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Franklin Earnest IV[1]
Glenn Forbes[1]
Burton A. Sandok[2]
David G. Piepgras[3]
Ronald J. Faust[4]
Duane M. Ilstrup[5]
LaDonna J. Arndt[1]

A prospective study of 1,517 consecutive cerebral angiographic examinations is reported. The incidence of all complications was 8.5%, and the incidence of all neurologic complications was 2.6%. The overall incidence of permanent neurologic deficit was 0.33%. The incidence of permanent neurologic deficit in patients referred for evaluation of symptomatic cerebrovascular disease was 0.63%. Older age, increased serum creatinine concentration, and the use of more than one catheter all were significantly associated with serious neurologic complications. Although patients with a recent stroke or frequent transient ischemic attacks had a higher incidence of serious neurologic complications, this increase was not statistically significant for this sample.

We report a prospective study of complications occurring in 1,517 consecutive cerebral angiographic examinations. This study was initiated to provide more insight into the assessment of risk for an individual patient. Although previous studies reported the occurrence of complications in patients undergoing angiography [1–10], we believe that the following conditions are necessary for accurate statistical analysis: (1) prospective, rather than retrospective, accumulation of data; (2) neurologic assessment before and after angiography; and (3) the inclusion of all complications, particularly all neurologic events, that occur during or 24 hr after the procedure.

Materials and Methods

We evaluated 1,517 consecutive procedures accumulated in the first 16 months of the study, which began December 1, 1980. All patients needing cerebral angiography for evaluation of intracranial abnormalities and cerebrovascular disease were referred to the section of neuroradiology. More than 95% of these patients were referred from the neurologic and neurosurgical services, and all patients undergoing cerebral angiography had a neurologic evaluation performed by either of these services before cerebral angiographic examination.

Patients usually had nothing by mouth on the day of angiography and received mild sedation intramuscularly before coming to the angiographic suite. All patients were monitored during the procedure by a nurse anesthetist or anesthesia technician, and an anesthesia record was maintained. The pulse, blood pressure, electrocardiogram, and neurologic condition of the patient were constantly monitored and were recorded at 5 min intervals. The nurse anesthetist or anesthesia technician was closely supervised by a neuroanesthesiologist.

All patients had an intravenous line inserted in the angiographic suite, and diazepam and fentanyl were given through it to supplement the sedative previously administered intramuscularly. Patients receiving medication intravenously, elderly patients, and diabetics had continuous fluid supplementation intravenously before arriving at the angiography area. The total volume of fluid administered ranged from 500 ml to 1.5 L, depending on the length of the procedure (mean procedure time, 46 min) and the volume of contrast medium administered (mean volume, 77.6 ml).

The angiographic examinations were performed by a staff neuroradiologist or under his

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[1] Department of Diagnostic Radiology, Mayo Clinic and Mayo Foundation, Rochester, MN 55905. Address reprint requests to F. Earnest IV.

[2] Department of Neurology, Mayo Clinic and Mayo Foundation, Rochester, MN 55905.

[3] Department of Neurologic Surgery, Mayo Clinic and Mayo Foundation, Rochester, MN 55905.

[4] Department of Anesthesiology, Mayo Clinic and Mayo Foundation, Rochester, MN 55905.

[5] Section of Medical Research Statistics, Mayo Clinic and Mayo Foundation, Rochester, MN 55905.

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direct supervision and with his assistance. The group of neuroradiologists used similar angiographic techniques with standard catheters, needles, and guide wires. A transfemoral catheterization was done in 1,453 procedures. Thirty-six direct carotid angiograms and 69 retrograde brachial angiograms were obtained, and two axillary catheterization procedures were performed. Twenty-six aortic arch studies were performed to supplement selective catheterization of the carotid or vertebral artery or to demonstrate proximal lesions of the brachiocephalic vessels. Seventeen spinal angiographic procedures performed during this study were not included in this data analysis of cerebral angiography. Thus, 1,560 procedures were done in 1,517 angiographic examinations in 1,387 patients. In most transfemoral procedures, a 5 French, 45° hockey-stick-shaped, 100 cm catheter was used first, and 66% of the studies were completed without catheter exchange. In the other 34%, a second catheter, often a larger one with a Simmons curve, was used to complete the study. Arch aortography was performed with a 6 or 7 French pigtail catheter. A Viamonte-Hobbs power injector was used for transfemoral and brachial injections.

End-hole catheters were connected to a continuous flushing system (C.F.S. Intraflow, Sorenson Research Co., Salt Lake City, UT) that used heparinized saline solution. A pressure transducer was connected in line to record arterial pressure. Multiholed catheters were manually flushed with heparinized saline solution at frequent intervals for arch aortography.

After completion of the angiographic procedure, the patients were moved to an adjacent room. The catheter was removed, and pressure was applied at the puncture site until hemostasis was achieved; a pressure dressing usually was applied. The patients were taken directly to the surgical recovery area, where they were again closely monitored for 30–60 min. If a high-grade internal carotid stenosis with slow flow was identified on the angiographic examination, anticoagulant therapy was intravenously administered in the surgical recovery area by means of a constant heparin infusion. After evaluation by a neuroanesthesiologist, the patients were dismissed to their room if no complications were evident.

A postangiographic neurologic evaluation was made by the hospital service for evidence of any angiographic complication. The next morning, the patient was evaluated by the attending hospital service and a member of the angiographic team to assess the presence of a complication. They interviewed the patient for subjective changes regardless of type or duration, and they looked for objective change in the neurologic examination, physicians' notes, nursing notes, and anesthesia record. They also examined the puncture site and the peripheral pulses.

Data Collection

A data sheet was filled out during the examination and was completed at the 24 hr evaluation unless a complication was identified. The information obtained to complete the data sheet is shown in table 1.

Neurologic complications were grouped according to type (hemiparesis, blindness, aphasia, ataxia, or other) and duration (transient, reversible, or permanent). Neurologic complications that completely resolved within 24 hr of onset were classified as transient, while those that persisted longer than 24 hr but resolved within 7 days were classified as reversible. Any neurologic complication with an onset of 24 hr after cerebral angiography that had not resolved after 7 days was considered a permanent complication for the purpose of this study.

In all instances, a change in the patient's neurologic status, either subjective or objective, of any type or duration was recorded as a complication. If there was a disparity in the evaluation of the patient's condition by different observers, the least favorable observation was recorded. If the patient had a transient neurologic event typical of preangiographic transient ischemic attacks, the event was recorded as a complication to prevent subjective judgments and inconsistent data bias. If the patient had a neurovascular or neurosurgical procedure performed on the day of angiography, any persistent neurologic deficit occurring before the operation was considered a permanent neurologic complication.

TABLE 1: **Information Obtained to Complete Cerebral Angiography Data Sheet**

Patient identification
Age, gender
Indication:
Cerebrovascular disease
Tumor
Subarachnoid hemorrhage, aneurysm
Arteriovenous malformation
Seizure
Other
Risk factors:
Diabetes
Hypertension (>160 mm Hg systolic)
Stroke (<30 days)
Frequent transient ischemic attacks (>1/day)
Creatinine >1.2 mg/dl
Neurovascular laboratory evaluation (oculopneumoplethysmography, bidirectional Doppler)
Staff neuroradiologist
Approach:
Retrograde femoral
Direct carotid
Retrograde brachial
Axillary
Catheters—one or more than one
Procedure time
Vessels studied:
Right or left carotid
Right or left vertebral
Aortic arch
Spinal
Contrast medium:
Type
Volume
Angiographic code
Date of follow-up
Complications:
Local:
Hematoma (regardless of size or excessive tenderness at the puncture site)
Thrombosis
Infection
Other (including iatrogenic dissection, perforation, and so forth)
Systemic or allergic:
Nausea, vomiting, transient hypotension
Urticaria, rhinorrhea
Chest pain, arrhythmia
Anaphylaxis, circulatory collapse
Acute renal failure
Death
Neurologic—transient (<24 hr); reversible (>24 hr, <7 days); permanent (>7 days):
Hemiparesis
Blindness
Aphasia
Ataxia
Other

Statistical Methods

The association between the risk factors and the incidence of complications was investigated with univariate methods: (1) two sample Student *t* tests [11] for associations of continuous variables, such as age and procedure time, with complications and (2) either chi-square tests [11] or Fisher exact tests [11] for associations of discrete variables, such as gender or previous transient ischemic attacks, with complications. The frequency of complications in the present sample was too low to warrant further multivariate analysis, such as Grizzle-Starmer-Koch log linear categorical analyses [12] or linear discriminant analyses [13] for continuous variables. These methods will be used in future publications when the frequency of complications is sufficient to enable their use.

Results

We reviewed a total of 1,560 procedures performed during 1,517 angiographic examinations in 1,387 patients. The complications encountered in these angiographic examinations are summarized in table 2.

A profile of the patients in whom the 1,517 angiographic examinations reported in this study were performed is recorded by indication in table 3. Patients with cerebrovascular disease as an indication were older than the others and predominantly male, and almost two-thirds had one or more risk factors (table 4).

TABLE 2: **Complications Encountered in 1,517 Cerebral Angiographic Examinations**

Complications	No. (%)
Local:	
Hematoma	66 (4.4)
All other	8 (0.5)
Total	74 (4.9)
Systemic	28 (1.9)
Neurologic:	
Transient (<24 hr)	33 (2.2)
Reversible (>24 hr; <7 days)	2 (0.1)
Permanent (>7 days)	5 (0.3)
Total	40 (2.6)

TABLE 3: **Group Profile by Indication for Cerebral Angiography**

Indication	No. of Examinations (%)	Mean Age (years)	Gender (M/F)	% with Risk Factors*
Cerebrovascular disease	637 (42)	61	410/227	64
Tumor	414 (27)	47	210/204	28
Subarachnoid hemorrhage	158 (10)	52	61/97	38
Arteriovenous malformation	63 (4)	37	40/23	14
Seizure	38 (3)	31	17/21	11
Other	207 (14)	49	115/92	39
Total	1,517 (100)		853/664	45

* Represents percentage of patients having one or more potential risk factors for angiographic complication as specified in table 1.

TABLE 4: **Positive Risk Factors by Indication for Cerebral Angiography**

Indication	Risk Factor (%)				
	Diabetes	Hypertension (systole >160 mm Hg)	Stroke (<30 days)	Frequent TIAs	Creatinine >1.2 mg/dl
Cerebrovascular disease	15	48	6.0	8.3	27
Tumor	4	17	0.2	0.7	12
Subarachnoid hemorrhage	8	30	4.4	1.9	9
Arteriovenous malformation	5	8	3.2	0	0
Seizure	3	11	0	2.6	3
Other	10	28	1.4	2.4	15

Note.—Association of each risk factor with cerebrovascular disease in comparison with all other indications is significant: $p < 0.001$, Fisher exact test. TIAs = transient ischemic attacks.

Increasing age, increasing volume of contrast medium, and longer procedure time were each associated with an overall increased incidence of complications ($p < 0.01$, *t* test). This relation primarily resulted from the association of these variables with local complications, almost always a small hematoma (4.4% of cases). When increasing age, increasing volume of contrast medium, and longer procedure time were analyzed for systemic complications, only procedure time was significant ($p < 0.03$, *t* test). When these variables were correlated with neurologic complications, the data showed no statistical significance for increasing volume of contrast medium or procedure time. Increasing age was a significant risk factor for all neurologic complications of cerebral angiography ($p < 0.03$, *t* test) (table 5).

The incidence of neurologic complications for each indication is outlined in table 6. More neurologic complications occurred in patients with symptomatic cerebrovascular disease (4.2%) than in patients with other diseases. We found a statistically significant association of neurologic complications with cerebrovascular disease ($p < 0.01$, chi-square) because of our criterion for inclusion of all events for 24 hr after an angiographic examination. Seven patients experienced either a reversible neurologic complication (persisting longer than 24 hr but resolving within 7 days) or a permanent neurologic complication (persistent deficit 7 days after cerebral angiography). We tried to establish a statistically significant relation between the reversible and permanent neurologic complications and the angiographic indication of cerebrovascular disease in these patients. Although the incidence of complications was increased in the group studied for cerebrovascular disease, no statistically significant association could be found.

Correlation of risk factors with all complications (neurologic and other) is outlined in table 7. The association of significant risk factors and neurologic complications only is shown in table 8. Hypertension was the only risk factor associated with local complications, usually small hematomas. Recent stroke, frequent transient ischemic attacks, and elevated serum creatinine were all associated with a

TABLE 5: **Relation of Age to Neurologic Complications of Cerebral Angiography**

Age (years)	No. of Examinations	Neurologic Complications (%)			
		None	Transient	Reversible	Permanent
0–9	20	100	0	0	0
10–19	58	100	0	0	0
20–29	108	97.2	2.8	0	0
30–39	138	98.6	1.5	0	0
40–49	202	97.5	2.0	0.5	0
50–59	327	98.2	1.8	0	0
60–69	433	96.8	2.5	0.2	0.5
70–79	214	96.3	2.8	0	0.9
80–89	17	88.2	5.9	0	5.9
Totals	1,517	97.4	2.2	0.1	0.3

TABLE 6: **Relation of Indication for Cerebral Angiography to Neurologic Complications**

Indication	Neurologic Complications (%)				
	None	Transient	Reversible	Permanent	Totals
Cerebrovascular disease	95.8	3.4	0.2	0.6	4.2
Tumor	99.0	0.7	0	0.3	1.0
Subarachnoid hemorrhage	96.2	3.2	0.6	0	3.8
Arteriovenous malformation	100	0	0	0	0
Seizure	100	0	0	0	0
Other	98.6	1.5	0	0	1.5
Totals	97.4	2.2	0.1	0.3	

TABLE 7: **Relation of Significant Risk Factors to All Complications of Cerebral Angiography**

Risk Factor	Complications			
	Local	Systemic	Neurologic	
			All	Reversible and Permanent
Diabetes	...	...	...	...
Hypertension (>160 mm Hg)	<0.01	...	...	...
Stroke (<30 days)	...	...	<0.01	...
Frequent TIAs (>1/day)	...	...	<0.01	...
Creatinine >1.2 mg/dl	...	...	<0.01	<0.01
Total no.	74	28	40	7

Note.—All values are for $p < 0.05$, Fisher exact test. TIAs = transient ischemic attacks.

TABLE 8: **Relation of Significant Risk Factors to All Neurologic Complications**

Risk Factor	Neurologic Complications		
	No	Yes (% Yes)	Totals
Stroke (<30 days):			
No	1,431	35 (2.4)	1,466
Yes	46	5 (9.8)	51
Totals	1,477	40	1,517
Frequent TIAs (>1/day):			
No	1,419	33 (2.3)	1,452
Yes	58	7 (10.8)	65
Totals	1,477	40	1,517
Creatinine >1.2 mg/dl:			
No	1,224	26 (2.1)	1,250
Yes	253	14 (5.2)	267
Totals	1,477	40	1,517

Note.—$p < 0.01$, Fisher exact test. TIAs = transient ischemic attacks.

TABLE 9: **Relation of Significant Risk Factors to Reversible and Permanent Neurologic Complications**

Risk Factor	Reversible and Permanent Neurologic Complications		
	No	Yes (% Yes)	Total
Stroke (<30 days)*:			
No	1,460	6 (0.4)	1,466
Yes	50	1 (2.0)	51
Total	1,510	7	1,517
Frequent TIAs (>1/day)†:			
No	1,446	6 (0.4)	1,452
Yes	64	1 (1.5)	65
Total	1,510	7	1,517
Creatinine >1.2 mg/dl‡:			
No	1,248	2 (0.2)	1,250
Yes	262	5 (1.9)	267
Total	1,510	7	1,517

Note.—TIAs = transient ischemic attacks.
* $p = 0.21$, Fisher exact test.
† $p = 0.26$, Fisher exact test.
‡ $p < 0.01$, Fisher exact test.

statistically significant increase in the incidence of neurologic complications.

When the risk factors were correlated with reversible and permanent neurologic complications, only increased serum creatinine concentration remained significant (table 9). Although examinations in patients with frequent transient ischemic attacks or recent strokes had increased risk of reversible and permanent neurologic complications, this correlation was not statistically significant for the sample size.

A retrograde transfemoral catheterization was performed in 1,453 (95.5%) of the angiographic procedures. A 5 French catheter was used in 66% of the examinations. A catheter exchange usually indicated the use of a larger catheter, most often with a Simmons curve. Statistically significant increases in local complications ($p < 0.01$, chi-square) and systemic complications ($p < 0.03$, chi-square) were associated with such an exchange.

The association of catheter exchange with neurologic complications is shown in table 10. There was a borderline increase in the incidence of all neurologic complications in examinations requiring a catheter exchange for completion of the angiographic study ($p = 0.051$, chi-square). This

TABLE 10: **Relation of Catheter Exchange to Neurologic Complications**

Catheter Exchange	Neurologic Complications					
	All			Reversible and Permanent		
	No	Yes (% Yes)	Total	No	Yes (% Yes)	Total
Transfemoral catheters*†:						
One	945	19 (2.0)	964	963	1 (0.1)	964
More than one	471	18 (3.7)	489	484	5 (1.0)	489
Totals	1,416	37	1,453	1,447	6	1,453
More than one catheter‡:						
Cerebrovascular disease				274	4 (1.4)	278
All other indications				210	1 (0.5)	211
Totals				484	5	489

* All complications: $p = 0.051$, chi-square test.
† Reversible and permanent complications: $p < 0.02$, Fisher exact test.
‡ $p = 0.28$, Fisher exact test.

association became statistically significant when only reversible and permanent neurologic complications were considered ($p < 0.02$, Fisher exact test). The data were then correlated with angiographic indication to determine if the severity of vessel tortuosity and diffuse atherosclerosis presumed to be present in patients with symptomatic cerebrovascular disease was the underlying factor responsible for the increased incidence of reversible and permanent neurologic complications. The incidence of reversible and permanent complications in patients with cerebrovascular disease and a catheter exchange was greater than that in patients with all other indications, but this increase lacked statistical significance for the sample size ($p = 0.28$, Fisher exact test).

Patients with an indication of aneurysm or subarachnoid hemorrhage had a high incidence of transient neurologic complications after cerebral angiography but experienced no increased risk of permanent neurologic deficit (table 6).

There was no statistically significant increased risk for local, systemic, or neurologic complications when they were analyzed for the vessels studied. In addition, 297 patients referred for symptomatic cerebrovascular disease had a preangiographic evaluation by oculopneumoplethysmography and bidirectional Doppler sonography. In 54% of these examinations, a pressure-significant lesion in the carotid circulation or abnormal flow (or both) was detected. Such an abnormality was of no value in predicting an increased risk for neurologic complications in this group.

Renal failure developed in one patient as part of a systemic process that resulted in death, presumably due to atheroembolism, in the postangiographic period. No other patient had clinical evidence of diminished renal function after cerebral angiography. To determine the incidence of transient renal failure, we reviewed the histories of 122 consecutive patients with elevated serum creatinine levels before angiography. Forty-nine patients had no further analysis of serum creatinine and were dismissed without evidence of clinically overt deterioration in renal function. A serum creatinine determination was made in 73 patients after cerebral angiography. None had an elevation of serum creatinine concentration greater than or equal to 1 mg/dl. Ten patients had a slight increase in serum creatinine concentration (less than 1 mg/dl), and 63 patients had either no change or a decrease in serum creatinine concentration. Table 11 lists permanent neurologic complications and deaths occurring in our study.

TABLE 11: **Serious Complications and Death After Cerebral Angiography**

Type of Complication	No. of Patients
Local:	
Hematoma:	
Prolonged hospitalization	1
Surgical evacuation	1
Arterial thrombosis:	
Surgical thrombectomy and repair	1
Heparin therapy with resolution	1
Infection—septic right knee after angiography	1
Total	5/74*
Systemic:	
Atheroembolization (died of acute renal failure and bowel infarction 3 days after angiography)	1
Transient hypertension (increase of 40 mm Hg systolic; treated with nitroprusside)	1
Transient hypotension (decrease of 40 mm Hg systolic; three required pressor therapy in addition to bolus of fluids intravenously)	5
Total	7/28*
Neurologic:	
Hemiparesis and aphasia	3
Hemiparesis and blindness	1
Hemiparesis	1
Total	5/40*

* Second value represents total number of patients with complications of this type, regardless of degree or duration.

Discussion

The 0.33% incidence of permanent neurologic complications in this report approximates the incidence of permanent paresis reported by Olivecrona [1] (0.2%), who used similar criteria for inclusion of all neurologic events 24 hr after angiography as neurologic complications. Our incidence of permanent complications in angiographic examinations for symptomatic cerebrovascular disease was

0.63%, which is similar to that reported by Huckman et al. [7], who noted complications in 0.5% of patients with transient ischemic attacks. We had more permanent complications than those reported in the studies of Kerber et al. [3] and Eisenberg et al. [8], who had no permanent complications in a total of 904 patients studied for cerebrovascular disease. These authors attributed their success to immaculate technique, hydration of critically ill patients, and, in particular, the exclusive use of 5 French catheters in performing these examinations. They assembled their data retrospectively, using criteria by which the relation of a neurologic event to angiography could be judged "clinically." Our highly controlled referral system, which uses a patient population almost exclusively from neurologic and neurosurgical services, provided an opportunity for clinical neurologic follow-up that may not have been possible in previous studies.

Faught et al. [10] reported their experience in evaluating the risk of angiography in patients with symptomatic cerebrovascular disease. Their approach was unique, and it served as the foundation on which this study was formulated. Studies by Olivecrona [1] and Faught et al. [10] eliminated inconsistent data bias present in other studies [2–9] by avoiding "clinical" judgments on the relation of a change in neurologic status to a preceding angiographic procedure. They included any worsening of neurologic status within 24 hr of an angiographic study as a neurologic complication. Faught et al. also specified that thorough preangiographic and postangiographic neurologic examinations be performed in all patients.

In the 147 angiographic procedures reviewed in patients studied for stroke or transient ischemic attack, Faught et al. [10] identified a neurologic complication in 12.2%; 5.4% of these were permanent. They noted that temporary complications in these patients often represented an exacerbation of a previous deficit or a transient ischemic attack resembling a preangiographic one, which is a necessary consequence of their criteria for neurologic complication. Our results were similar: transient neurologic complications in 10.8% of patients with frequent transient ischemic attacks and 9.8% of patients with a recent stroke (table 8). The reported incidence of permanent complications in their patients exceeded that observed in our study. Although an increase in reversible and permanent neurologic complications for the frequent transient ischemic attack and recent stroke groups was identified, this increase was not statistically significant for the sample size (table 9).

In discussing the relation of cardiovascular disease to neurologic complications, Faught et al. [10] noted that "most patients were rendered relatively normotensive at the time of study, to minimize bleeding at the arterial puncture site." Patients with symptomatic cerebrovascular disease are often hypertensive, as shown by both the data of Faught et al. [10] and the data assembled in our report (48%). Almost all local complications in our series and most other reports are insignificant to the overall well-being of the patient, and maintenance of perfusion pressure through hemodynamically significant lesions is a critical part of angiographic technique. Rendering hypertensive patients normotensive may upset a delicate perfusion homeostasis, with deleterious results. This practice may have contributed to the high incidence of permanent neurologic complications reported by Faught et al. [10] and may have been especially critical in their patients with high-grade stenosis who suffered permanent complications (35%). Hydration of patients with symptomatic cerebrovascular disease and constant monitoring and maintenance of blood pressure are essential for cerebral angiographic procedures. In patients with high-grade stenosis and slow flow, we routinely institute anticoagulant therapy after completion of the angiographic procedure (usually a constant heparin infusion), a practice also reported by Eisenberg et al. [9].

The relation of catheter sizes and numbers to angiographic complications and the severity of atherosclerosis is a complex question, but trends in our data lend credence to the contention of previous authors [3–6, 8, 9] that the use of smaller, softer catheters is associated with a decreased rate of neurologic complications. This benefit is greatest in patients with cerebrovascular disease, who presumably have diffuse atheromatous disease readily traumatized by larger catheters (table 10). In a large, multihospital retrospective study, Mani et al. [4–6] attempted to correlate the incidence of complications with clinical diagnosis, arteriographic findings, arteries studied, type and volume of contrast medium, age of patient, and duration of procedure. They noted only one death and two permanent neurologic complications in 5,000 cerebral angiographic procedures reviewed, and their overall permanent complication rate was 0.1%. They did not find a higher complication rate for patients with a clinical diagnosis of cerebrovascular disease or arteriographic diagnosis of vascular occlusive disease, but they did note an increasing risk with age and duration of procedure beyond 80 min. We found no statistically significant correlation between the length of procedure and neurologic complications, an observation also made by Olivecrona [1]. Mani et al. [4–6] found a significantly higher complication rate in training institutions studied than in private hospitals. It would appear from the incidence of normal examinations studied in the private hospital group (50%) compared with those in the teaching hospital group (23%) that the populations used to compare complication rates were statistically different. We found no abnormalities in 17% of 1,517 angiographic examinations.

We found no statistically significant difference in the incidence of neurologic complications among direct carotid, brachial, and transfemoral techniques. This finding is biased by selection of these techniques for a small group of patients, usually with advanced atherosclerosis. Huckman et al. [7] showed a lower incidence of neurologic complications with direct carotid and brachial techniques, although no specification of statistical significance was indicated. We find all these techniques useful in examination of selected patients with cerebrovascular disease. In addition, we could find no statistically significant difference in the incidence of complications with vessel studied. This finding agrees with that reported by Mani and Eisenberg [6] and is contrary to that of Olivecrona [1].

In patients with compromised renal function manifested by a preangiographic serum creatinine level of more than 1.2 mg/dl, clinically overt renal failure did not appear to

develop. In a review of 122 consecutive patients with elevated serum creatinine levels, 73 had postangiographic serum creatinine determinations. None had a transient elevation of serum creatinine greater than or equal to 1 mg/dl. This result supports previous findings of Eisenberg et al. [14] and Kumar et al. [15].

The single death in this report was attributed to diffuse atheroembolization (cholesterol embolization). This entity has been a recognized complication of major angiography since its initial description by Flory [16] in 1945. Subclinical atheroembolism occurs in many patients undergoing major angiography, as revealed in an autopsy study [17], at a rate far above that seen in age- and disease-matched controls. It is a potential complication of catheter introduction and manipulation and pressure injection in patients with diffuse atheromatous disease. In his study of complications of cerebral angiography, Olivecrona [1] reported one death due to embolism of cholesterol material from a cervical carotid atheroma. Stroke, renal failure, bowel infarction, pancreatitis, and ischemia of the lower extremities are recognized complications of atheroembolism [18–22]. Fortunately, such complications are infrequent.

We noted no statistically significant relation between the diagnosis of cerebrovascular disease and reversible or permanent complications, a finding also reported by Mani and Eisenberg [5], but trends in our data suggest that there may be increased risk for neurologic complications in this group.

We found a significant correlation between reversible and permanent neurologic complications and both older age and increased serum creatinine concentration. The latter association is previously unreported. We speculate that these factors not only may correlate with the severity of systemic atheromatous vascular disease but also may represent a level of small vessel disease that precludes the formation of pial or transcortical collateral flow to areas of ischemia. This collateral supply and endogenous thrombolysis are probably protective factors that prevent permanent neurologic complications in young patients, as noted in studies of angiographic complications and in reports reviewing the incidence of iatrogenic embolization in both adults [23] and children [24]. Systemic heparinization of patients having evidence of advanced atherosclerosis and elevated serum creatinine concentration may be a means of decreasing neurologic complications at the cost of an increase in local complications [25]. Heparinization would not be of benefit in embolization of dislodged atheromatous debris, which may be the responsible embolic material in most permanent deficits occurring after cerebral angiography in adults.

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