Outpatient DSA in Cerebrovascular Disease Using Transbrachial Arch Injections

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Outpatient DSA in Cerebrovascular Disease Using Transbrachial Arch Injections

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Experience with intravenous digital subtraction angiography (DSA) has proven disappointing in the outpatient evaluation of cerebrovascular disease. Vessel superimposition, patient motion, and poor vascular opacification all prevent definitive studies in a significant percentage of patients. These problems were addressed by turning to an intraarterial outpatient DSA technique composed of several elements: (1) right transbrachial catheterization of the ascending aorta using a thin, multiple side-hole, straight catheter; (2) arch injections of relatively small volumes of contrast material; (3) pulsed digital image acquisition with multiple projections; and (4) a limited period of postprocedure observation. A total of 43 outpatients and 16 inpatients was studied in this manner with only two complications, both local. Images of definitive quality and completeness were obtained in 82%–98% of cases, and included the major intracranial as well as the extracranial vessels and their circulatory dynamics. Because the iodine load per injection was relatively low, up to 10 angiograms per case were available for delineating superimposed anatomy and motion degradation. Variations in cardiac output had little impact on image quality, and the average case required less than 60% of the contrast load routinely used for intravenous DSA. The transbrachial approach proved as safe and convenient as intravenous DSA but was more thorough and dependable.

A medicoeconomic climate that favors aggressive surgical therapy of atherosclerotic cerebrovascular disease but discourages hospital admission for diagnostic procedures fostered the widespread use of intravenous digital subtraction arteriography (DSA), which was initially fueled by the favorable reports of early experience from several large centers [1–7]. More recent reports, however, reflect growing frustration with the inadequacies of intravenous DSA in *definitive* preoperative evaluation of atherosclerotic cerebrovascular disease [8–10]. Our own experience suggests that intravenous DSA is unreliable in an unacceptably large number of cases because of recurring problems of vessel superimposition, patient motion, and poor vascular opacification (usually related to poor cardiac output). The large iodine load required per run amplifies the deficiencies and makes intravenous DSA more operator-dependent than is generally appreciated [11].

We attempted to address these problems by adopting a previously unreported outpatient intraarterial DSA technique using arch injections of relatively small amounts of iodine via a 4-French catheter placed in the right brachial artery. A description of this technique, hereafter referred to as arch/brachial DSA, and our experience with it in our first 59 patients are the subjects of this report.

Subjects and Methods

From December 1983 through June 1984, 59 patients underwent arch/brachial DSA examinations. Of these, 43 were outpatients and 16 were inpatients. None of the inpatients were admitted specifically for arch/brachial DSA; in fact, most were studied just before discharge for cerebrovascular problems discovered during admission. Specifically, study indications ranged from asymptomatic bruits to histories of completed infarction. Nonspecific

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indications such as syncope and dizziness were less common. There were 24 men and 35 women aged 29–84 years (average, 65). No patients were excluded from this initial group.

The same protocol was used in all patients, whether in- or outpatient. With the patient's right arm extended on an arm board, the antecubital fossa was aseptically cleaned and draped. The puncture site chosen was the most superficial palpable point along the brachial artery segment lying in the antecubital fossa. Intradermal injection of 1% Xylocaine provided adequate anesthesia in all cases. (Deeper injection, especially ulnar to the artery, risks median nerve blockade thereby confusing postprocedure neurovascular evaluation.) Seldinger technique permitted placement of a 4 French multiple side-hole, straight, nylon catheter (Mallinckrodt, St. Louis) over a guide wire into the ascending aorta without difficulty in most cases. Catheter and wire tips were monitored fluoroscopically, particularly as they passed the right vertebral and carotid origins.

A tight J-wire (tip curvature radius 3 mm or less) with a 15 cm tapered core worked well in almost all cases and was preferred for its reduced potential for intimal damage in small vessels. Puncture of the brachial artery was generally performed with an 18 gauge intravenous infusion cannula (Jelco, Critikon Corp., Tampa, Fl) 3.8–5.1 cm long. The sheathed intravenous cannula had the advantage of providing its own introducer and dilator, thus obviating a skin incision over the brachial artery, which can be difficult to perform safely when that vessel lies very superficially, as it often does. Since not all brands of 18 gauge intravenous cannulas will pass a 0.035 inch (0.089 cm) wire guide smoothly, the resistance to wire passage should be checked before puncture.

Injection parameters differed slightly at the two institutions involved in the study, but without discernible difference in image quality. Table 1 details contrast concentrations, rates, and volumes for each institution and compares them with those previously used for intravenous DSA at the University of California, San Francisco (UCSF). At both centers, iodine load per angiogram for arch/brachial DSA was roughly one-third that required for intravenous DSA, making possible over 10 runs per case without exceeding the contrast load limits previously set for intravenous DSA.

Pulsed-mode digital image acquisition over the carotid bifurcations was performed in multiple projections until both bifurcations had been seen well on at least two views. Most patients also had head or arch studies as indicated by the clinical situation and the state of the bifurcations. The average number of injections and iodine load per case appear in table 1. All studies were performed on commercially available DSA units from Philips (DVI II, Methodist Hospital) and Picker-ADAC (UCSF), using a 512 × 512 matrix, standard video chain, and image intensifier modes of 4.5–14 inches (11.4–35.6 cm).

Procedure time averaged 50 min. Four hours of observation in a special holding area (outpatients) or on the ward (inpatients) followed each procedure and included neurovascular checks at appropriate intervals. An arm board immbolized the right elbow in a slightly bent position throughout this period, but the patients were free to move or sit in a chair during observation. The radiologist performing the procedure examined each patient for neurovascular complications at the end of the observation period.

TABLE 1: **Comparison of Injection Parameters Used in Arch/Brachial and Intravenous Digital Subtraction Angiography**

	Institution		
	Methodist	UCSF	UCSF
Injection method	Arch/brachial	Arch/brachial	Intravenous
Contrast material	Renografin 60	Hypaque 45	Conray 400
Volume/run (ml)	18*	30	40
Rate (ml/sec)	8–12	15–20	25
Iodine load/run (g)	5.2*	6.3	16
No. of runs/case	5.3*	6.1*	4*
Iodine load/case (g)	27.5*	35.3*	64*

Note.—UCSF = University of California, San Francisco.
* Average.

TABLE 2: **Results of Arch/Brachial Digital Subtraction Angiography in 59 Patients**

Imaging Objective	No. of Patients		Primary Causes of Failure
	Attempted	Successful (%)	
Both bifurcations (two views)	58	93 (54)	Superimposition, swallowing
Both siphons	57	82 (47)	Superimposition
Both vertebral origins	57	84 (48)	Superimposition
Both A1 and M1 segments	49	86 (42)	Superimposition
Brachial catheterization	59	98 (58)	Brachial spasm

Results

The results of our first 59 arch/brachial DSA examinations are shown in table 2. Arch/brachial DSA produced a definitive examination of the carotid bifurcations in 92% of all referrals. For the purpose of this tabulation, a study was considered successful if the clinically important parts of the vessels listed in table 2 were well opacified without obscuration by vessel overlap or by motion or bone artifact. For the carotid arteries, we also required that the proximal segments of both internal and external branches meet these criteria separately in at least two projections.

Definitive demonstrations of both carotid siphons, both vertebral origins, and the proximal parts of both anterior and middle cerebral arteries were obtained in 82%, 84%, and 86% of patients, respectively, when attempted. Here, we tabulated a success if the segment was seen in one good view. Most failures were caused by vessel superimposition. Swallowing artifacts produced relatively few failures.

Vascular opacification was good to excellent in all patients. Variations in cardiac output, as judged subjectively by evaluation of flow dynamics on fluoroscopic test injections in the arch and actual aortograms, had no discernible effect on image quality.

Only one catheterization failure occurred. The patient developed brachial artery spasm immediately upon puncture, and the wire guide could not be passed into the vessel despite a clear intraluminal needle position confirmed by contrast injection. The procedure was therefore terminated. The spasm produced no untoward neurovascular effects and resolved spontaneously.

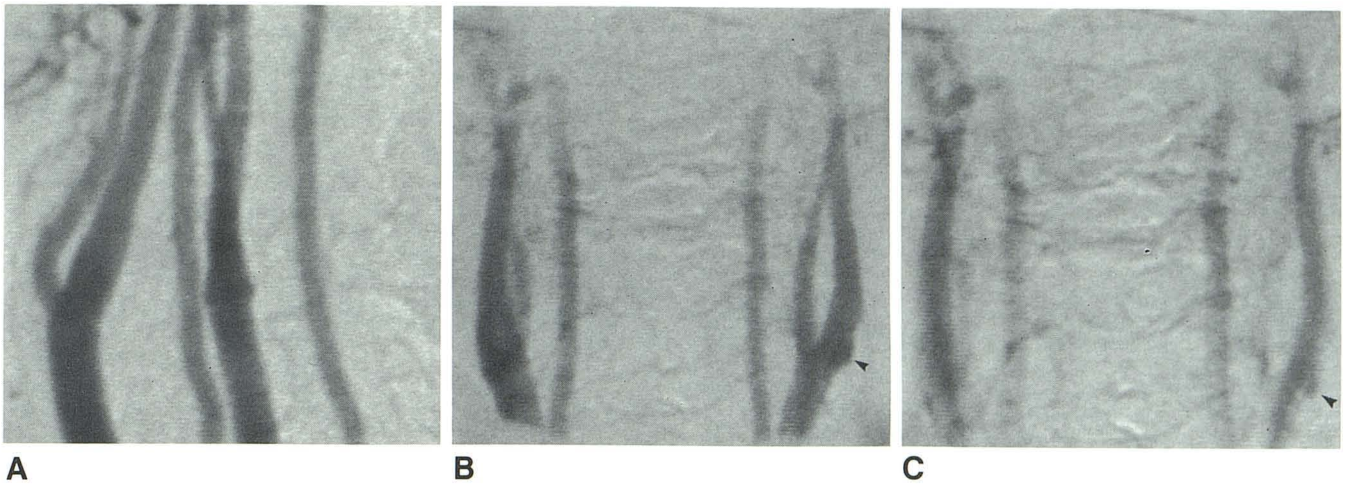

Fig. 1.—61-year-old woman with left amaurosis fugax. **A**, Left anterior oblique (LAO) view. Right common carotid bifurcation with superimposition of origins of left internal carotid and left external carotid arteries, which here appear normal. Right anterior oblique (RAO) view (not shown) also failed to demonstrate left bifurcation. **B**, Anteroposterior (AP) view, early arterial phase. Ulceration of left internal carotid origin (*arrowhead*). **C**, Later frame. Delayed washout of ulcer (*arrowhead*).

Only two complications (3.4%), both local in nature, developed in the 59 cases. The more serious of these consisted of transient loss of the radial and ulnar pulses accompanied by ischemic pain of the right hand. Neurovascular function returned to normal in this patient after an 8 hr course of intravenous heparin without other intervention. The other complication occurred in a patient who complained of fingertip numbness in a nonanatomic distribution after the procedure. These symptoms were unaccompanied by any objective evidence of neurovascular compromise and resolved completely within 48 hr. No permanent injuries occurred as a result of brachial puncture in our series; nor were there any neurologic complications referable to the central nervous system. No patient in our series developed a complication after release from observation. No reactions to contrast material were encountered.

Discussion

Ideally, any arteriographic method suitable for the evaluation of patients with clinically suspected atherosclerotic cerebrovascular disease should deliver complete, definitive studies reliably. Clear depiction of both carotid bifurcations, free of obscuring superimposed densities in at least two projections, is a reasonable goal. The inadequacy of a single projection of the bifurcations is well illustrated by the experience of Hoffman et al. [8], who found that of 126 bifurcations clearly seen on two or more views, a full 15% appeared normal on one view and clearly abnormal on another. Figure 1 illustrates this point in our series.

To be definitive, an examination should also evaluate sites of possible tandem lesions that affect surgical planning [12, 13]. With the advent of external-to-internal carotid bypass procedures, information regarding the intracranial collateral circulation and the state of the vertebrobasilar system may also be required in some cases.

TABLE 3: **Reliability of Intravenous Digital Subtraction Angiography in Imaging Carotid Bifurcations**

[Ref. No], No. of Cases	Average Iodine Load/Patient (g)	% of Patients with Diagnostic Images of Both Bifurcations
[4], 98	37	60
[5], 100	50+*†	90‡
[6], 105	60*†	96‡
[7], 500	50*	97‡
[8], 130	60+*†	26

* Estimated from authors' data.
† Includes attempts to image intracranial vessels or arch.
‡ Criteria for diagnostic quality not specified.

Intravenous DSA unfortunately cannot reliably meet these goals in an acceptable percentage of the referral population, especially in the presurgical groups of patients [10]. Table 3 shows percentages of patients receiving "diagnostic" examinations of the carotid bifurcations in five of the larger intravenous DSA series published to date [4–8]. Our own experience with intravenous DSA is similar to that of Chilcote et al. [4]. Only the reports of Hoffman et al. [8] and Chilcote et al. [4] explicitly stated the criteria for a diagnostic evaluation, which were equivalent to those used in our series. Given such well defined criteria, these authors performed diagnostic examinations of the bifurcations in only 26% and 60% of their patients, respectively. In contrast, with arch/brachial DSA we performed diagnostic studies in 92% of our patients. Although the other intravenous DSA series listed reported success rates with the bifurcation as good as or better than ours with arch/brachial DSA, the criteria for diagnostic quality were not specified.

In the series cited in table 3, vessel superimposition caused most inadequate studies, followed next by motion-related artifacts, which usually arose from the larynx. These problems proved especially damaging to intravenous DSA because

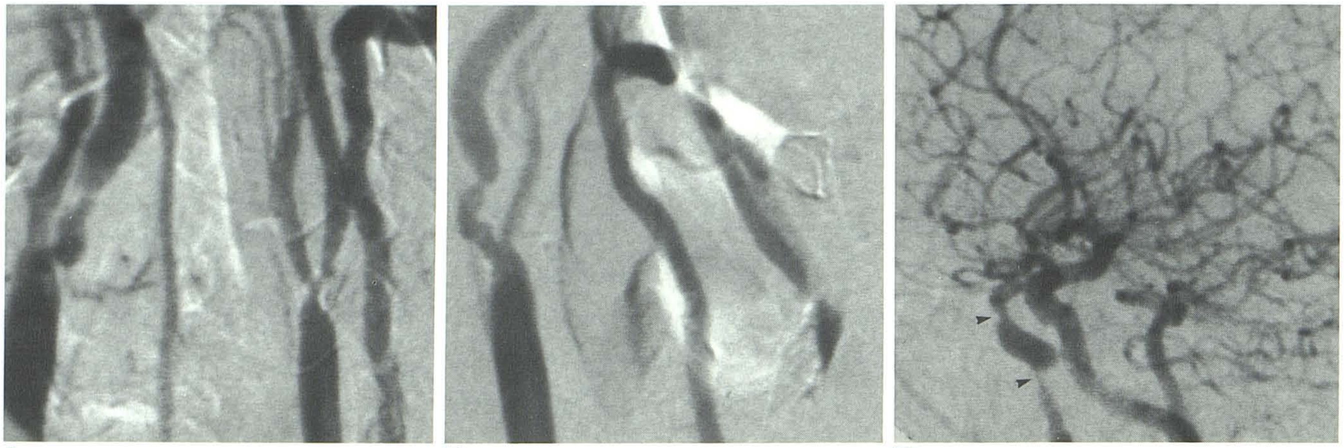

Fig. 2.—73-year-old woman with syncope and bilateral neck bruits. **A**, LAO view. Tight stenosis of terminal left common carotid and bifurcation secondary to calcified plaque. Proximal right internal carotid lesion is visible but not well seen. **B**, RAO projection. Right internal carotid lesion is as tight as left. **C**, Steep RAO view of carotid siphons. Excellent intracranial vascular detail. Serial high-grade left carotid siphon stenoses (*arrowheads*) directed surgical attention from left to right internal carotid lesion.

contrast load limitations allowed only a limited number of injections (four to five in all series) per case. Nonselective intraarterial techniques, on the other hand, can provide more injections because of their much-reduced iodine load per angiogram. Zimmerman et al. [14] reported their favorable experience with cerebrovascular DSA by arch injection using a transfemoral approach. The improved bolus characteristics afforded by arch injection [10, 15] produced significantly better vascular opacification, particularly intracranially, and did so with only a third the iodine per injection required for intravenous DSA. Moreover, these authors found that variations with cardiac output had little inpact on their images, which were also less degraded by motion artifacts.

We adapted the arch DSA technique to outpatient use simply by changing the puncture site from the groin to the right antecubital fossa. By this route, the ascending arch is as easy to catheterize as the superior vena cava is transvenously. Furthermore, patients can more easily monitor arm than groin puncture and can walk and sit without encumbrance immediately after the procedure.

The importance of the additional number of injections per case made available by arch/brachial DSA cannot be overemphasized. Due to the vagaries of patient cooperation and unexpected bifurcation positions and orientations, obtaining a diagnostic set of basic bifurcation images often consumes four or more injections alone. Bringing specific lesions into profile may require multiple projections, particularly when these are posteriorly situated, as is often the case [9, 16]. Head and arch views may provide critical information for surgical planning, especially when the bifurcation findings do not entirely explain the clinical presentation. Moreover, evaluation of the vertebrobasilar system, which often requires views (such as a true lateral head) not routinely used in carotid imaging [17], can also be incorporated into the examination when indicated. Finally, the nonselective nature of arch/brachial DSA, combined with the superior demonstration of intracranial vasculature, provides information on intracranial circulatory dynamics not easily obtained from selective studies [18–20]. We routinely include a frontal head view, for example, when surgical carotid lesions at any level are discovered, to better define the collateral pathways of cerebral perfusion. The cases shown in figures 2–5 illustrate some of the points discussed.

Having the option of more projections is irrelevant if the option is not exercised. Almost all of the nondiagnostic cases in our series could have been salvaged by doing more injections in different projections without exceeding contrast limit. The need to break out of the "IV [intravenous] mentality" of limiting the number of injections is the most important lesson we have learned with arch/brachial DSA.

The absence of serious complications in our series testifies to the safety of our brachial approach. We puncture the brachial artery at its most superficial point in the proximal antecubital fossa, where it overlies only brachial muscle and the distal humeral condyle. These latter structures provide a firm base for compression of the arteriotomy after catheter removal. The median nerve lies close by on the ulnar side but is avoidable. Several large and fairly constant collaterals span the puncture site and afford protection against distal ischemia [21]. The use of a tight J-wire, a small (4 French) catheter diameter, fluoroscopic guidance, and the avoidance of catheter manipulations other than for initial placement and withdrawal all serve to minimize vascular trauma. Our local complication rate of 3.4% is on the order of those reported elsewhere for comparable percutaneous brachial catheterization procedures. Field et al. [22] reported a total local complication rate of 1.7% in a series of 1000 patients undergoing craniocervical arteriography via a total of 1202 brachial catheterizations, of which about 90% were percutaneous. Of their patients with local complications, only two

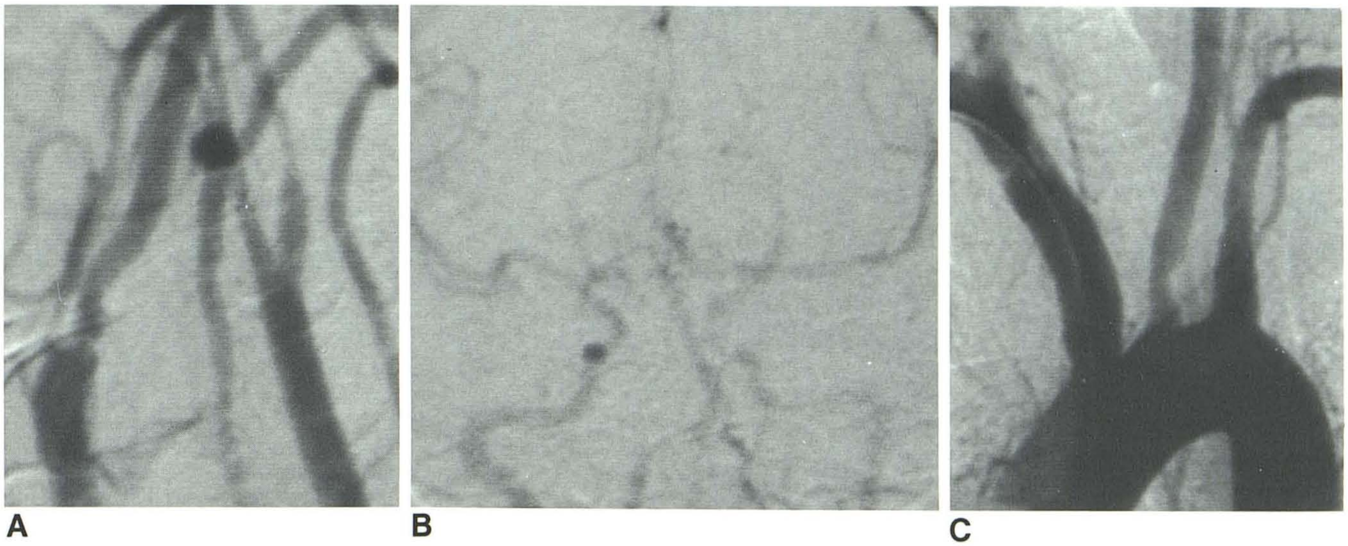

Fig. 3.—58-year-old man, severe diabetic with bilateral carotid bruits and history of multiply revised aortofemoral bypass grafts. **A**, Moderate stenoses affect proximal internal carotids bilaterally. **B**, Asymmetry of hemispheric perfusion suggested on this early arterial phase frontal head view (improved opacification was seen on later frame). **C**, LAO arch view. Stenotic left common carotid origin. Arch/brachial DSA spared this patient the risks of puncture of tenuous grafts and selective catheterization of diseased common carotid origin.

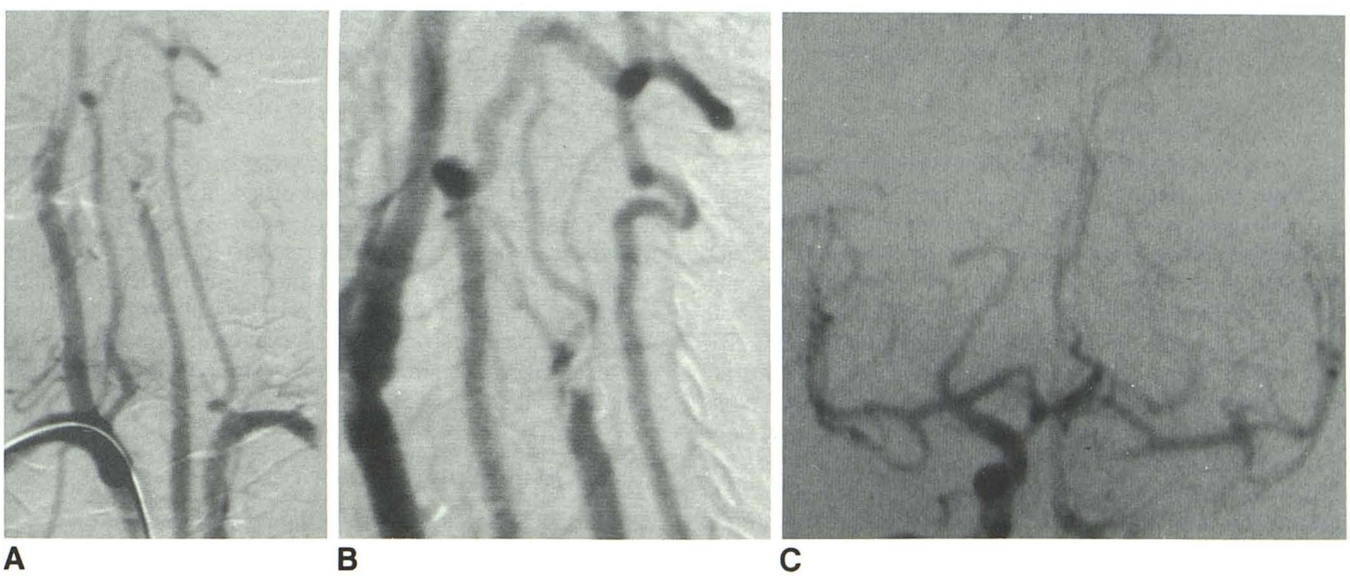

Fig. 4.—62-year-old woman with left amaurosis fugax. **A**, Complete left internal carotid occlusion. Both vertebral arteries are widely patent throughout their extracranial course. Calcific plaque narrows right common carotid bifurcation. **B**, Detail of **A**. Only left external carotid branches continue distal to bifurcation, which contains calcified plaque. **C**, Immediate cross-filling of left hemispheric circulation via anterior communicating artery makes bypass procedure unnecessary. Reflux into terminal left internal carotid artery stump. Proximal anterior and middle cerebral artery segments are seen with clarity routine for arch/brachial DSA.

(0.2%) had significant injuries, both of which required surgery; one had a permanent loss of radial pulse and the other developed a pseudoaneurysm at the puncture site. All of their cases used 18 gauge needles and 5 French catheters that reached to either the midbrachial or proximal subclavian regions. Their procedure was thus similar to ours in the potential for brachial trauma. Central neurologic deficits, either transient or permanent, occurred in 1.9% of their cases, as compared with the 2.6% rate most recently reported by Earnest et al. [23] using 5 French selective, largely transfemoral techniques in 1517 cerebral arteriograms.

The safety of brachial artery puncture is also attested to by the 1.3% local complication rate reported by Fergusson and Kamada [24], who used a 7 French "extra-stiff" Sones cath-

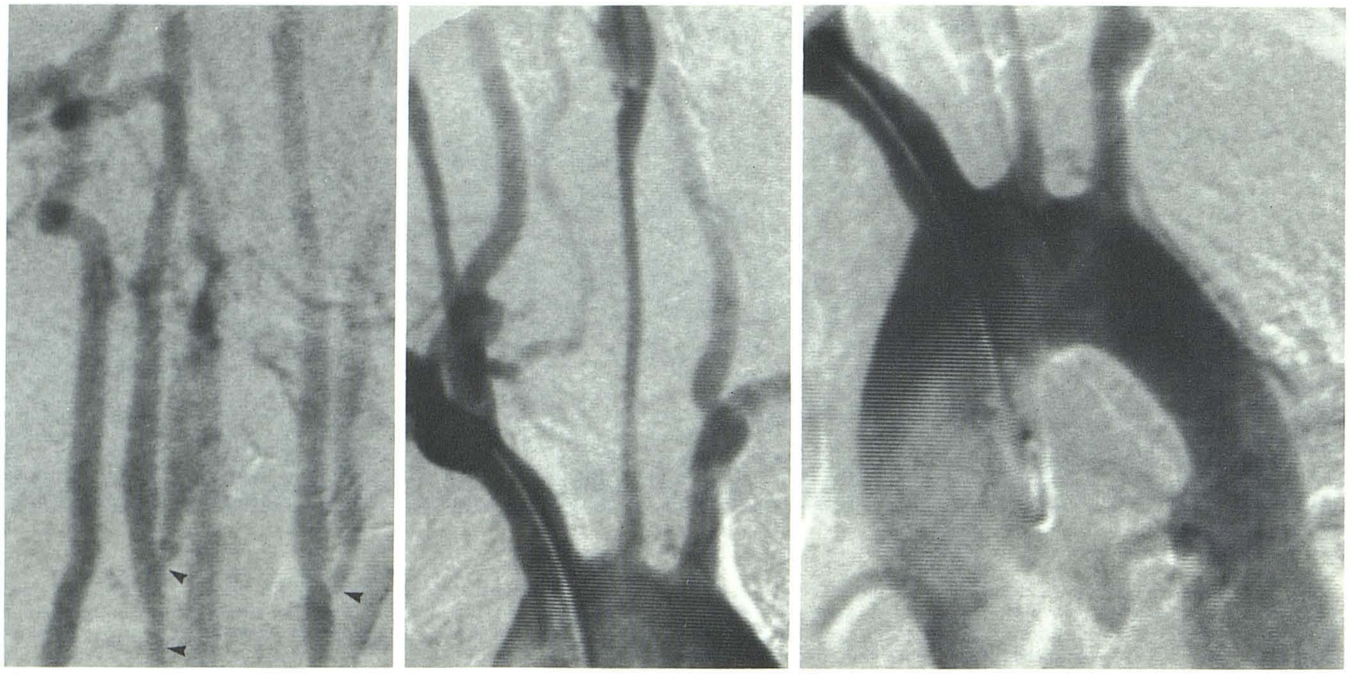

Fig. 5.—29-year-old woman with months of dizziness. **A**, Bizarre bilateral common and internal carotid narrowings (*arrowheads*). Poor carotid opacification suggested need to look proximally. **B**, LAO arch view with standard centering shows process to extend to carotid origins. Dilated vertebral and right ascending cervical arteries. Right internal mammary (not shown here) was also dilated, suggesting arch stenosis as well. **C**, Second arch run with lower centering shows narrowing of proximal descending aorta, helping to confirm ultimate diagnosis of Takayasu arteritis.

eter via a percutaneously placed coaxial sheath to perform left heart catheterizations in 223 patients. Three patients had transient radial pulse losses; two of them required surgery.

Transient distal pulse losses, with or without associated evidence of ischemia, is by far the most common local complication of percutaneous brachial arteriotomy, whether with needle or catheter, for angiographic purposes [22–26]. The most common mechanism is probably spasm [27], but transient thrombosis and dissection probably occur in some cases. Signs of vascular insufficiency, including pallor, coolness, paresthesias, ischemic pain, poor capillary filling, and claudication, will generally appear in the first 4–8 hr after catheter removal [22]. Failure of the distal pulses to return to normal after an appropriate period of time (4–8 hr) is an indication for surgical exploration in most centers [22]. In some cases a trial of thrombolytic agents or intravenous heparin (as in one of our cases) might be considered before exploration.

Other reported local complications of percutaneous brachial catheterizations are uncommon or rare and include distal embolization, dissection, false aneurysm formation, immediate or delayed hematoma formation, and distal transient sensory changes variably referable to the median nerve or to ischemia [22–26]. Delayed hematomas have been reported only in anticoagulated patients [22]; this group might therefore warrant special postprocedure observation. Careful monitoring of the puncture site and distal neurovascular function is essential during and after the procedure.

In conclusion, we believe that arch/brachial DSA is a safe, simple, well tolerated outpatient procedure that can reliably yield cerebrovascular studies of *definitive* quality and completeness in nearly all patients referred for the examination. Its low iodine load per run and superior intracranial vascular imaging give arch/brachial DSA the flexibility to evaluate the carotid bifurcations, sites of possible tandem lesions, the vertebrobasilar system, and intracranial circulatory dynamics, all in one sitting.

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