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Intravenous digital subtraction angiography (DSA) was peformed in 111 patients with vertebrobasilar ischemia. Ninety percent of the vertebral images were of diagnostic quality; 23% of the basilar images were good quality and 53% fair quality; and 58% of the posterior cerebral images were poor. Compared with selective film arteriography in 23 patients, DSA tended to underestimate the degree of atheromatous disease. Segments of the basilar artery were often poorly seen, which could result in false-negative errors. DSA can provide a general assessment of atheromatous disease of the brachiocephalic vessels, including the vertebral and carotid arteries, and in many cases can exclude occlusion or critical stenosis of the vertebrobasilar system. However, it does not adequately image the posterior cerebral or cerebellar artery.

Digital subtraction angiography (DSA) has emerged as a less invasive alternative to conventional selective arteriography for cerebral vascular disease [1, 2]. This new technique can evaluate the carotid artery bifurcations with a high degree of accuracy and a success rate of 75%–80% [3–5]. More recent reports indicate some applications for the intracranial vasculature as well [6–8]. The vertebrobasilar system has received relatively little attention. Arteriosclerotic disease of the vertebrobasilar system can cause deficits in visual fields, cerebellar function, and the cranial nerves, including the auditory vestibular apparatus. Although the vertebral and basilar arteries are not as amenable to surgical repair as the carotid arteries, determination of the degree of atheromatous involvement of these arteries is still desirable in making therapeutic decisions regarding antiplatelet or anticoagulant therapy.

No noninvasive tests are available to adequately evaluate the vertebrobasilar system. Doppler sonography has been used to determine whether a vertebral artery is open or occluded, but this technique is less reliable for vertebral stenosis and gives no information about the basilar artery [9, 10]. Before DSA, the only definitive diagnostic methods were arch aortography or retrograde brachial or selective vertebral arteriography. These angiographic procedures have a small but real risk of stroke. Therefore, we were interested in investigating the ability of DSA to evaluate arteriosclerotic disease of the vertebrobasilar system.

Subjects and Methods

The 111 patients referred for DSA had varying symptoms of vertebrobasilar disease, including dizziness, vertigo, diplopia, dysarthria, ataxia, visual field deficits, and fainting spells. In some cases the clinical presentation suggested both vertebrobasilar and carotid disease.

DSA was performed using a Technicare DR 960 digital angiographic system. After sterile preparation and using a Seldinger technique, a 5.5 French Teflon (Universal Medical Instrument Corp., Ballston Spa, NY) catheter with six side holes was introduced into an antecubital vein and positioned in the superior vena cava with fluoroscopic monitoring. Forty ml of Renografin-76 (Squibb, Princeton, NJ) was injected at a rate of 15 ml/sec.
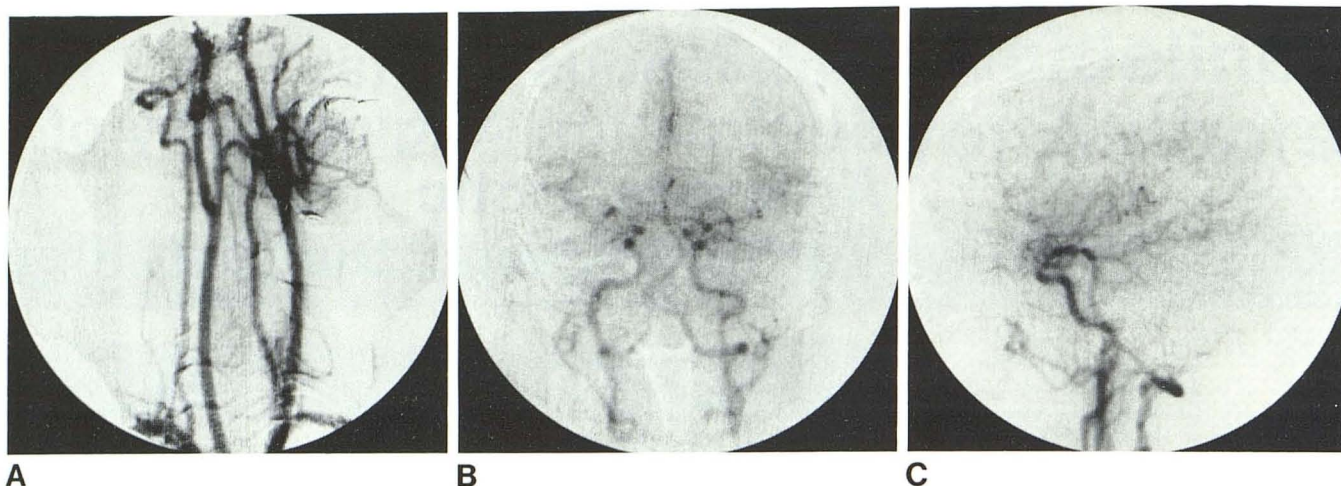
Fig. 1.—Normal study. **A**, Oblique view of vertebral arteries. AP (**B**) and lateral (**C**) views of basilar artery.

Images were acquired at a rate of 1.25 frames/sec on a 512 × 512 matrix using a 6 inch (15.24 cm) mode on the image intensifier. Routine views consisted of one or two 65° oblique views (the patient's head turned 45° away from the side of interest and the x-ray tube rotated a further 20°) of the cervical vertebral arteries and anteroposterior (AP) and lateral views of the basilar artery (fig. 1).

In a subset of 23 patients, both DSA and selective arteriography were performed. The cervical vertebral arteries were not routinely included on vertebral arteriograms and, therefore, an accurate comparison could not be made for the vertebral artery.

The image quality of the vertebral, basilar, and posterior cerebral arteries was evaluated for each patient and categorized as good, fair, or poor (table 1). On a good image, the entire artery was visualized and an accurate assessment of atheromatous disease could be made. On a fair image, most of the artery was visualized, but some segments were seen less well and could result in false-negative errors. On a poor image, gross patency of a vessel could sometimes be determined, but often little or no information could be obtained from the study.

The studies of diagnostic quality (fair and good) were further evaluated to assess the amount of atheromatous disease in the vertebral, basilar, and posterior cerebral arteries (table 2) (figs. 2 and 3). Moderate disease consisted of at least 25% narrowing of an artery, and the severe category represented stenoses with a residual lumen of 2 mm or less.

Observations

Accuracy (DSA vs. Arteriography)

The DSA images of the basilar artery were considered of diagnostic quality in 21 of the subset of 23 patients. In these cases the amount of atheromatous disease in the basilar artery was evaluated independently on DSA and arteriography. The arteries were graded as normal or showing mild, moderate, or severe atheromatous disease or complete occlusion. In four cases, DSA underestimated the disease by one category. Nevertheless, statistically, there was good correlation between DSA and arteriography for evaluating basilar artery disease ($p < 0.01$). Although DSA and arteriography were evaluated independently, this was not a

double-blind study, and there was obviously some subjectivity in assessment.

An insufficient number of the DSA images of the posterior cerebral artery were of diagnostic quality to allow for statistically significant comparison with arteriography. In one case, where the arteriogram clearly showed an occlusion of the ambient segment of a posterior cerebral artery, the DSA image was called normal.

Association of Carotid Disease with Vertebrobasilar Disease

The amount of atheromatous disease of the carotid arteries was correlated with the vertebrobasilar disease in the same population (table 3). A statistically significant correlation was found between carotid disease and vertebrobasilar disease ($p < 0.005$).

TABLE 1: **Quality of Intravenous DSA in 111 Patients**

Artery Visualized	Quality of Visualization (%)			
	Good	Fair	Poor	Total of Diagnostic Quality
Vertebral	53	37	10	90
Basilar	23	53	24	76
Posterior cerebral	9	33	58	42

TABLE 2: **Extent of Atheromatous Disease Revealed by Intravenous DSA**

Artery Visualized	Amount of Atheromatous Disease (%)				
	Normal	Mild	Moderate	Severe	Occlusion
Vertebral	66	22	7	1	4
Basilar	76	13	7	3	1
Posterior cerebral .	98	2	0	0	0

Fig. 2.—Moderate atheromatous disease. **A,** Oblique view of right vertebral artery reveals moderate atheromatous disease (*arrowheads*). **B,** Lateral view of basilar artery shows atheromatous disease with focal stenosis (*arrow*).
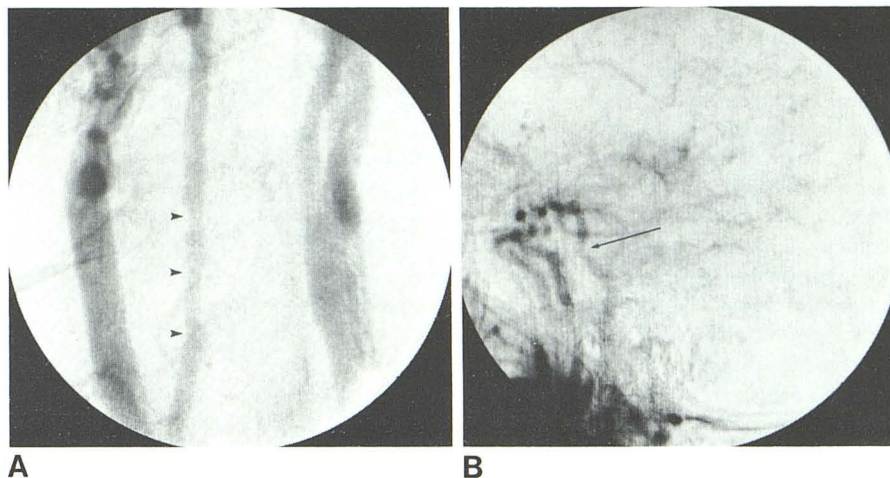

A   **B**

Fig. 3.—Vertebral occlusion. Arch (**A**) and oblique neck (**B**) views demonstrate complete occlusion of right vertebral artery at its origin and reconstitution of cervical segment (*arrowheads*) via collateral arteries from thyrocervical trunk (*short arrows*). Left vertebral artery is not identified. Right internal carotid artery is also occluded (*long arrow*).
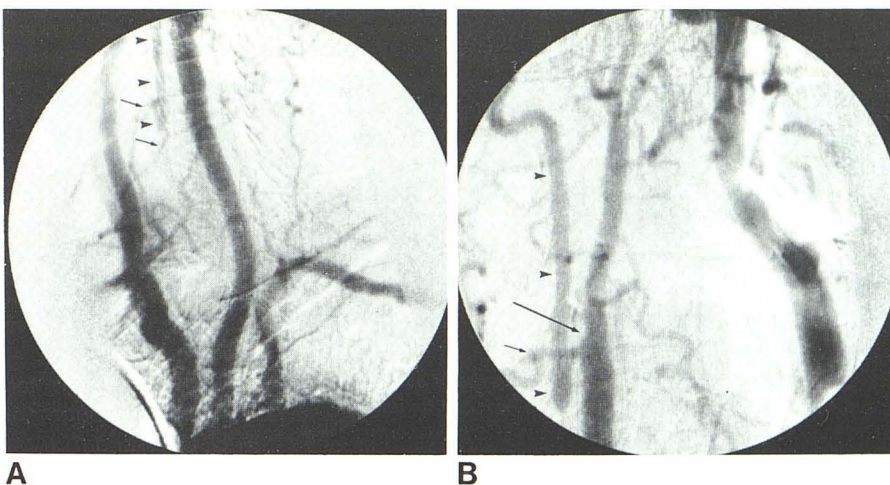

A   **B**

TABLE 3: **Associated Carotid Disease in Patients with Vertebrobasilar Disease**

Vertebrobasilar Disease	Condition of Carotid Artery (No. of Patients)		
	Normal	Minimal Disease	Moderate or Severe Disease
Normal	42	11	5
Mild	13	8	4
Moderate	5	5	2
Severe	2	2	1
Occlusion	1	3	2

Effect of DSA Results on Therapy

The patient records were examined to see if the DSA influenced therapeutic decisions. The degree of atheromatous disease was scaled against three types of therapy: 1 = none; 2 = aspirin and Persantine; and 3 = heparin and Coumadin. Initially it appeared that the DSA results were not seriously considered and that clinicians were electing anti-platelet and anticoagulant therapy when the DSA showed relatively little atheromatous disease. Further correlative studies revealed that additional factors influenced the choice of therapy, such as the amount of carotid disease, evidence of previous infarcts on computed tomographic (CT) scan, and clinical information. When the extent of carotid disease was excluded, there was better correlation between the DSA results and therapeutic choice.

Discussion

Ischemia of the vertebrobasilar system can be caused by atheromatous disease, vertebral artery compression with head rotation, hypotension, and embolic episodes. Patients present with various symptoms including dizziness, vertigo, ataxia, diplopia, blurred vision, partial deafness, tinnitus, numbness or weakness of extremities, dysarthria, dysphagia, hiccups, headache, nausea, and vomiting [11-13]. If sensory and motor symptoms predominate, vertebrobasilar ischemia may mimic carotid artery disease. Also, if a fetal-type posterior cerebral artery is present, carotid

artery disease can result in visual field deficits referable to the occipital lobe.

Imaging of the posterior circulation requires evaluation of the vertebral artery and basilar artery and its major branches. Ideally, assessment of the vertebral arteries includes views of the subclavian arteries and vertebral origins, the cervical segments, and the intracranial segments to their junction with the basilar artery. Proximal stenoses or even occlusion of a vertebral artery may not be symptomatic if the other vertebral artery is patent and of adequate size. Frequently, there are also good collaterals from the thyrocervical trunk and occipital artery to the vertebral artery to compensate for a proximal stenosis.

The basilar artery is the major vessel of concern in vertebrobasilar ischemia. Although the small perforating arteries to the brainstem cannot be imaged even with conventional magnification angiography, assessment of the disease in the basilar artery is helpful for correlating with the clinical presentation, for giving a prognosis, and for electing the appropriate therapeutic regimen. A complete examination includes visualization of the anterior inferior cerebellar, superior cerebellar, and the posterior cerebral arteries, the latter being more important in patients with visual deficits.

To accomplish these goals many different radiographic views were investigated. Since an intravenous injection results in opacification of all the arteries, projections that are ideal for selective catheter studies may result in overlap of vessels on an intravenous study. One also needs to consider contrast limitations. Each injection consists of 40 ml of Renografin-76 or about 14.8 g of iodine. We prefer to limit the study to three injections and have set five as our maximum, which amounts to 74 g of iodine. Some views need to be repeated due to patient motion or overlap of vessels.

Initially, we tried to obtain an arch view for the vertebral origins, an oblique view of the neck, and AP and lateral views of the head, but found that too often we were reaching our contrast limit. As a compromise we now do one oblique view of the lower neck using a 9 inch (22.9 cm) mode on the image intensifier (fig. 1A). This view includes the vertebral origins at the bottom of the field and the carotid bifurcations at the top. If stenosis of a vertebral origin is suspected, another view can be obtained using a 4 inch (10.2 cm) or 6 inch (15.2 cm) mode for better resolution.

A straight lateral view of the head was found to be the best view for imaging the basilar artery (fig. 1C). Subtraction artifacts from the dense petrous bone are a problem and may obscure a segment of the artery. Occasionally the AP view is helpful, but in general the image quality is not as good as the lateral view (fig. 1B). An oblique view invariably results in overlap of one of the carotid arteries on the basilar artery. Waters and base projections are more difficult for the patient and are more subject to misregistration due to motion and/or swallowing.

It is apparent from the data in table 1 that there is an inverse relation between image quality and the distance of the vessel of interest from its point of origin. Ninety percent of DSA images of the vertebral arteries were of good or fair image quality compared with 76% for the basilar and 42% for the posterior cerebral arteries. Alternatively, 24% of the

basilar arteries were seen poorly, and in another 53% segments were seen poorly that could have led to false-negative interpretation. In general, the images for the vertebral arteries were as good and those for the basilar artery not as good as those reported for the carotid arteries [4]. Compared with selective arteriography, DSA tended to underestimate atheromatous disease, although statistically the difference was not significant.

A number of factors can adversely affect the image quality. Many of the patients are elderly. If they are unable to cooperate, misregistration is a major problem. Many have generalized arteriosclerosis. An ectatic aorta and tortuous brachiocephalic vessels cause more mixing of the contrast bolus with the blood. Coronary artery disease with ventricular dilatation is very likely an important factor. It is apparent that a prolonged circulation time results in poor contrast density in the arteries.

The question remains whether intravenous DSA can provide enough information about the vertebrobasilar system to establish a diagnosis and make therapeutic decisions. It is easier to say what DSA cannot do. It cannot adequately image the posterior cerebral artery. Even on the better quality images, occlusion of a posterior cerebral artery can be missed (fig. 4). Also, the origin of the posterior inferior cerebellar, anterior inferior cerebellar, and superior cerebellar arteries cannot be visualized consistently. It follows that in a patient with a homonymous hemianopia or lateral medullary syndrome, DSA probably is not the procedure of choice. If bypass surgery [14] or angioplasty procedures [15] on the posterior circulation become more popular, the detail of selective arteriography would be required.

What can intravenous DSA accomplish? In many cases, it can give a good view of the vertebral arteries and an adequate view of the basilar artery. Stenotic lesions and complete occlusion of the vertebral or basilar artery can be seen (figs. 2 and 3). In cases of suboptimal imaging, early filling of the top of the basilar artery before opacification of the distal vertebral and lower basilar arteries suggests significant disease of the vertebrobasilar system (fig. 5). DSA may overlook minor atheromatous disease and tends to underestimate the extent of disease. DSA also gives a general assessment of the brachiocephalic arteries and the carotid bifurcations (fig. 3). Information about the carotid arteries is significant, because our data (table 3) and data in the literature [16] indicate that a definite correlation exists between carotid disease and vertebrobasilar disease. Incidentally, this information would not be available on a single-vessel selective vertebral arteriogram. Furthermore, in the surgical literature, independent groups of investigators have reported improvement in vertebrobasilar ischemia after carotid endarterectomy [17, 18].

At present most stenoses of the vertebrobasilar system are not amenable to surgical endarterectomy, so detailed anatomic imaging is not imperative. The resolution must be sufficient to get a general assessment of the atheromatous disease of the basilar artery and to exclude a significant basilar stenosis. The three standard choices of therapy are: (1) no medication; (2) aspirin and Persantine; and (3) heparin and Coumadin. The type of therapy depends on the
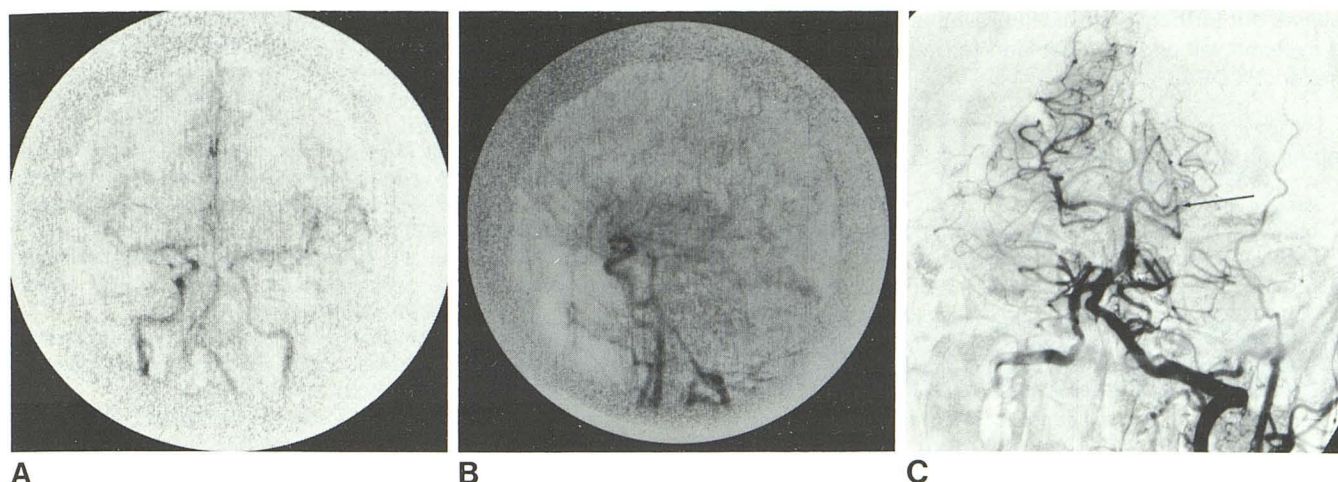
A   B   C

Fig. 4.—Posterior cerebral artery occlusion. AP (**A**) and lateral (**B**) views of basilar artery show no apparent abnormality. **C**, AP view of selective left vertebral arteriogram reveals occlusion of ambient segment of left posterior cerebral artery (*arrow*).

Fig. 5.—Probable basilar artery occlusion. **A**, Early lateral image demonstrates filling of top of basilar artery (*arrow*) before there is any filling of distal vertebral arteries. **B**, Later image. Basilar artery has tapered appearance at site of occlusion or critical stenosis (*arrow*). Vertebral arteries are faintly visualized (*arrowheads*). Selective arteriography was not done.

A   B
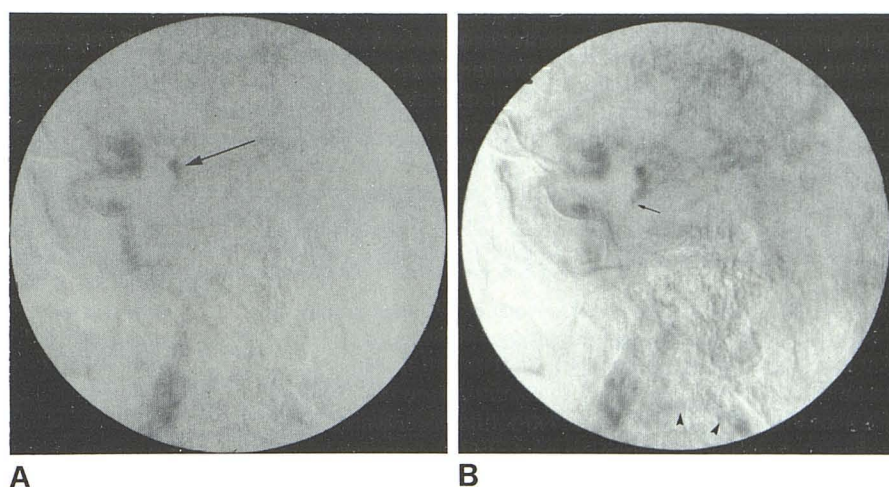
severity of disease. Our investigation disclosed that a number of factors, in addition to the angiographic evidence of vertebrobasilar disease, influence the choice of therapy, such as clinical symptoms and signs, CT findings, and any associated carotid disease. However, our results also show that the clinicians did use the information from DSA to help decide on appropriate therapy [19]. Only 19 of the patients had selective vertebral arteriograms after DSA. Four other patients had arteriograms sometime before DSA for other reasons.

Intravenous DSA has some advantages over selective vertebral arteriography. There is minimal risk of stroke, and the study can be done on an outpatient basis and while the patient is on anticoagulant therapy. The complication rate for selective cerebral angiography is 1.4%–2.6%, the risk being higher in patients with arteriosclerotic cerebral vascular disease [20–22]. Although a higher rate of complications was reported by Takahashi and Kawanami [21] for vertebral studies, Mani and Eisenberg [23] showed no statistically significant difference between carotid and vertebral arteriograms. Nevertheless, the attendant risk of stroke led Jones [24] to state that arteriography is not indicated unless symptoms continue while the patient is receiving anticoagulant therapy.

If one decides that intravenous DSA does not provide adequate detail of the vertebrobasilar system, arterial DSA is a less invasive alternative to conventional selective vertebral arteriography. This technique provides better images than the intravenous route. With a 5 French catheter in the arch, injection of 15–20 ml of Renografin-76 usually gives good opacification of the cerebral vessels, but still does not approach the resolution of conventional film arteriography. Selective catheterization in conjunction with DSA would require less radiographic contrast material than conventional arteriography. A 1 or 2 ml injection of Conray-60 (Mallinckrodt, St. Louis) would be sufficient in a vertebral artery. Further investigation is needed to determine the role of alternative techniques in the evaluation of vertebrobasilar

disease, but further technical improvements in digital imaging systems will undoubtedly lead to better resolution with intravenous DSA.

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