CEREBRAL ANGIOGRAPHY

Why is Cerebral Angiography performed?

The examination is carried out because a disorder of the brain or nearby structure is suspected. It is particularly helpful in disorders of the arteries such as abnormal narrowing (stenosis) and widening (aneurysm). It is usually carried out where the simple tests have failed to give the diagnosis.

Preparations needed for Cerebral Angiography

The test is always carried out in hospital and usually means an inpatient stay of two nights. You will need to be at rest for a few days afterwards, resulting in at least a week off work. It will be another week before you will be able to return to full physical activity. The test is usually carried out under local anaesthesia.

What Happens during Cerebral Angiography

THE PRINCIPLE The test outlines the arteries and veins of the brain and nearby organs, such as the pituitary gland. An iodine-containing dye (called contrast medium) is injected into the arteries supplying the brain through a needle or thin plastic tube (catheter), and x-ray films are taken. The arteries and veins show up on the x-ray, and any abnormality will be shown.

THE PROCEDURE The test takes about 2 hours and is carried out by a medically trained specialist (radiologist). He or she will be assisted by a small team of radiographers and nurses. Tell your doctor beforehand of any known allergies to drugs. With a general anaesthetic, you will need to have fasted for 6 hours to make sure that the stomach is empty. However, if you are being examined under local anaesthetic, you will usually be allowed a light snack 2 hours before the procedure. Arterial injections are usually given through the groin and both groins are shaved before the you are brought to the x-ray department. You are also likely to have received a sedative injection on the ward and will be feeling sleepy by the time you come to the x-ray department. Here you will be placed on an x-ray table. If you are to have a general anaesthetic, you will be given an injection into the arm or hand by the anaesthetist and will go to sleep within a few seconds. The next thing you will remember is waking up and answering simple questions. There will be a feeling of pressure on the groin at the site of the injection and this will last for at least 10 minutes. Some patients are examined under local anaesthesia. The radiologist injects the local anaesthetic into the groin until the area becomes numb. A larger needle is passed into the artery and is replaced by the arterial catheter which can be seen on the x-ray TV screen. The catheter can be guided into the arteries supplying the brain. It is usually necessary to give several injections of dye and to take x-rays at different angles. This usually takes about 1 2 hours. Some people have a sensation of flushing or heat in the face with each injection but this disappears within a few seconds and is not painful. The head may be moved into different positions for different injections. It is important to keep quite still when the x-rays are taken to avoid blurring the pictures. You will be aware of the arterial catheter being moved in the groin from time to time, but will feel no pain. The catheter is removed when all the x-ray films have been taken. Pressure is then applied to the groin for at least 10 minutes to prevent bleeding. This can be uncomfortable but it is not painful. You are then lifted from the x-ray table onto a stretcher and placed in bed. Most will be kept in bed for 12 hours afterwards, to avoid the risk of bleeding from the entry point of the catheter.
Possible Complications of Cerebral Angiography

You will have a small bruise where the injection was given. This is hardly a complication and clears within a week. Some patients develop a large bruise at the site of the injection, which is painful but not serious. Allergic reactions to sedative, painkilling and anaesthetic drugs occur rarely. Allergic reaction to the dye also occurs. This is readily controlled by drugs such as anti-histamines or cortisone-like (steroid) drugs and is rarely serious. The most serious complication is that you could develop a stroke. This is extremely rare. Even if it does occur, it usually gets better in a few days without treatment. However, it is important to point out that it can very occasionally result in long-term or even permanent disability. The artery can also be damaged at the injection site in the groin. This results in a reduced blood supply to the leg. This usually gets better without treatment, but an operation is occasionally required.

After Cerebral Angiography

If you were active before the procedure, you should be up and walking about the day afterwards. There will be some stiffness of the groin and a small bruise will be visible. Even larger bruises will clear in 2-3 weeks. You should be able to return to full physical activity 2 weeks after the procedure.

If Cerebral Angiography is not performed

If the test was not carried out, an accurate diagnosis could not be made and the treatment could not be planned. This is particularly important if an operation is being considered. However, in some circumstances CT scanning or magnetic resonance imaging may be able to be used instead.

http://www.surgerydoor.co.uk/medical_conditions/Indices/C/cerebral_angiography.htm
Neuroradiology

Neurologic Complications of Cerebral Angiography: Prospective Analysis of 2,899 Procedures and Review of the Literature

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ABSTRACT

PURPOSE: To prospectively identify risk factors for neurologic complications related to cerebral angiography.

MATERIALS AND METHODS: A total of 2,899 consecutive cerebral digital subtraction angiograms obtained with nonionic contrast material were prospectively evaluated. Neurologic complications were categorized as transient (<24 hours), reversible (24 hours to 7 days), and permanent (>7 days). The neurologic complication rate was correlated with patient age, type of indication for catheter angiography, medical history, fluoroscopic time, number and size of catheters, type and number of vessels injected, operator experience, and the quartile in which the study was performed. The correlations were statistically analyzed with Fisher exact tests and a multiple logistic regression model.

RESULTS: There were 39 (1.3%) neurologic complications in 2,899 procedures; 20 were transient (0.7%), five (0.2%) were reversible, and 14 (0.5%) were permanent. Neurologic complications were significantly more common in patients 55 years of age or older (25 of 1,361; 1.8%) (P = .035), in patients with cardiovascular disease (CVD) (20 of 862; 2.3%) (P = .004), and when fluoroscopic times were 10 minutes or longer (24 of 1,238; 1.9%) (P = .022). The neurologic complication rate was higher in procedures performed by fellows alone (24 of 1,878; 1.3%) compared with that when staff alone performed the procedures (three of 598; 0.5%), but the difference was not significant (P = .172). Neurologic complications were lower in the fourth quartile of the study (six of 171; 0.9%) compared with the first quartile (16 of 776; 2.1%), which was likely due to fewer patients being examined for carotid stenosis or ischemic stroke and fewer patients with CVD (P = .085).

CONCLUSION: Age-related vascular disease accounted for the failure to lower the neurologic complication rate of cerebral angiography despite technical advances.
INTRODUCTION

Noninvasive imaging of the craniocervical vessels has dramatically improved during the past decade (1–4). Despite advances, cerebral angiography continues to be used for the examination of patients with cerebrovascular diseases. In the past decade, safer contrast agents have been used and there have been important technical advances including smaller catheters, hydrophilic guide wires, and digital imaging systems (5–7). The purpose of this prospective study was to identify the risk factors for neurologic complications that are related to cerebral angiography.

MATERIALS AND METHODS

Patients
Between January 1996 and June 2001, 2,900 consecutive diagnostic cerebral angiograms obtained at one institution were studied prospectively, with institutional review board approval and patient informed consent. All studies were performed on basis of accepted clinical indications for treatment. One procedure was excluded since it was performed to confirm brain death. Diagnostic cerebral angiograms obtained as part of neurointerventional endovascular procedures were not included in this study. Three diagnostic procedures were complicated by thromboembolism, which prompted immediate direct intraarterial thrombolysis with a microcatheter. The three procedures were included in this report.

Technique
Patients were restricted from having solid foods 6 hours before the procedure but were allowed clear fluids. A questionnaire that included past medical health was filled out for all outpatients. The outpatient procedures were performed in the morning, and the patients were observed for a minimum of 4 hours until discharge. A nurse monitored the vital signs and neurologic status of the outpatients until discharge. A family member or a friend accompanied all outpatients overnight. Outpatients who developed complications within 4 hours of the procedure were admitted.

In all patients, an intravenous catheter was placed prior to angiography. Electrocardiography, pulse oximetry, and vital signs were monitored throughout the procedure. Femoral arterial punctures were performed in all but one procedure, which was performed by using a retrograde brachial approach. A 5-F sheath (Radiofocus Introducer II; Terumo, Tokyo, Japan) was used in all femoral punctures. The sheath was constantly flushed with heparinized saline (6,000 IU of heparin in 1,000 mL of normal saline). A similar heparinized saline solution was
used for intermittent flushing of the catheter. In 51 procedures, a bolus of 2,000–2,500 IU of heparin was administered at the beginning of the procedure and was not repeated or reversed. Manual compression at the puncture site for 8–15 minutes was performed at the completion of all procedures.

An angled 0.35-inch radiofocus guide wire (Terumo) was used in 2,704 cases; a 0.35-inch heparin-coated guide wire (Cook, Bloomington, Ind), in 167 cases; and both guide wires, in 28 cases. A one-way stopcock (Cook) was used with the selective catheter. Intermittent flushing techniques were used to prevent clots from developing in the catheter. Special attention was devoted to avoiding any dead-space within the catheter when the guide wire was used. Manipulation with the guide wire was generally less than 60 seconds between catheter flushing.

Nonionic contrast media (Omnipaque 300; Nycomed, Oslo, Norway) were used in all cases. All injections in the angiography suite were performed with a power injector (Mark V; Medrad, Indianola, Pa). The intraoperative procedures were performed with hand injections. Standard injection rates and volumes were as follows: 4–6 mL/sec for 8–12 mL for common carotid artery, 4–5 mL/sec for 8–10 mL for internal carotid artery, 2–3 mL/sec for 5 mL for external carotid artery, 3–4 mL/sec for 7–9 mL for vertebral artery, 6–8 mL/sec for 14 mL for subclavian artery, and 15–20 mL/sec for 30–40 mL for aortic arch. The distribution of the catheterized arteries was as follows: 1,649 (56.9%) right internal carotid arteries, 1,663 (57.3%) left internal carotid arteries, 1,502 (51.8%) left vertebral arteries, 957 (33.0%) right vertebral arteries, 945 (32.6%) right common carotid arteries, 968 (33.4%) left common carotid arteries, 607 (20.9%) right external carotid arteries, 611 (21.1%) left external carotid arteries, 237 (8.2%) right subclavian arteries, and 255 (8.8%) left subclavian arteries. In 220 procedures (7.6%), selective injections of additional vessels, including occipital, ascending pharyngeal, facial, and lingual arteries, were performed.

From January 1996 to December 1998, 1,533 procedures were performed with single-plane digital subtraction angiography (DSA) (LUA; GE Medical Systems, Milwaukee, Wis). Between January 1999 and June 2001, 1,245 cases were performed with biplane DSA (LCN; GE Medical Systems) and 71, with single-plane DSA. Fifty intraoperative angiograms were obtained with a DSA unit (OEC 9800; GE Medical Systems). Neuroradiology fellows and staff performed the procedures. Fellows were allowed to perform the procedures on their own once it was clear that they had reached a safe level of using the technique. A staff neuroradiologist (R.A.W., R.I.F., K.t.B., W.M.) supervised the procedures performed by the fellows alone. Procedures performed by both staff and fellows were performed early during the fellow’s training or when the fellow was having difficulty with a part of the procedure.

**Data Collection**

At the beginning of the procedure, a technologist prepared the data forms and filled in the patient demographics. At the completion of the procedure, the angiographer filled in the contrast material volume and the fluoroscopic time. The data forms included the date of the procedure, name of the referring physician, inpatient versus outpatient status, reason for the procedure (hemorrhage, aneurysm, arteriovenous malformation, carotid stenosis, ischemic stroke, sodium amytal test results, tumor, trauma), medical history (not significant, coronary artery disease, peripheral vascular disease, hypertension, renal disease, diabetes mellitus), catheter size and type, type and number of vessels injected, type of anesthesia (local, neuroleptic, general), heparin bolus (dose), complications within 4 hours (none, neurologic, nonneurologic), complications within 24 hours (none,
neurologic, nonneurologic), adverse events, and operator experience. Outpatients were contacted by phone on the next working day. Inpatients were evaluated the next day by the attending staff and the next working day by the angiographer.

A neurologic complication was defined as any new neurologic sign or symptom or worsening of a preexisting neurologic deficit that occurred during the procedure or within 24 hours. Neurologic complications were classified as transient if they resolved within 24 hours, reversible if they lasted more than 24 hours and resolved within 7 days, and permanent if they persisted more than 7 days. A nonneurologic complication was defined as any sign or symptom occurring either locally at the puncture site or systemically within 24 hours of the procedure. An adverse event was defined as a procedure-related angiographic finding without neurologic signs or symptoms that may or may not have required treatment (eg, arterial dissection). The exact nature of the complication was clarified on the data form. Hematomas at the puncture site were recorded as small if they were less than 5 cm in diameter and large if they were 5 cm or larger in diameter. Adverse events and their management were documented on the data sheet. A chart review approved by the institutional review board was performed (R.A.W., S.M.T.) for patients with neurologic and nonneurologic complications that persisted more than 24 hours.

Statistical Analysis
For the analysis (R.A.W., S.M.T., G.T.) of preexisting comorbidity, coronary artery disease, hypertension, and peripheral vascular disease were grouped as cardiovascular disease (CVD). All patients with multiple preexisting comorbidities had at least one of the CVDs; the diseases were grouped as cardiovascular. For the analysis of the indication for catheter angiography, carotid stenosis and ischemic stroke were grouped together. The Fisher exact test was used to test associations between the neurologic complication rate and patient age, indication for catheter angiography, medical history, fluoroscopic time, type of vessels injected, number of vessels injected, catheter size, number of catheters, operator experience, and the quartile in which the procedure was performed (R.A.W., S.M.T., G.T.). The relationships between the complication rate and the risk factors that were significant in these bivariate analyses were analyzed (G.T.) with a multiple logistic regression model to determine which factors were independently associated with complications. Interactions between individual cardiovascular risk factors could not be performed with regression models, since we could not adhere to the widely recognized principles of regression analysis that recommend as a guideline a minimum of 10 outcomes per parameter.

RESULTS

A total of 1,368 (47.1%) procedures were performed in female patients and 1,531 (52.8%) were performed in male patients. The age range was 5–91 years, with a mean age of 52.5 years (Table 1). A total of 1,344 procedures (46.3%) were performed as outpatient and 1,555 (53.7%) were performed as inpatient; 2,777 (95.8%) were performed with local anesthesia; 61 (2.1%), with neuroleptic anesthesia; and 61 (2.1%), with general anesthesia. The medical history and indications for catheter angiography are outlined in Tables 2 and 3.
The mean fluoroscopic time was 11.5 minutes (median time, 8.6 minutes). The mean contrast material volume was 114.7 mL. A bolus of 2,000–2,500 IU of heparin was administered in 51 (1.8%) patients. A total of 2,589 (89.3%) procedures were performed with 5-F catheters; 279 (9.6%), with 4-F catheters; five (0.2%), with 6-F catheters; one (0.03%), with a 7-F catheter; and 25 (0.9%), each with more than one size catheter. A multipurpose hockey-stick curved catheter (Bern 1 Performa; Merit Medical, South Jordan, Utah) was used in 2,414 (83.3%) procedures; a Sidewinder catheter (Sim 2; Merit Medical), in 228 (7.9%); a Mani cerebral catheter (Cook), in 29 (1.0%); and more than one type of catheter, in 228 (7.9%). A total of 1,888 patients had one angiogram, 344 had two, 78 had three, 16 had four, and five had five. One to three vessels were studied in 1,621 (55.9%) procedures; four to six vessels, in 1,138 (39.2%); and seven or more vessels, in 140 (4.8%).

**Neurologic Complications**

There were 39 (1.3%) neurologic complications in 2,899 procedures; 20 were transient (0.7%), five (0.2%) were reversible, and 14 (0.5%) were permanent. Seven (0.25%) of 2,899 permanent complications were considered major or disabling strokes. In the outpatient group, all neurologic complications were evident within 4 hours of the procedure. Two of the transient and one of the permanent complications were related to thromboembolism, which was evident on the angiogram during the procedure. All three were treated with intraarterial thrombolysis. Of 20 transient complications, six had the typical findings and course of transient global amnesia.
Neurologic complications were significantly more common in procedures performed in patients who were 55 years of age or older (25 of 1,361; 1.8%) compared with those performed in patients younger than 55 years of age (14 of 1,538; 0.9%) \((P = .035)\) (Table 1). From a logistic regression against age, the estimated odds ratio for neurologic complications was 1.22 per 10 years of age (95% CI: 1.00, 1.52; \(P = .05\)). Neurologic complications were significantly more common in patients with CVD (20 of 862; 2.3%) compared with those without these risk factors (19 of 2,037; 0.9%) \((P = .004)\) (Table 2). When the fluoroscopic times were 10 minutes or longer, there were significantly more neurologic complications (24 of 1,238; 1.9%) compared with those when fluoroscopic times were shorter than 10 minutes (15 of 1,661; 0.9%) \((P = .004)\).

Multiple logistic regression was used to analyze which of the factors (age, CVD, and fluoroscopic time) were independently related to the neurologic complication rate. There were eight \((2 \times 2 \times 2)\) regression models that could be formed by including or excluding each of these three factors. Each of these models was fitted, and the best model was chosen on the basis of likelihood ratio tests. The best model was one that included only fluoroscopic time and CVD. In that model, the estimated relative risk for neurologic complications associated with CVD was 2.32 (95% CI: 1.22, 4.43; \(P = .010\)). The estimated relative risk for neurologic complications associated with fluoroscopic times longer than 10 minutes was 1.97 (95% CI: 1.00, 3.87; \(P = .039\)). Addition of age to this model did not significantly improve its fit \((P = .40)\).

The fellows alone had a higher neurologic complication rate (24 of 1,878; 1.3%) compared with that of the staff alone (three of 598; 0.5%), but this did not reach significance \((P = .172)\) (Table 4). When the fellow and staff together performed the procedures, there was a significantly higher neurologic complication rate (12 of 423; 2.8%) compared with that when a fellow or staff alone performed the procedures (27 of 2,476; 1.0%) \((P = .009)\).

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<th>TABLE 4. Operator Experience as a Risk Factor for Neurologic Complication</th>
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<td>There were differences in the neurologic complication rates when they were analyzed for an association with age, indication for catheter angiography, type and number of vessels studied, number of catheters, catheter size, and the quartile in which the study was performed, but these were not significant (Table 5). The neurologic complication rate was similar in male (17 of 1,367; 1.2%) and female (22 of 1,532; 1.4%) patients ((P = .747)). Neurologic complications were more common when the indication for catheter angiography was carotid stenosis or ischemic stroke (17 of 965; 1.8%) compared with that of other indications (22 of 1,934; 1.1%) ((P = .174)) (Table 3). When four or more vessels were injected, the neurologic complication rate was 1.4% (18 of 1,278) compared with 1.2% (21 of 1,621) when fewer than four vessels were injected ((P = .871)). When the posterior circulation was studied (vertebral artery or subclavian artery injections), the neurologic complication rate was higher (27 of 1,798; 1.5%) compared with that when the posterior circulation was not studied (12 of</td>
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When the right vertebral artery was injected, the neurologic complication rate was higher (17 of 1,082; 1.6%) compared with that when the right vertebral artery was not injected (22 of 1,817; 1.2%) \((P = .41)\). When more than one catheter was used, there was a higher neurologic complication rate (five of 245; 2.0%) compared with that when one catheter was used (34 of 2,654; 1.3%) \((P = .375)\). When 4-F catheters were used, there was a lower neurologic complication rate (two of 279; 0.7%) compared with that when 5-F catheters were used (37 of 2,589; 1.4%) \((P = .581)\).

A lower neurologic complication rate was found in the fourth quartile of the study (six of 671; 0.9%) compared with that in the first quartile (16 of 776; 2.1%) \((P = .085)\) (Table 6).

### Table 6. Quartile Study as a Risk Factor for Neurologic Complication

Asymptomatic Adverse Events
There were two asymptomatic arterial dissections. One was in the right vertebral artery and required no treatment. The other was in the left internal carotid artery and was treated with systemic heparinization.

Nonneurologic Complications
There were three allergic cutaneous reactions in the 2,899 procedures (0.1%), including urticaria in two procedures and hives in one. These developed within 1 hour of the procedure and resolved without treatment. There were 14 hematomas (0.4%) at the puncture site; seven were small and seven were large. A pseudoaneurysm was associated with one of the large hematomas and was treated with 15 minutes of compression with ultrasonographic (US) guidance. One of the procedures was complicated by a myocardial infarction. The patient remained in the hospital for 19 days and fully recovered. None of the 2,899 patients developed renal failure as a consequence of angiography.

### DISCUSSION
Summary of the Literature
The combined transient and reversible neurologic complication rate of cerebral angiography has been reported to be as low as 0.4% and as high as 12.2% (6–18). The reported permanent neurologic complication rate varies from 0% to 5.4% (6–18). Limiting the review to prospective studies of 1,000 or more procedures reveals a combined transient and reversible neurologic complication rate from 0.4% to 2.3% (mean, 1.3%), a permanent neurologic complication rate from 0.1% to 0.5% (mean, 0.3%), and a mean overall rate of 1.6% (7–9,12). The series reported here had a slightly lower combined transient and reversible neurologic complication rate of 0.9% (25 of 2,899), a slightly higher permanent rate of 0.5% (14 of 2,899), and a slightly lower overall rate of 1.3% (39 of 2,899). The prospective series reported here, with 2,899 procedures performed at one institution, is, to our knowledge, the largest study of its kind to date.

Authors of most of the studies who investigated the complication rates of cerebral angiography have included complications that occurred within 24 hours of the procedure. The study of Dion et al (8) is unique in that it included complications that occurred 24–72 hours after the procedure. Factors that significantly correlated with increased neurologic events between 24 and 72 hours included the volume of contrast material, patient age, and diabetes. In patients with frequent transient ischemic attacks and carotid stenosis, it is likely that at least some of these events are part of the natural history of the disease.

Pathophysiology
A number of mechanisms have been proposed to account for the neurologic complications of cerebral angiography. The most common cause implicated is thromboembolism from the catheters or guide wires. These thrombi most likely develop inside the catheter during the manipulation of the guide wire. This is most likely to occur if the guide wire is withdrawn into the catheter, allowing blood to stagnate within this dead-space. In our practice, we stress the importance of avoiding this dead-space and keeping the guide wire manipulations to a minimum time. Continual flushing of the catheter with heparinized saline with use of a three-way stopcock has been advocated to reduce thromboembolic events (8). In our practice, we have used one-way stopcocks, and we keep a full contrast material column in the catheter between manipulations.

Disruption of an atherosclerotic plaque by the catheter or guide wire has been commonly implicated as a mechanism for stroke. Other causes include arterial dissections related to the catheter or guide wire, platelet activation, changes in clotting factors, and neurotoxicity of contrast agents (19–22).

Patient Factors
The neurologic complication rate has been reported to increase with patient age (8,9,12,13,15). In our series, the risk of neurologic complications increases a relative 22% for each 10-year increase in age (Table 1) (P = .05). We found a significantly higher neurologic complication rate in procedures performed in patients 55 years of age or older. Heiserman et al (12), in their prospective series of 1,000 patients, reported no neurologic complications in 363 patients who were younger than 50 years of age. Dion et al (8) reported no neurologic complications in 204 patients who were younger than 30 years of age. In our study, there was only one permanent complication in patients younger than 45 years of age. This complication occurred in a teenager during intraoperative angiography. The high neurologic complication rate (one of 50; 2.0%) in our study with use of intraoperative angiograms may be a reflection of the difficulty with working in the operating room. In previous reports, the permanent neurologic complication rate
from intraoperative cerebral angiography was also noted to be higher, ranging from 0.5% to 1.5% (23–25).

Ischemic stroke has been reported to be a risk factor in cerebral angiography (8–14,16,26,27). In a meta-analysis by Cloft et al (28), the neurologic complication rate was lower in patients with a subarachnoid hemorrhage, aneurysm, or arteriovenous malformation compared with that in patients with ischemic stroke. Faught et al (11), in a retrospective study of 147 patients to evaluate stroke, found neurologic complications in 12.2% of the procedures, and 5.2% were permanent. Results of Earnest et al (9) were similar, with transient neurologic complications in 10.8% of patients with frequent transient ischemic attacks and in 9.8% of patients with recent stroke. Earnest et al did not find a significant difference between the reversible (3.6%) and permanent (0.6%) neurologic complication rate in patients with recent ischemic events compared with their overall rates of 2.3% and 0.3%, respectively. In our study, patients with ischemic stroke or carotid stenosis had a higher neurologic complication rate (1.8%), but it was not significant (P = .174). Heiserman et al (12) also found that carotid stenosis correlated with an increased rate of neurologic complications when compared with their entire group but not in the subset that had ischemic stroke. In 297 patients examined with Doppler US of the carotid artery, Earnest et al (9) found no difference in the neurologic complication rate between those with carotid stenosis and those without.

Dion et al (8) found that hypertension was a significant risk factor for neurologic events developing within 24 hours of the procedure. Earnest et al (9) found that elevated levels of creatinine were associated with an increased incidence of neurologic complications. In our study, there was a significantly higher complication rate in patients with CVD (2.3%) (Table 2).

**Procedural Factors**

Long procedural times have been implicated to be a risk factor in cerebral angiography (15). Heiserman et al (12) found significant correlations between the neurologic complication rate and patient age, length of the procedure, volume of contrast material, carotid stenosis, and ischemic stroke. Within the ischemic stroke group, age was the only significant variable (12). In our series, fluoroscopic times of 10 minutes or longer were associated with a significantly higher neurologic complication rate. The fluoroscopic times were not dependant on whether a staff or fellow performed the procedure (Table 4). A higher neurologic complication rate did correlate with longer fluoroscopic times in procedures performed by both the fellow and staff. Fluoroscopic time was the best measure of the difficulty of the procedure and reflected the time taken to catheterize the blood vessels.

A multiple logistic regression model was used to determine if the significant risk factors (CVD, age older than 55 years, and fluoroscopic times longer than 10 minutes) were independently associated with a higher neurologic complication rate. CVD and fluoroscopic times were found to be independent predictors, whereas age was not a significant predictor once the cardiovascular status and fluoroscopic time were known.

Higher volume of contrast material has been considered a risk factor in cerebral angiography performed with ionic contrast material (8,15). In a prospective evaluation of 230 patients with symptomatic cerebrovascular disease, McIvor et al (16) found a slightly lower neurologic complication rate with use of nonionic contrast material compared with that with ionic contrast material, but it was not statistically significant. In a retrospective study of 1,509 procedures in which ionic
contrast material was used and of 1,000 procedures in which nonionic contrast material was used, Skalpe (29) reported a lower neurologic complication rate in procedures performed with nonionic contrast material. The neurologic complication rate in our study with use of nonionic contrast material was similar to that in large prospective studies in which ionic contrast material was used (8,9).

Wishart (30) reported a higher neurologic complication rate when cerebral angiography includes selective injections in the posterior circulation. Later reports did not support this finding (8,9,15). Our study findings did not show a significantly higher neurologic complication rate when the posterior fossa was injected compared with that with only carotid artery injections. We found no difference in the neurologic complication rate when it was correlated with the number of vessels injected, which is similar to the results of Dion et al (8).

The association between the number of catheters used, the catheter size, and fluoroscopic times with the neurologic complication rate is complex owing to the relationship to atherosclerotic disease. Earnest et al (9) found a higher rate of neurologic complications when more than one catheter was required. Dion et al (8) did not find a difference until more than three catheters were used. Heiserman et al (12) found no association with the number of catheters used. Our study findings did not show a significantly higher neurologic complication rate and the number of catheters used. Earnest et al (9) found a lower neurologic complication rate when smaller catheters were used, similar to our study results, but the rate was not significant.

DSA has replaced cut-film changers in most centers. Procedural time has been reduced with DSA compared with cut-film angiography. Grzyska et al (7), in a large series in which cut-film angiography was used, attributed their lower neurologic complication rate (0.4% transient, 0.1% permanent) to the use of DSA and nonionic iso-osmotic contrast material. Later studies in which DSA and nonionic contrast material were used demonstrated similar neurologic complication rates to those of series that were performed with cut-film angiography and ionic contrast material (8,9,12–14). Our study had a similar neurologic complication rate as did these large prospective studies, despite the use of DSA and nonionic contrast material.

During the 5 1/2 years of our study, we found that the neurologic complication rate had decreased from the first quartile to the fourth quartile (Table 6). This improvement correlated with the reduction in the percentage of patients who were being treated for carotid stenosis or ischemic stroke and the lower percentage of patients with CVD. The similar neurologic complication rate in the second and third quartiles may reflect the similar percentage of patients with CVD. We believe that the lower neurologic complication rate during the period when biplane DSA was used compared with that when single-plane DSA was used was not related to the technology, since it was not evident when second and third quartiles were compared. As expected, the mean contrast material volume decreased during the period when biplane DSA was used.

Heparinized saline is the standard flush solution used during cerebral angiography. In addition to heparinized saline, Dion et al (8) used a heparin bolus of 2,000 IU in selected cases (32.3% of procedures). Authors of other large prospective studies did not use a heparin bolus (7,9,12). In our study, we used a heparin bolus in 51 (1.7%) of the 2,899 procedures that were considered as high risk. This included some patients with frequent transient ischemic attacks or a recent stroke thought to be due to vasculitis. In comparing our study findings with those in the report by Dion et al, there was a similar overall neurologic
complication rate, but their permanent complication rate was lower, which suggests there may be a benefit with the more liberal use of heparin. The disadvantage of heparin is hematomas at the puncture site, 6.9% in the series of Dion et al compared with 0.5% in our series (8). Delayed hemorrhage at the puncture site is more common in patients who underwent systemic heparinization (31).

**Operator Experience**

The neurologic complication rate of cerebral angiography has been reported to be lower in the hands of more experienced angiographers (3,11,32). Mani et al (15) found a higher rate of neurologic complications in training hospitals (3.9%) compared with that in nontraining hospitals (0.9%). Mani et al also found that general radiologists or angiographers had more than double the neurologic complication rate (1.8%) compared with that of fully trained neuroradiologists (0.7%). Findings of smaller prospective studies (16,32) also demonstrated significantly higher neurologic complication rates in trainees compared with those of consultant radiologists. Heiserman et al (12) found no difference in the neurologic complication rate and the level of training. In our study, the neurologic complication rate in procedures performed by fellows was higher than that in procedures performed by staff (Table 4). The difference can be explained in part by the higher percentage of patients with CVD in procedures performed by fellows. The mean fluoroscopic time and the mean patient age in the procedures performed by staff alone and fellows alone were similar. This finding differs from the report by Grzyska et al (7) who found that trainees use longer fluoroscopic times.

In our study, procedures performed by both fellows and staff together had a significantly higher neurologic complication rate compared with that of staff or fellows alone (Table 4). In the majority of these procedures, the staff participated in the procedure once the fellow was having difficulty. The complexity of these cases is reflected by the longer fluoroscopic times. The procedures performed by fellows and staff together consisted of patients who were slightly older and with a higher percentage of CVD, carotid stenosis, and ischemic stroke.

Technical advances in cerebral angiography have not overcome the patient-related risk factors associated with neurologic complications. The risk of neurologic complications increases with age. CVD and fluoroscopic times longer than 10 minutes were independent predictors of risk. These findings substantiate the argument that patients at a higher risk should undergo noninvasive imaging of the craniocervical vessels and that catheter angiography should be avoided. In patients without these risk factors, neurologic complications still occur and, therefore, the indications for catheter angiography should be limited. Our data support the shift to noninvasive imaging of the craniocervical vessels.

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FOOTNOTES

Abbreviations: CVD = cardiovascular disease, DSA = digital subtraction angiography


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Cerebral angiography

Definition

The arteries are not normally seen in an x-ray, so a contrast dye is injected into one or more arteries to make them visible. For the cerebral angiography, the contrast dye is injected into one or both of the carotid or vertebral arteries in the neck.

Alternative Names

Vertebral angiogram; Angiography - head; Carotid angiogram

Why the Test is Performed

The test is most frequently used to confirm cases of stroke, tumor, bulging of the artery walls, a clot, a narrowing of the arteries, and to evaluate the arteries of the head and neck before a corrective surgery. It is used to get more exact information after something abnormal has been detected by an MRI or CT scan of the head such as bleeding within the brain.

How the Test is Performed

This test is done in the hospital. You will lie on the x-ray table. Your head is positioned and immobilized by using a strap, tape, or sandbags. Electrocardiogram (ECG) leads are taped to your arms and legs to monitor your heart during the test.

The area where the contrast dye will be injected is shaved and cleansed. The site is usually in the leg. You are given a local anesthetic, the artery is punctured, and a needle is inserted into the artery.

A catheter (a long, narrow, flexible tube) is inserted through the needle and into the artery. It is then threaded through the main vessels of the abdomen and chest until it is properly placed in the arteries of the neck. This procedure is monitored by a fluoroscope (a special x-ray that projects the images on a TV monitor).

The contrast dye is then injected into the neck area through the catheter, and the x-ray pictures are taken. The catheter is kept open by flushing it periodically with a saline solution containing heparin, which will keep the blood in the catheter from clotting. Your pulse, blood pressure, and breathing are monitored during the procedure.

After the x-rays are taken, the needle and catheter are withdrawn. Pressure is immediately applied on the leg at the site of insertion for 10 - 15 minutes to stop the bleeding. After that time, the area is checked and a tight bandage is applied. Your leg should be kept straight for 12 hours after the procedure.
Digital subtraction angiography (DSA) uses a computer to "subtract" out the bones and tissues in the region viewed such that only the vessels filled with contrast are seen.

**How to Prepare for the Test**

- Advise the health care provider if you are pregnant or if you have ever had any bleeding problems. Allergic reactions to x-ray contrast dye or any iodine substance and any other allergic reactions should be mentioned.
- You must sign a consent form.
- Routine blood tests will be done and an examination of the nervous system performed before the procedure.
- Food or fluid may be restricted 4 - 8 hours before the procedure.
- You will be given a hospital gown to wear. You must remove all jewelry.
- A sedative or pain pill may be given to you before the procedure.

Infants and children:

The preparation you can provide for this test depends on your child’s age, previous experiences, and level of trust. For general information regarding how you can prepare your child, see the following topics:

- Infant test or procedure preparation (birth to 1 year)
- Toddler test or procedure preparation (1 to 3 years)
- Preschooler test or procedure preparation (3 to 6 years)
- Schoolage test or procedure preparation (6 to 12 years)
- Adolescent test or procedure preparation (12 to 18 years)

**How the Test Will Feel**

The x-ray table may be hard and cold, but you may ask for a blanket or pillow. There is a brief sting when the local anesthetic is given. This does not numb the artery, so there will be brief, sharp pain as the catheter is inserted into the artery. There is a slight feeling of pressure as the catheter is advanced.

As the dye is injected, there may be a warmth or burning sensation. You may experience a slight headache or feel flushed on the side of the face. There may be slight tenderness and bruising at the site of the injection after the test.

**Risks**

There is the possibility of significant complications:

- A reaction to the contrast dye can occur.
- There is some risk of the catheter damaging the artery or knocking loose a piece of the artery wall, which can block blood flow and cause a stroke. This is rare, however.
- A clot or bleeding at the puncture site may result in a partial blockage of the blood to the leg.

**Considerations**

Notify your health care provider immediately if you have:

- Facial weakness
- Slurred speech
- Visual trouble
- Numbness in your leg during or after the procedure
What Abnormal Results Mean

If the contrast dye flows out of the blood vessel, it may indicate internal bleeding. Narrowed arteries may suggest cholesterol deposits, a spasm, or inherited disorders. If the vessels are displaced, it may be caused by tumors or bleeding within the skull, aneurysm (bulging of the artery walls), or malformation.

Additional conditions under which the test may be performed:

- Arteriovenous malformation (cerebral)
- Cerebral aneurysm
- Hypertensive intracerebral hemorrhage
- Intracerebral hemorrhage
- Lobar intracerebral hemorrhage
- Metastatic brain tumor
- Neurosyphilis
- Optic glioma
- Pituitary tumor
- Polycystic kidney disease
- Primary brain tumor
- Stroke secondary to carotid dissection
- Stroke secondary to carotid stenosis
- Stroke secondary to FMD
- Stroke secondary to syphilis
- Syphilitic aseptic meningitis

Endovascular Coiling in Cerebral Aneurysms
Critical Care Nursing
California State University, Fresno
Leah Barbo, Vanessa Garcia, Lilli Goishi,
Jamie Johnson, Rebecca Luna

Left: CT Scan with a giant internal carotid artery aneurysm. A large round density demonstrates calcification of the wall of the aneurysm with thrombosis within the lesion. Right: Coronal MRI scan demonstrating thrombus within the lesion and a small area of the aneurysm which still fills with blood

PATHOPHYSIOLOGY:
An intracerebral **aneurysm** is a small, thin walled dilatation of one of the large **vessels** that supplies blood to the brain. The probably theory behind why aneurysms occur is a result of two factors: arterial degeneration, and developmental deficiency. Arterial degeneration is seen in defects of the arterial, and the tunica media, particularly where there is a lack of muscular layer evidence of developmental deficiency. As a result, the adventitia and the intima come in contact with each other causing the aneurysm. Some other factors such as intimal hypoplasia and atheroma may play a role in pathogenesis. Hemodynamic factors include blood lesions or systemic disease like polycystic kidney disease, fibromuscular dysplasia, connective tissue deficiency syndromes and intracranial tumors. Intracerebral aneurysms may also have a genetic predisposition. In some families the existence of intracranial aneurysms is as high as 10%.

*Lateral Angiogram of Giant Internal Carotid Aneurysm*

Intracranial aneurysms are a health risk due to their potential for rupture. If a rupture occurs, subsequent bleeding leads to subarachnoid (fluid-filled spaces that surround the brain) hemorrhage. Rupture most often occurs in patients between the ages of forty to sixty and prevalence is equal in both sexes. Risk factors of rupture include cigarette smoking and excess alcohol use. Prior to rupture aneurysms are usually asymptomatic. However, an expanding aneurysm can cause problems of double vision, loss of vision, numbness in face, enlarged pupil size, or drooping eyelid. Patients who have rupture of an aneurysm usually experience sudden onset of severe headache, frequently accompanied by transient loss of consciousness, and in some cases vomiting. The rupture of an aneurysm occurs during activity as opposed to during sleep.

*Left: AP view of the internal carotid angiogram demonstrating a giant aneurysm with a small neck.*

*Right: Postoperative AP angiogram demonstrating complete obliteration of the aneurysm at the neck.*
If rupture occurs, approximately half of all patients survive. The best predictor of risk of aneurysm rupture is size. Most ruptured aneurysms are equal to or greater than ten millimeters in diameter (half-inch). The neurologic Hunt and Hess Grade I-V is used as a guide to determine prognosis when rupture occurs. Those with a Grade I-II = awake with slight to moderate severe headache and neck stiffness have a good prognosis with a low mortality rate (4%). Grades IV-V = stupor with neurological deficits to deep coma have a higher mortality rate (up to 46%).

The most serious complications associated with rupture of an aneurysm are: cerebral vasospasm, rebleeding from the aneurysm, swelling of the ventricles (hydrocephalus), and seizures.

Intracerebral aneurysms are diagnosed by carotid and vertebral angiography. CT scans of the head will confirm the presence of blood within the brain or subarachnoid spaces if rupture of an aneurysm has occurred. A lumbar puncture can be performed to evaluate for the presence of blood in CSF if results of a CT are questionable. Recently, non-invasive studies such as magnetic resonance imaging (MRI) and magnetic resonance angiography (MRA) have been performed in the diagnosis. However, intracerebral angiogram is most reliable.

**PATIENT HISTORY**

B.T. is a 71-year-old female with a previous history of cerebral aneurysm and subsequent subarachnoid hemorrhage (11/88). During that hospitalization she underwent surgical clipping and ventricle peritoneal shunt placement. She was in a coma for seven weeks following surgery. Her only neurological deficits were blindness in her left eye and poor peripheral vision in her right eye.

One week prior to current admission, B.T. presented to her primary care doctor with complaints of headache. He ordered a cerebral angiogram which revealed a second left internal carotid cerebral aneurysm. With the aneurysm still intact patient underwent elective endovascular coiling and embolization.

**PROCEDURE COILING**

It is estimated that 2% of the population harbors an intracerebral aneurysm, with 25,000 rupturing in North America each year. Of the 25,000 hemorrhages, 45-50% of patients die even with aggressive treatment. Of those patients who do survive, at least half suffer significant neurological damage or death due to re-hemorrhage or vasospasm (Choi, p.1). Traditionally, treatment has consisted of open craniotomy and surgical clipping of the aneurysmal neck, however in some cases, conditions such as "unfavorable configuration, size of neck, or location" have precluded the possibility of proper clipping (Choi,p.1). This treatment also
entails a high risk for the patient including risk of rupture during surgery, residual neurological deficits from the surgery itself, and a prolonged recovery time (Healthwatch, p.1). Beginning in the 1970’s, the introduction of "transarterial intracranial navigation of catheters" has allowed for the development of new endovascular methods which may possibly occlude difficult aneurysms (Choi, p.1). Some initial success was seen with placement of small latex balloons, however complications have occurred due to migration of the balloon out of the aneurysm and rerupture (Choi, p.1).

Pioneered in the early 1990’s by Dr. Guido Guglielmi, a neuroradiologist at UCLA, and approved by the FDA in September, 1995 (NSA, p.1), is the Guglielmi detachable coil (GDC); the first endovascular device cleared for the treatment of patients with aneurysms deemed inoperable or at high risk for surgery (Preston). Coil placement takes place in the angiography suite under local anesthesia and sedation, where a catheter is inserted into the femoral artery and advanced to the area of the aneurysm (Healthwatch, p.1). The GDC, which is made of a soft, platinum alloy with a preformed helix, is attached to a delivery wire and fed through the catheter to the aneurysm (Choi, p.1). The coil exits the catheter and fills in the spaces of the aneurysm. The surgeon is able to check placement of the coil using the patient’s angiogram (MGH News, p.4). When the surgeon is satisfied with the coil’s placement, a small electrical current is applied to the delivery wire which detaches the coil. The delivery wire and catheter are then withdrawn. Once inside the aneurysm, blood begins to clot around the coil, sealing off the aneurysm from blood flow and preventing, or reducing the risk of, rupture (Healthwatch, p.1). This is called embolization (NSA, p.1). Benefits of this procedure include the surgeon’s ability to withdraw the coil before final placement, allowing for re-positioning or exchange of the coil for a different size, and the placement of as many coils as necessary to seal off the aneurysm from the artery (Choi, p.1). The blood vessel lining then eventually grows over the neck of the aneurysm (MGH News, p.4).

Studies have found coil placement and embolization to be effective and relatively safe, however, there are risks involved, including improper or incomplete filling of the aneurysm, embolism, and aneurysmal rupture during the procedure (Healthwatch, p.1). Moreover, with incomplete packing of the aneurysm, the remnant may expand into a new aneurysm over time (Choi, p.2).

According to Choi (p.2), possibilities for future treatment include a probable combination of one or more therapies. For example, initial coil placement, followed by clipping, as a way to avoid any aneurysmal remnant; or initial treatment with a coil in order to facilitate a surgical approach with less risk.

1A. Lateral angiogram of a patient who presented in poor neurologic condition with vasospasm and a large basilar tip aneurysm.
1B. Lateral angiogram of the same patient one week after coil embolization of the basilar tip aneurysm. The patient is making a good neurologic recovery.

2A. AP angiogram demonstrating a left giant carotid artery aneurysm (large arrowhead) and a smaller ruptured anterior communicating artery aneurysm (small arrowhead).

2B. AP angiogram of the left carotid artery in the same patient after coil embolization of the giant internal carotid aneurysm (large arrowhead) and microsurgical clip obliteration of the anterior communicating artery aneurysm (small arrowhead).

NURSING CARE FOR CEREBRAL ANGIOGRAPHY AND ENDOVASCULAR COILING
Endovascular coiling for a cerebral aneurysm uses cerebral angiography to visualize the blood flow of the brain. Nursing care for patients who undergo this procedure focuses on both neurological and vascular assessments.

**NEUROLOGIC**

A baseline neurologic assessment is necessary both before and after the procedure to indicate any deviation from normal function. It may not be necessary to get an in depth assessment each time, however key areas should be focused on. Any past neurological problems and pre-existing sensory or motor impairment indicated in the patient’s history should be noted. This patient’s history of subarachnoid hemorrhage and resultant left eye blindness with pupillary fixation and dilatation to five millimeters indicates her baseline assessment and was not before the procedure.

In some instances the individual may experience major or minor arterial block due to embolism, thrombosis or hemorrhage, producing a neurological deficit. Neurological checks can be divided into four areas: Level of Consciousness (LOC), motor/sensory function, pupillary response, and Glasgow Coma Scale.

**LOC:** The most important factor to note is any change in LOC. It is the earliest and most sensitive index of change in neurological status. Note responsiveness, ease of arousal, and state of orientation. This can be assessed by asking questions about a person’s name, where the person is, and what year it is. Note the quality of verbal response and any deficits. If the person is alert, note whether or not they are able to follow directions appropriately. If the person is not alert, note the amount of stimulus that is necessary to arouse him or her. Responses to both auditory stimuli and painful stimuli should be observed and noted.

**MOTOR:** Motor function can be assessed by checking the voluntary movements of each extremity by giving commands. Assess upper arm strength by checking hand grips and lower extremity strength by having the person push one foot at a time against your hand’s resistance. Strength is classified on a scale from zero to five; zero being no movement or contraction and five being normal movement against gravity and resistance. If a person has decreased LOC, note if movement is spontaneous or determined (e.g. the patient’s response of pushing away a hand after noxious stimuli is applied).

**PUPILLARY RESPONSE:** This can be a good indicator of neurological function but often is variable, related to the patient’s baseline. It is also a late indicator of deficit. The size, shape and symmetry of the pupils are evaluated. Pupil reaction is assessed by shining a light into both pupils and noting their direct and consensual light reflex. Both pupils should constrict briskly and evenly. Size is expressed in millimeters; with a size of two to six millimeters considered within normal range. Unequal sized pupils is a finding that is normal for some people and does not necessarily indicate impairment. All pupil reactions should be considered with other neurologic changes to provide a complete picture of neurologic function.

**GLASGOW COMA SCALE (GCS):** This is an objective assessment tool that describes LOC by numerical value. This widely used evaluation tool indicates responses in three areas: eye opening, verbal response and motor response. Each area is rated separately and given a number for the
person’s best response in each area. The three numbers are added and the total score reflects the brain’s functional level. Fifteen = fully alert, normal person. Seven or less = coma and a poor prognosis. **VASCULAR**

Circulatory assessment is also an important nursing intervention. Immediately post-procedure, the patient is kept on bedrest with the affected limb immobilized and straight while the sheath is in place and for approximately four to six hours post-sheath removal. The head of bed is kept flat or elevated to no more than twenty degrees during this time. A pressure dressing is applied to the puncture site; usually the femoral artery. The patient is instructed to apply pressure to the site during coughing, sneezing, vomiting or any other valsalva maneuvers to prevent clot dislocation and subsequent embolization. The puncture site is inspected for hematoma or bleeding. Discomfort and swelling can be relieved by intermittent application of an ice bag on the site. Circulatory checks are performed bilaterally, including femoral and pedal pulses as well as color, temperature, and sensation of distal extremities. Signs or symptoms of infection are also noted. Vital signs and puncture site checks are made every fifteen minutes for two to four hours; then every thirty minutes for one to two hours, then hourly, while the sheath is in place.

<table>
<thead>
<tr>
<th>PHYSICAL FINDINGS</th>
<th>LABS</th>
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<tbody>
<tr>
<td>Physical findings post-operation revealed patient to be alert and oriented, friendly and cooperative. Pupils unequal. Left eye fixed and dilated to five millimeters due to blindness as sequel from previous aneurysm. Right eye reactive to light and accommodation. Pedal pulses: left dorsalis pedis and posterior tibial 1+; right 2+. Radial pulses 2+ bilaterally. She denied pain, numbness, and tingling. All extremities pink, warm, and dry. Lower abdomen ecchymotic following femoral artery sheath removal. All other systems within normal limits. No further neurological deficits.</td>
<td>WBC: 3.4 (3.1-12.0)</td>
</tr>
<tr>
<td>Gran: 47.0 H; High due to inflammatory response. Need to continue to monitor this value in order to determine need for treatment.</td>
<td>RBC: 3.93 L (4.0-5.3); Not significantly low, but need to monitor these values for blood loss.</td>
</tr>
<tr>
<td>HCT: 36.3 (36-45)</td>
<td>ACT: 115 L (75-105 secs); Slightly high due to administration of ASA as anti-PLT agent. Need to monitor for risk of bleeding.</td>
</tr>
<tr>
<td>All other values within normal limits. Overall, with this patient, there was a need to monitor CBC in order to detect infection or blood loss; clotting times and platelets for bleeding risk.</td>
<td></td>
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</tbody>
</table>

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