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# Aortic Arch Digital Arteriography: An Alternative Technique to Digital Venous Angiography and Routine Arteriography in the Evaluation of Cerebrovascular Insufficiency

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**Digital arch arteriography is a technique in which the cervicocerebral vasculature is studied by injecting small amounts of contrast material (20 ml or less of diatrizoate meglumine 60%) into the aortic arch. It was used as the initial phase of arteriography in 100 patients with cerebrovascular disease. Five to ten series were obtained in various projections to evaluate the cerebrovascular system. Because suboptimal studies may be repeated, only 3% of carotid bifurcations were suboptimally visualized by digital arch arteriography as compared with 17% by film arch angiography. Intracranial vascular pathology was identified less reliably than with selective angiography. Digital arch arteriography yielded excellent studies in cases when digital venous angiography was suboptimal (20%). Digital arch arteriography may be preferable to digital venous angiography as a screening test in patients with significant cardiac or renal dysfunction because of the lower contrast load.**

The advent of digital subtraction angiography (DSA) [1–3] has revolutionized the workup of patients with cerebrovascular disease. Many recent reports document its rapid development and acceptance as a technique for the intravenous, noninvasive evaluation of cervical [3–7] and intracranial [8, 9] vasculature. Digital systems may also be used in patients undergoing the arteriographic evaluation of cerebrovascular disease [14]. The major advantage of digital arch arteriography (DAA) is the small amount of contrast material needed to visualize the cervical and intracranial vessels. It is possible to safely obtain injections in various projections and avoid the pitfalls and complications related to both film arch angiography (FAA) and digital intravenous angiography (DIVA). We report our experience with an initial 100 patients.

## Materials and Methods

One hundred patients referred to Montefiore Medical Center for evaluation of cerebrovascular disease were included in this study. All procedures were performed on a CGR A-star angiographic unit coupled with a Xyram DAX-1 digital subtraction unit. The factors used in the study are listed in table 1. The catheters and contrast material used for DAA were specifically chosen to allow for rapid and simple changeover from aortic arch to selective angiography. Several popular selective catheters were used, including: (1) USCI 7 French "Headhunter 1," Simmons II & III; and (2) Cook 6.5 French "H1 H" and 5 French Newton HN4. The first 10 patients had both FAA and DAA, but, after evaluation of these cases, it was decided to eliminate the routine FAA; thus, in the other 90 cases only DAA was performed. Bilateral selective carotid angiography was performed in 71 patients, unilateral selective angiography of the symptomatic circulation in 22 patients, and no selective angiography was performed in seven patients. Selective subclavian digital arteriography was performed in four patients with vertebral basilar insufficiency. We also retrospectively reviewed 25 FAA (a total of 35 FAA studies were reviewed: 10 with FAA and DAA, 25 with FAA only) and 100 DIVA studies. Twenty-two of the patients had both DIVA and DAA and direct comparisons were made in these cases.

## Results

*Comparison of FAA and DAA*

The FAA images had greater spatial resolution than those obtained by DAA, however, this difference did not result in significant errors in interpretation on DAA. Evaluation of the aortic arch and its proximal branches yielded studies of equivalent quality (fig. 1). Because of the small, discrete bolus of contrast material used with DAA (table 1), rapid washout of the common carotid arteries often allowed for better visualization of the more slowly opacifying vertebral artery origins. In patients with evidence of vertebral basilar insufficiency, DSA was performed after injection of contrast material directly into the subclavian artery to ensure good visualization of the vertebral artery origins. Significant disease of the proximal common carotid arteries was identified in only two patients, one with Takayasu arteritis. In this patient with an occlusion of the proximal left common carotid artery the larger field size of FAA allowed for better appreciation of collateral pathways to the narrow but patent left internal carotid artery. The second patient had proximal atherosclerosis with multiple stenoses, and the multiple projections obtained with DAA were more helpful than the single projection of FAA in delineating the full extent of the disease. The DAA also functioned as a road map aiding in selective catheterization of the carotid arteries. In 25% of our patients, marked atherosclerotic tortuosity and/or anomalous vessel origins caused us to immediately choose catheters and/or catheterization strategies that

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TABLE 1: **Comparison of Film Arch, Digital Arch, and Digital Intravenous Angiography**

| | FAA ($n$ = 35) | DAA ($n$ = 100) | DIVA ($n$ = 100) |
|---|---|---|---|
| Catheter: | | | |
| Placement | Aortic arch (invasive) | Aortic arch (invasive) | Central or peripheral venous (noninvasive) |
| Type | 7 French multipurpose (multiple side holes) | 5–7 French selective cerebral (end-hole) | 5 French pigtail (multiple side holes) |
| Contrast agent: | | | |
| Type | Diatrizoate meglumine; diatrizoate sodium 76% | Diatrizoate meglumine 60% | Diatrizoate meglumine; diatrizoate sodium 76% |
| Volume/injection (ml) | 50–65 | 10–20 | 30–40 |
| Rate (ml/sec) | 25 | 6–8 | 12–18 |
| Average volume (ml) | 78 | 68 | 150 |
| Average iodine load (g) | 29 | 19 | 55 |
| Standard views: | | | |
| Aortic arch | RPO +/− LPO | RPO | RPO + LPO |
| Carotid bifurcation | " | RPO + LPO | RPO + LPO |
| Head | " | AP + lateral oblique | Lateral oblique ± AP |
| No. series: | | | |
| Average | 1.2 | 5.4 | 3.8 |
| Maximum | 3 | 8 | 5 |
| Sources of suboptimal study (%): | | | |
| Motion* | 3 | 2 | 8 |
| Poor cardiac output | 0 | 0 | 7 |
| Overlap vasculature structures | 17 | 4 | 5 |
| Total (%) | 20 | 6 | 20 |

Note.—FAA = film arch angiography; DAA = digital arch angiography; DIVA = digital intravenous angiography; RPO = right posterior oblique, LPO = left posterior oblique; AP = anteroposterior.

* Motion problems were caused by uncooperative patients in FAA and DAA studies; in the DIVA studies most motion problems were caused by swallowing, followed by respiration and uncooperative patients.

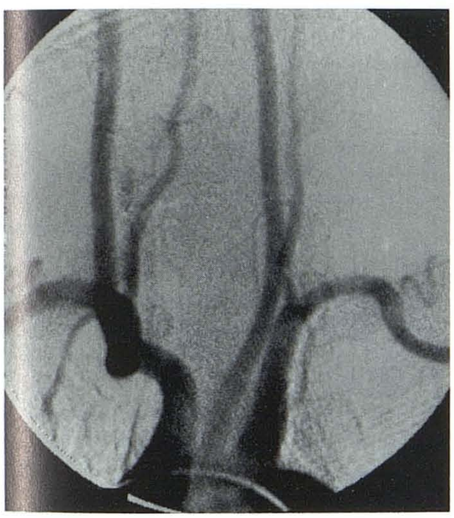


Fig. 1.—Right posterior oblique view of aortic arch and proximal branches performed with 16 ml of diatrizoate meglumine 60% injected at 8 ml/sec. Good opacification of proximal vasculature, including both common carotid arteries, subclavian arteries, and vertebral arteries.

were most likely to be successful, thus decreasing overall procedure time.

Evaluation of the carotid artery bifurcations (fig. 2) was more reliable with DAA than FAA, because of the multiple views obtained. Seventy carotid artery bifurcations (all 35 FAA cases) were evaluated with FAA, and 12 (17%) were partially obscured by overlap of the external carotid artery origin or the vertebral artery. With DAA, two or more views of the carotid artery bifurcations were routinely obtained and in only six (3%) of 200 were the bifurcations obscured. Six "surgically significant" lesions (50% stenosis and/or ulcerative plaque at the origin of the internal carotid artery) [11] were missed or deemed "nonsurgical" (stenosis of less than 50%) on FAA because of a failure to visualize a focal ulcerated plaque or noncircumferential stenosis when viewed en face in a single projection. All stenoses were accurately diagnosed by DAA. One small ulceration subsequently identified on selective angiography was missed due to overlap of the plaque by a small vertebral artery. A repeat DAA series in a slightly different projection would also have demonstrated this lesion.

Intracranial vessels were visualized with variable success (figs. 3 and 4) because of limitations of spatial resolution of the digital system [8, 9]. DAA revealed four of five stenoses of greater than 50% of the cavernous carotid artery. One patient had a 90% stenosis at the origin of the internal carotid artery and atherosclerotic irregularity of the rest of this vessel demonstrated by DAA. Selective angiography revealed a second tandem 80% stenosis of the tortuous cavernous segment. Intracerebral atherosclerosis was identified in several patients (fig. 4). However, three clinically significant intracranial lesions identified by selective angiography were not visualized by DAA. Two of these patients also had normal CT scans and thus we concluded (at least given current limitations of spatial resolution on digital systems) that those patients with clear-cut evidence of cerebrovascular insufficiency (e.g., transient ischemic attack) and a normal DAA should have selective angiography to exclude intracranial disease.

### *Comparison of DAA and DIVA*

Twenty-two patients of the 100 who had DAA studies also had DIVA studies. Given good cardiac output (with good intraarterial contrast concentration), a nonmoving patient, and no vascular overlap, DIVA and DAA series yielded similar results in evaluation of

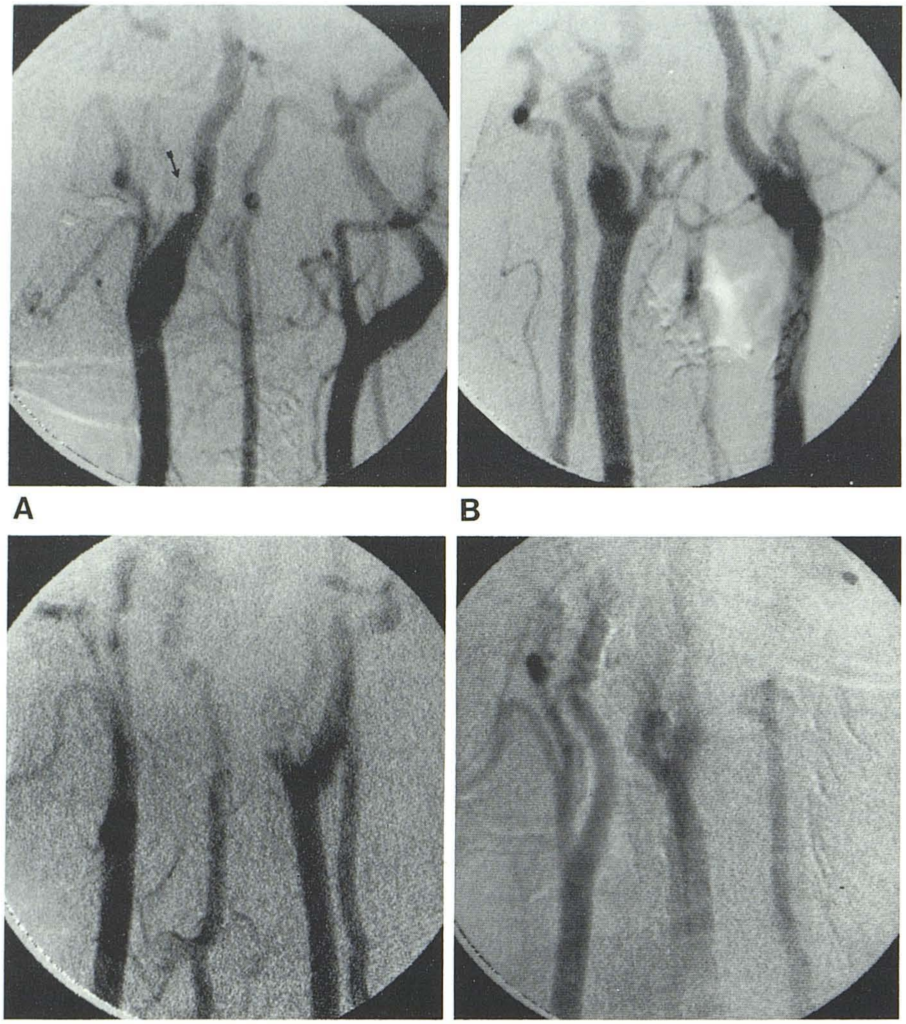
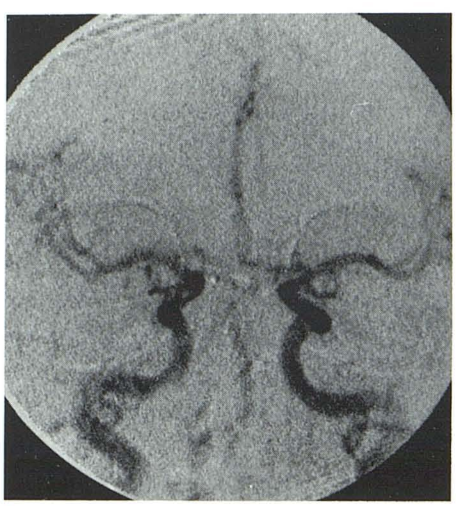



Fig. 2.—Right (**A**) and left (**B**) posterior oblique views demonstrate both carotid arteries well in two projections. "Filling" defect overlying right internal carotid artery in **A** (*arrow*) is subtraction artifact due to metallic tooth filling. **C**, Another patient. Good visualization of left internal carotid artery origin, but obscuration of right carotid bifurcation by external carotid artery. **D**, More steeply angled (70°) view. Better visualization of carotid artery bifurcation and proximal right internal carotid artery.



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4A 4B

Fig. 3.—Anteroposterior intracranial view. Good visualization of intracranial carotid arteries, ophthalmic arteries, and anterior and middle cerebral arteries. Lenticulostriate arteries not visualized due to limitations in spatial resolution.

Fig. 4.—Anteroposterior (**A**) and steep lateral oblique (**B**) views. Complete occlusion of left internal carotid artery. Good cross filling from right to left and distalmost part of left internal carotid artery is opacified (*large arrows*). Slight irregularity of right cavernous carotid artery and right middle cerebral artery stenosis (*small arrow*).

extracranial disease since both procedures use the same imaging-processing systems, and thus have the same spatial and density resolution. Intracranial vessels are better visualized by DAA due to improved maintenance of intraarterial contrast concentration at these distal sites when contrast is injected directly into the aorta.

Twelve patients underwent arteriography (DAA with or without selective angiography) because initial DIVA was suboptimal due to patient motion (five cases), poor cardiac output (three cases), or failure to completely visualize clinically suspicious regions due to vascular overlap (four cases). In all of these cases, DAA produced satisfactory studies. A review of all DIVA studies revealed that 20% were suboptimal as compared with 6% of DAA studies (table 1). Motion artifacts (due to involuntary swallowing and/or respiration) were the most common cause of suboptimal DIVA studies (8%), but motion rarely caused problems on DAA. The contrast material passes through and visualizes the carotid arteries before reaching the mouth and thus swallowing artifacts occur later and less often. With direct aortic contrast injection there is no lag time between injection and opacification of the carotid arteries and thus the patient need not suppress respiration for long periods. The lower dose of contrast material used with DAA produces less patient discomfort and this factor may also contribute to the patient's ability to remain motionless during this study [10]. Patients who move because they are uncooperative or demented are poor candidates for both procedures. Seven percent of DIVA studies were suboptimal due to poor cardiac output with prolongation of circulation time and dilution of the contrast bolus. In these cases DAA was performed without difficulty since cardiac output is less critical in maintaining a contrast bolus when contrast material is injected so close to the carotid arteries themselves. Severe reduction in cardiac output (two cases) was overcome by increasing the contrast volume and rate of injection. The third major source of suboptimal DIVA studies was overlap of vascular structures. Although this occurred with DAA as well, the larger doses of contrast material per injection with DIVA limited the number of series that could be performed (table 1). Thus, repeat examination of a specific area was often not possible at a single sitting. With DAA, suboptimal series from any cause (be it motion or vascular overlap) were easily repeated, since in no case was contrast dose the limiting factor in the number of DAA studies that were performed. In addition, with DAA the option of selective angiography was readily and easily available and, therefore, in our experience, an unsatisfactory angiogram (DAA with or without selective carotid arteriography) was rare (1%).

## Discussion

Digital fluoroscopic systems allow for excellent visualization of the cervicocerebral vasculature at much lower iodine concentrations than film-screen systems [1–3]. We specifically chose to perform DAA in a manner that would avoid the disadvantages and limitations of FAA while keeping the advantages of this technique in the evaluation of patients with cerebrovascular disease. Therefore, we performed the studies with the same catheters and contrast agents subsequently used for selective film-screen angiography. This eliminated time-consuming and often awkward changes of contrast agent and catheters when switching from DAA to selective cerebral angiography.

There has also been a concern (although undocumented as far as we know) that the large volumes of highly concentrated contrast material used for FAA might produce ischemia by flooding an already compromised cerebrovascular system. The low volumes and iodine concentrations of contrast agent used in DAA make this complication highly unlikely.

The advantages of performing arch angiography as a preliminary study were identified in our series. The preliminary view of the aortic arch and its proximal branches serves as a "road map" facilitating selective catheterization. Although it has been argued that this "road map" is not necessary for such catheterization [12], it is both intuitively obvious and empirically true that a clear knowledge of the arterial anatomy aids in catheterization, thus decreasing procedure time and increasing patient safety. In our series, 25% of the patients had abnormalities of the aortic arch that necessitated special catheterization strategies (e.g., "looping" of selective catheters) which could be done without time-consuming and futile efforts at catheterization by more standard techniques or with different catheters.

By evaluating the carotid and vertebral artery from the aortic arch it is possible to avoid "blindly" passing the catheter through areas of severe atherosclerotic involvement. Significant involvement of the proximal carotid artery is uncommon [12] (2% in our series), but in view of the excellent visualization possible with DAA even this small risk seems unwarranted, especially given the large number of patients studied for cerebrovascular disease.

The large volume of contrast material necessary to achieve good opacification of the cervicocerebral vasculature with FAA severely restricts the numbers of series that may be performed. When FAA is done as a prelude to selective angiography a right posterior oblique view is often obtained and it is rare for more than two series to be performed. Even when patient habitus permits use of biplane technique (38 of 70 cases in our series of FAA) the lateral oblique view (which is not equivalent to the opposite oblique view) often does not yield additional useful information. This accounts for the high rate of both: (1) suboptimal internal carotid artery origin visualization (17%) and (2) failure to visualize surgically significant lesions (8.5%) identified in our review of FAA. Because of the smaller volumes of contrast agent injected with DAA, contrast dosage is not a limiting factor, and thus multiple views of important areas such as the carotid bifurcation and intracranial regions are routinely obtained. With DAA complete visualization of the carotid artery may often be obtained without selective angiography. At this time selective studies remain valuable in specific cases, especially at the two extremes of the spectrum of cerebrovascular disease. When the carotid arteries are normal on DAA, selective studies are necessary to demonstrate changes in second and third order intracranial branches (improvements in spatial resolution of digital fluoroscopic systems should allow for better visualization of intracranial structures in the future). In patients with occluded carotid arteries (especially candidates for external carotid to internal carotid bypass) selective studies are necessary to: (1) identify the anatomy of the external carotid artery; (2) evaluate for the presence of distal reconstitution of the internal carotid artery; (3) identify those patients with a narrow but minimally patent internal carotid artery (the "string" sign) [13]; and (4) demonstrate the pattern of collateral filling of the affected intracranial circulation. Selective angiography may be avoided when a surgically significant lesion (50% or more stenosis and/or ulceration) is identified and the rest of the carotid artery is well visualized by DAA. It is precisely these patients with patent but severely atherosclerotic vessels who are most at risk for complication of selective angiography.

DAA may serve as a substitute for DIVA under certain circumstances, in particular, in patients with significant compromise of renal and/or cardiac function in whom the large volumes of contrast material necessary for DIVA may produce clinical deterioration. These patients may be more safely and completely studied with DAA where the lower doses of contrast agent allow for safer and more complete evaluation of these patients. DAA is also the procedure of choice for those patients known to have poor cardiac output.

When arteriography is performed after DIVA, the DAA study is tailored on the basis of the DIVA findings. Those areas adequately visualized by DIVA need not be restudied since no additional information will be gained. The DAA may either be omitted or used to evaluate areas not well seen on DIVA (in particular intracranial regions). On the basis of a combination of DIVA and DAA studies, plus clinical data, decisions on selective angiography may be made.

When DIVA studies are suboptimal due to motion, poor cardiac output, or overlap of vascular structures, DAA will routinely give better results and should be performed as the initial phase of the arteriographic workup of these patients. When DAA runs are suboptimal they may be easily repeated because of the small volumes of contrast agent involved. This ability to perform repeat examinations is a major advantage of DAA, allowing the radiologist to more completely and safely evaluate the cerebrovascular system. The option of immediate selective angiography gives the radiologist added flexibility once it has been ascertained that such catheterization is safe and likely to yield important clinical information.

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