injection of contrast material. This phenomenon occurs even when a nonionic contrast agent is used [9]. Motion of the larynx from swallowing produces subtraction artifacts resulting from misregistration of the iodine-containing image in relation to the mask image. The difference image is degraded and the carotid bifurcation may be clearly seen in only one projection. If this view does not profile the lesion adequately, abnormalities may remain undetected. Pulsation of the arterial walls also causes misregistration artifacts that can obscure lesions such as vascular webs and small ulcerations. Although selection of an alternate mask may improve the quality of the image [2], many of these lesions are so small that they approach the limit of spatial resolution possible with current digital equipment. Therefore, small ulcerations cannot be reliably detected by present intravenous DSA techniques. The impact of this limitation is perhaps mitigated by the fact that ulcerated lesions are not always identified

TABLE 1: **Causes of Diagnostic Error in Intravenous Digital Subtraction Angiography**

Cause	Diagnostic Error			Totals
	Underestimated Stenosis	Overestimated Stenosis	Nonvisualized Ulceration	
Vessel overlap:				
External carotid artery	1	2	...	3
Vertebral artery	...	1	...	1
Subclavian artery	1	...	...	1
Lesion not in profile	2	...	2	4
Misregistration artifact:				
Swallowing	1	1	...	2
Pulsation of vessel wall	3	...	1	4
Pulsation of calcified plaque	...	1	1	2
Degraded contrast bolus	1	...	...	1
Totals	9	5	4	18

even with standard angiography [10]. Pulsation of large calcified atherosclerotic plaques also produces misregistration artifacts that can obscure severe atheromatous lesions.

In patients with poor cardiac output, the prolonged circulation time degrades the contrast bolus [11]. The decrease in vascular contrast results in less definition of the arterial wall secondary to a reduced iodine signal.

Other possible causes of diagnostic error, not encountered in this clinical group, are incorrect logarithmic amplification and excessive image noise. Logarithmic amplification of the iodine signal ensures visualization of the entire arterial structure as it passes through regions of dense bone. Insufficient amplification may lead to loss of the iodine signal, simulating a vascular occlusion (fig. 4). Similarly, an inadequate flux of x-ray photons produces excessive image noise, resulting in decreased spatial resolution and poorly defined lesions.

In summary, DSA is a safe and accurate method of assessing patients with extracranial carotid occlusive disease. However, superimposed vessels and incompletely profiled lesions can result in diagnostic errors. Lesions such as vascular webs and small ulcerations cannot be reliably identified with current DSA techniques. Any inconsistencies between the DSA examination and the clinical presentation should be resolved with standard angiography.

REFERENCES

1. Kruger RA, Mistretta CA, Houk TL, et al. Computerized fluoroscopy in real time for noninvasive visualization of the cardiovascular system. *Radiology* **1979**;130:49–57
2. Christenson PC, Ovitt TW, Fisher HD, Frost MM, Nudelman S, Roehrig H. Intravenous angiography using digital video subtraction: intravenous cervicocerebrovascular angiography. *AJNR* **1980**;1:379–386, *AJR* **1980**;135:1145–1152
3. Mistretta CA, Crummy AB, Strother CM. Digital angiography: a perspective. *Radiology* **1981**;139:273–276
4. Mistretta CA, Crummy AB. Diagnosis of cardiovascular disease by digital subtraction angiography. *Science* **1981**;214:761–765
5. Strother CM, Sackett JF, Crummy AB, et al. Clinical applications of computerized fluoroscopy. *Radiology* **1980**;136:781–783
6. Chilcote WA, Modic MT, Pavlicek WA, et al. Digital subtraction angiography of the carotid arteries: a comparative study in 100 patients. *Radiology* **1981**;139:287–295
7. Sundberg J. Localisation of atheromatosis and calcification in the carotid bifurcation: a post mortem radiographic investigation. *Acta Radiol [Diagn]* (Stockh) **1981**;22:521–528
8. Kasef LG. Positional variations of the common carotid artery bifurcation: implications for digital subtraction angiography. *Radiology* **1982**;145:377–378
9. Sackett JF, Mann FA, Turski PA. Digital video angiography—a study of contrast media. *Excerpta Medica* (in press)
10. Edwards JH, Kricheff II, Riles TS, Imparato AM. Angiographically undetected ulceration of the carotid bifurcation as a cause of embolic stroke. *Radiology* **1979**;132:369–373
11. Hurst JW. *The Heart*. New York: McGraw-Hill, **1982**:1854–1855