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*AJNR Am J Neuroradiol* 1998, 19 (8) 1541-1547
http://www.ajnr.org/content/19/8/1541

*AJNR Am J Neuroradiol* 19:1541–1547, September 1998

# Thromboembolic Events Associated with the Treatment of Cerebral Aneurysms with Guglielmi Detachable Coils

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*BACKGROUND AND PURPOSE:* **The purpose of this study was to document the prevalence, radiologic appearance, and treatment of thromboembolic events related to GDC embolization of cerebral aneurysms.**

*METHODS:* **The clinical and radiologic records of all patients undergoing GDC treatment of intracranial aneurysms at our institution were reviewed. All cases in which unexpected complications occurred were selected. Those complications related to presumed thromboembolic events were analyzed.**

*RESULTS:* **Of 59 patients (60 aneurysms) treated with GDCs, 17 (28%) experienced thromboembolic events. Seven patients had transient ischemic attacks and 10 had strokes. In 10 patients, the deficits occurred during or immediately after the procedure; in the rest, the complications were delayed. In six patients, all radiologic investigations were negative for infarction and in seven patients, CT scans showed new ischemic lesions. In four patients, MR imaging alone showed infarcts, and in four of nine patients who underwent subsequent angiography, acute ischemic findings were demonstrated. Eight patients were treated with volume expansion, eight with full heparinization, and one patient underwent intraarterial thrombolysis. Clinical outcome was excellent or good in 14 of 17 patients, with only three patients (5%) incurring permanent neurologic deficits.**

*CONCLUSION:* **Thromboembolic events related to GDC treatment may be more common than has been reported in the literature. In our experience, this rate was 28%, with persisting deficits in 5%. These events can occur after uncomplicated procedures and may be unaccompanied by radiologic findings. Clinical outcome is usually favorable.**

The treatment of intracranial aneurysms has been revolutionized by the introduction of detachable coils for endovascular therapy (1–4). The Guglielmi detachable coil (GDC) is the most popular of these devices, and there is growing evidence that it is a safe and effective method for treating aneurysms (5). The role of endovascular therapy relative to surgery has not yet been defined.

As operators gain experience with coil treatment, the prevalence of such procedure-related complications as aneurysmal rupture, parent artery occlusion, coil migration, and vasospasm has decreased to under 10% (5). The prevalence of thromboembolic complications, including transient ischemic attack (TIA) and stroke, has been reported to be between 2.5% and 21% (5, 6). It is not unusual, however, to encounter either transient or permanent ischemic events during and after an uneventful embolization procedure. Although radiologic investigations are often negative, and patients usually recover, we decided to review our experience in an attempt to quantify the frequency, clinical and radiologic findings, possible origins, treatment, and outcome of these thromboembolic events.

## Methods

The clinical and radiologic records of all patients who underwent GDC treatment of intracranial aneurysms at our institution since 1991 were reviewed. All cases in which transient or permanent complications or unexpected events occurred were then selected. Cases in which complications were related to grade of subarachnoid hemorrhage, vasospasm, or technical events, such as aneurysmal rupture, coil migration, vessel occlusion, or dissection, were excluded. For the remaining cases, we analyzed the clinical presentation, radiologic findings, treatment, and clinical outcome.

Received October 9, 1997; accepted after revision February 9.

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**TABLE 1: Clinical and radiologic findings, treatment, and outcome in 17 patients with thromboembolic complications associated with GDC treatment for cerebral aneurysms**

| Case | Age, y/Sex | Presentation | Size and Location of Aneurysm | Reason for Coils | Coil Treatment |
|---|---|---|---|---|---|
| 1 | 52/F | Incidental | Small (8 mm), R MCA | Prior infarcts, medical concerns | 28-cm GDC, NLA, heparin (9600 U) |
| 2 | 72/F | Confusion, speech and gait difficulties | Giant, wide-necked, ant. comm. | Unclippable | 3 GDC, NLA, heparin (3600 U) |
| 3 | 77/F | Imbalance, diplopia | Large, L post. comm. | Patient's choice | 10 GDCs, NLA, heparin (19,000 U) |
| 4 | 49/M | SAH | Basilar bifurcation, wide-necked | Unclippable | 2 GDCs (20 cm), NLA, heparin (3600 U) |
| 5 | 64/F | Vertigo | Large R post. comm., wide-necked | Unclippable | 11 GDCs, 80% occlusion, GA, heparin (18,500 U) |
| 6 | 45/F | SAH | Basilar bifurcation (12 mm) wide-necked (6–7 mm) | Unclippable | 2 GDCs, partial occlusion, GA, heparin (9000 U) |
| 7 | 65/M | Headaches, visual disturbances | Large L carotid ophthalmic, wide-necked | Patient's choice | 7 GDCs, NLA (2 sessions) heparin: session 1, 12,000 U; session 2, 10,000 U |
| 8 | 53/F | Dizziness | Basilar fenestration, large, wide-necked | Unclippable | 4 GDCs, NLA, heparin (9000 U) |
| 9 | 60/M | SAH | Ant. comm. | Unclippable | Nearly complete occlusion, GA, 5 GDCs, 61 cm, heparin (14,000 U) |
| 10 | 72/F | SAH | L MCA | Too ill for surgery | Nearly complete occlusion, GA, 5 GDCs, 95 cm, heparin (6000 U) |
| 11 | 67/M | SAH | Ant. comm., large, wide-necked | Too ill for surgery | 7 coils, nearly complete occlusion, NLA, heparin (10,000 U) |
| 12 | 37/M | SAH | Giant L MCA | Incomplete clipping | 4 GDCs, 43 cm, nearly complete occlusion, NLA, heparin (11,000 U) |
| 13 | 59/F | SAH | L paraophthalmic, large, wide-necked | Unclippable | 6 GDCs, tiny neck remnant, NLA, heparin (7300 U) |
| 14 | 55/M | Brain stem findings | Giant L vertebrobasilar | Unclippable | 4 GDCs, incomplete cclusion, NLA, heparin (23,000 U) |
| 15 | 54/M | Gait disturbance | Giant R ACA, wide-necked (4–5 mm) | Unclippable, calcified | Complete occlusion, GA, 5 GDCs, heparin (9000 U) |
| 16 | 52/F | Vertigo, bruit | Giant L petrous ICA, wide-necked | Unclippable persistent trigeminal artery | 27 GDCs, 95% occlusion, GA, heparin (45,000 U) |
| 17 | 70/F | SAH | R ICA (paraophthalmic) | Unclippable | 80-cm GDCs, GA, heparin (11,000 U) |

Note.—ACA, anterior cerebral artery; angio, angiography; ANT, anterior; comm, communicating artery; GA, general anesthesia; GDC, Guglielmi detachable coils; ICA, internal carotid artery; LOC, level of consciousness; MCA, middle cerebral artery; neg, negative; NLA, neuroleptanesthesia; post, posterior; SAH, subarachnoid hemorrhage; TPA, tissue plasminogen activator.

## Results

### *Clinical Presentation and Radiologic Findings*

In all, 60 aneurysms were treated with GDCs in 59 patients. We identified 17 cases (28%) in which thromboembolic events occurred during or immediately after the procedure (Table). The study population included 10 women and seven men ranging in age from 45 to 77 years. Nine patients had subarachnoid hemorrhage and eight had other neurologic symptoms. Aneurysmal locations are shown in the Table. Five aneurysms were giant (>2.5 cm diameter), three were large (1 to 2.5 cm), and the rest were small (<1 cm). Nine aneurysms were wide-necked (5 mm or larger).

### *Embolization and Clinical Findings*

Nine of the procedures were performed with the patient under neuroleptanesthesia and eight with the patient under general anesthesia. Heparin dosages during treatment varied considerably (see Table). Bolus injections at the beginning of the procedure were between 3000 and 5000 U, with 1000 U given approximately every hour. In three procedures performed immediately after unsuccessful

**Table 1 continued.**

| Complications | Treatment | Radiologic Findings | Outcome |
|---|---|---|---|
| Immediate L hemiplegia, L neglect lasting 20 min | Heparin, fluids | Angio and CT neg | Complete recovery |
| Decreased LOC, R hemiparesis within 12 hr | Fluids | CT neg, delayed angio 1 wk showed probable L ACA embolus with recanalization | Good recovery |
| Immediate R hemiparesis, aphasia lasting several days | Heparin | CT neg, MR showed L parietal and occipital infarcts and metal artifact | Nearly complete recovery |
| Mild L hemiparesis at 48 hr, transient intermittent disorientation | Fluids | CT neg, MR showed L splenial and deep white matter infarcts | Good recovery |
| Immediate L arm plegia on awakening from anesthesia | Oxygen, fluids | Angio normal, CT showed R caudate and capsule, frontal infarcts | Good recovery but residual deficits |
| L hemiplegia on awakening from anesthesia | Fluids | Angio neg, MR and CT showed L occipital, cerebellar, and brain stem infarcts | Complete recovery |
| Immediate receptive aphasia, R-sided drift during first procedure | Fluids | Angio neg, CT neg, MR at 48 hr showed L frontal and parietal infarcts | Complete recovery |
| Reading difficulty at 48 hr | Fluids | Angio neg, MR showed tiny L cerebellar and occipital infarcts | Complete recovery |
| Immediate L hemiparesis on awakening from anesthesia | Heparin, fluids | CT and angio neg | Complete recovery in 24 hr |
| Transient aphasia at 36 hr | Heparin, ASA | Angio showed slow filling of L MCA branches distally | Stroke |
| L arm and leg paresis at 6 hr | Fluids, volume expansion | Angio showed slow filling of distal R A2, CT showed L frontal lucencies | Nearly complete recovery |
| Immediate L arm drift, speech difficulty, R homonymous hemianopsia | TPA, thrombolysis (10 mg TPA) 6 hr after embolization | Angio showed multiple MCA branch occlusions, CT showed small L frontal infarct | Nearly complete recovery |
| R drift, speech difficulties, R leg neglect at 6 hr | Heparin, volume expansion | Angio and CT neg, MR showed L MCA infarct | Good recovery |
| L hemianopsia within 12 hr | Heparin | Angio neg | Complete recovery within hr |
| Immediate L hemiparesis on awakening from anesthesia | Heparin, volume expansion | Angio showed slow filling of ACA branches, CT and MR showed small R frontal infarcts | Complete recovery in 48 hr |
| Immediate expressive aphasia, R drift progressing to hemiplegia | Heparin, volume expansion | CT next day showed "watershed" infarcts | Good recovery |
| Immediate L hemiplegia, slurred speech | Fluids | Angio neg, CT next day showed R frontal and frontoparietal infarcts | Severe persistent deficits |

surgery, initial bolus injections were not given. Catheter flushing solutions contained 3000 U per 500 mL, and ranged from a total dose of 3000 U to 30,000 U, depending on the length of the procedure. Combined bolus and catheter flush solution dosages ranged from 3600 U to 45,000 U. Initially, the bolus injections were not routinely administered in patients with acute subarachnoid hemorrhage, but as we gained experience, bolus injections were given in these cases as well.

Seventeen patients (28%) had clinical or radiologic evidence of a TIA or stroke during or after embolization (see Table). Seven patients experienced TIAs and 10 had strokes. In 10 patients, the deficits were noted immediately after the procedure or upon awakening from general anesthesia. Neurologic deficits were noted within 12 hours after the procedure in four patients, at 36 hours in one patient, and at 48 hours in two patients.

### *Postprocedural Radiologic Findings and Treatment*

In six patients, all radiologic investigations were negative for new infarction, and in seven patients, CT scans showed new ischemic lesions. In four patients, MR images alone initially showed infarcts, and in four of nine patients who underwent subsequent angiography, branch occlusions, distal emboli, or slow flow were demonstrated. Aneurysmal occlusion was angiographically complete in seven patients, nearly complete in five, and incomplete in five.

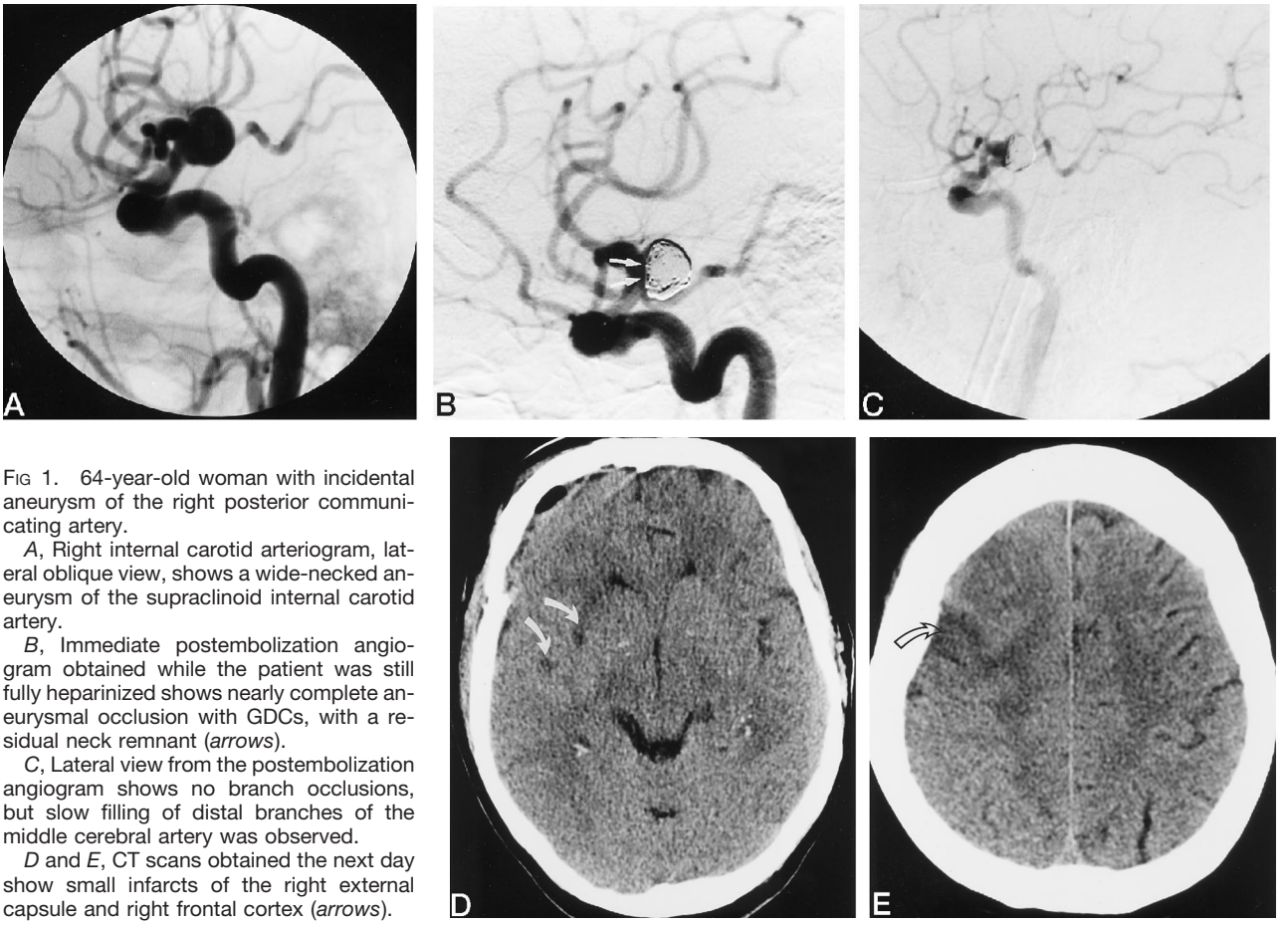


FIG 1. 64-year-old woman with incidental aneurysm of the right posterior communicating artery.

*A*, Right internal carotid arteriogram, lateral oblique view, shows a wide-necked aneurysm of the supraclinoid internal carotid artery.

*B*, Immediate postembolization angiogram obtained while the patient was still fully heparinized shows nearly complete aneurysmal occlusion with GDCs, with a residual neck remnant (*arrows*).

*C*, Lateral view from the postembolization angiogram shows no branch occlusions, but slow filling of distal branches of the middle cerebral artery was observed.

*D* and *E*, CT scans obtained the next day show small infarcts of the right external capsule and right frontal cortex (*arrows*).

Eight patients were treated with volume expansion, fluids, and oxygen; eight patients with full systemic heparinization and aspirin; and one patient underwent intraarterial thrombolysis. Clinical outcome was excellent or good in 14 of 17 patients, with only three patients (5%) incurring permanent neurologic deficits.

## *Representative Cases*

*Case 5.*—A 64-year-old woman with vertigo and light-headedness had an incidental aneurysm of the right posterior communicating artery (Fig 1A). The aneurysm could not be clipped owing to atherosclerotic calcification of the neck, and GDC embolization was performed under general anaesthesia with a total dose of 18,000 U of heparin. Because of the wide neck of the aneurysm, a double microcatheter approach was used in which the first coil (8 mm × 30 cm) was not detached but was used as a mesh to stabilize smaller coils, which were introduced and detached through a second microcatheter. Approximately 80% of the aneurysmal lumen was occluded using five coils, and the postembolization angiogram showed no evidence of branch occlusion (Fig 1B). Upon awakening from anesthesia, the patient was noted to have paralysis of the left arm, although repeat angiography showed no evidence of branch occlusion (Fig 1C). Full systemic heparin therapy was begun, but left-sided weakness and parietal signs persisted. A CT head scan on the day after the procedure showed right frontal and deep temporal infarcts (Fig 1D and E), and repeat angiography showed slow filling of posterior frontal branches of the middle cerebral artery but no branch occlusions. The patient made a good recovery over several months but was left with some residual weakness in her left hand.

*Case 7.*—A 65-year-old man with a mild visual disturbance had a large, partially calcified aneurysm of the left internal carotid–ophthalmic artery (Fig 2A). Owing to the size, location, and calcification of the lesion, the patient agreed to endovascular therapy. The procedure was performed with the patient under neuroleptanesthesia, with a total dose of 12,000 U of heparin. The aneurysm was incompletely packed with four GDCs, which resulted in approximately 85% obliteration (Fig 2B). After deposition of the last coil, a receptive aphasia developed. Repeat angiography showed no branch occlusions. Full systemic heparin therapy was continued, and findings on an immediate CT head scan were normal. An MR study performed 2 days later showed left frontal, parietal, and corona radiata infarcts (Fig 2C and D). The patient made an excellent recovery, and 3 months later he was asymptomatic. The aneurysm was then completely packed with GDCs during a second embolization procedure.

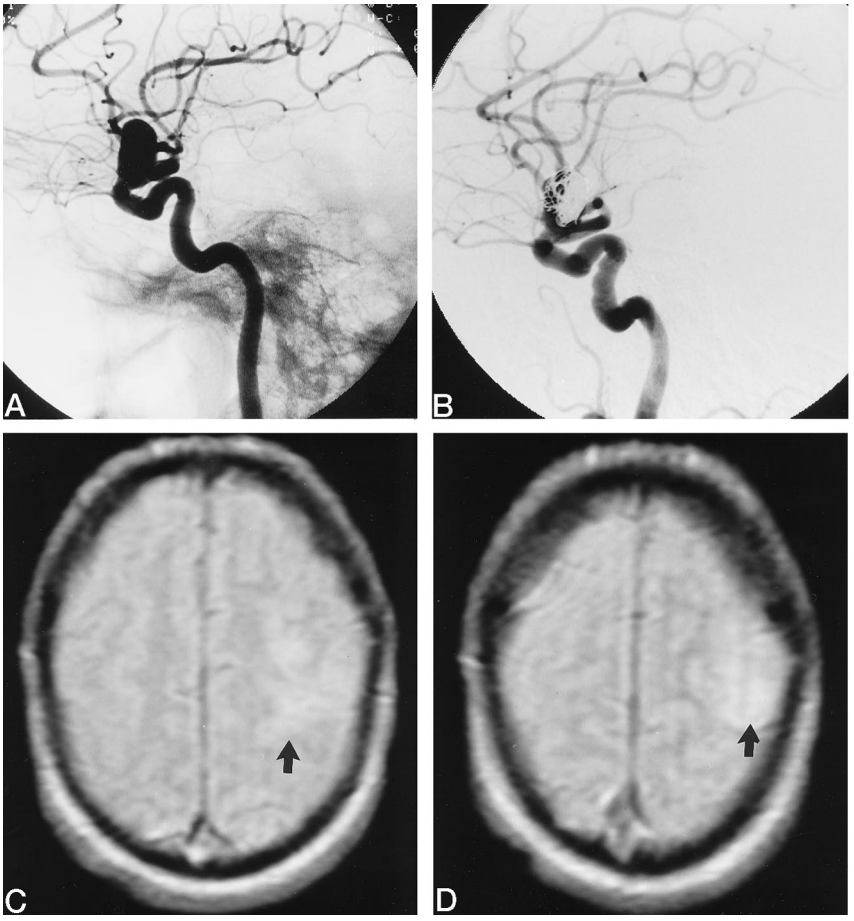


FIG 2. 65-year-old man with partially calcified aneurysm of the left carotid–ophthalmic artery.

*A*, Left internal carotid arteriogram, lateral view, shows a wide-necked aneurysm of the internal carotid–ophthalmic artery.

*B*, The first postembolization angiogram shows subtotal occlusion of the aneurysm by GDCs. No further embolization was performed at this time owing to the development of a neurologic deficit.

*C* and *D*, Proton density–weighted MR images of the brain obtained 1 day later show cortical infarcts in the left frontal convexity (*arrows*).

## Discussion

Endovascular therapy is now an accepted method for treating intracranial aneurysms, although its precise relationship to surgical repair remains undefined. Endovascular techniques have evolved from proximal balloon occlusions (7) to intraaneurysmal balloon placement (8) to packing with platinum coils (2). The GDC system is now the most widely used endovascular treatment for aneurysms, and its safety and therapeutic efficacy have been well documented. In the largest series of 403 patients undergoing GDC treatment (5), 9% had complications related to technical difficulties. These included such events as unintentional parent artery occlusion, aneurysmal rupture, coil migration, and distal embolization. The prevalence of untoward cerebral embolization was 2.5% and tended to occur in wide-necked aneurysms with small residual necks. In other, smaller series, initial thromboembolic complication rates were as high 21% (6); however, as experience accumulated and routine heparinization during and after the procedures became routine, these reported rates of TIA and stroke have decreased to less than 10% (5, 9).

Review of our experience showed that the occurrence of postprocedural thromboembolic events in otherwise uncomplicated cases was not unusual, occurring in 28% of 60 embolization procedures and resulting in nine strokes (15%), although only three patients (5%) were left with neurologic deficits. It is unclear why our detection rate of thromboembolic episodes is higher than that generally reported in the literature. It may relate to the fact that nine of our 17 patients underwent the procedure under neuroleptanesthesia, thus permitting better neurologic monitoring and detection of new deficits. Our dosage of heparin given during the procedures has gradually increased over the years, and some of the early episodes may have been due to low levels of anticoagulation, although all patients except those treated immediately after unsuccessful surgical exploration received at least 8000 to 12,000 U by bolus and catheter flush infusion during the procedures. Thromboembolic episodes were still observed with our current regimen of heparinized saline catheter flushing infusions, a 5000-U bolus at the beginning of the procedure and 1000 U given every hour to keep the activated clotting time at approximately twice the normal value. In two of our procedures, a double catheter technique was used, in which two microcatheters were employed for coil introduction, and this may have increased the likelihood of thrombus formation and distal embolization.

There are many possible explanations for these embolic events. During initial catheterization of an aneurysm, the parent artery may be damaged. Friable clot or plaque within the parent artery or within the aneurysm may be disturbed, resulting in distal embolization. In the past, the electrolytic coil detachment process itself resulted in distal embolization of metal fragments that originated from the platinum–stainless steel solder junction. These metallic fragments were easily seen on MR images in one of our patients, but this problem was corrected by the manufacturer in 1994 (10). We have observed air bubbles in the heparinized saline solutions used to continuously irrigate guiding catheters during the procedures, and, if unnoticed, these can cause distal embolic complications. The strokes observed in case 17 are believed to have originated from this mechanism.

Initial imaging findings have usually been negative, with distal branch occlusions observed in only two patients, and slow distal flow in two of the nine patients who underwent angiography after their events. CT examinations, in our experience, are usually negative initially and may remain so, as MR imaging alone showed small lesions in four of the nine patients who had strokes.

There is abundant evidence that detachable coils induce chronic thrombus formation within experimental aneurysms (1, 11–13). These studies examined the aneurysms pathologically weeks to months after treatment. The evidence that clot forms rapidly during coil placement and electrolytic detachment in human aneurysms is less convincing. Horowitz et al (14) reported a case in which surgical exposure of an intracranial aneurysm 2 hours after embolization with GDCs revealed no evidence of thrombus formation. Despite the relative lack of evidence of rapid clot formation, we believe that clot at the aneurysmal neck that forms during or immediately after embolization is the likely cause of most of these thromboembolic events. These events tend to happen more often with wide-necked lesions (5), and our experience would support this, as nine of our cases fit this description. The clot that migrates from the thrombosing neck is usually small and will occlude small intracranial vessels, which accounts for the difficulty in immediate radiologic detection.

Treatment will depend on the radiologic appearance immediately after the event. Thrombus in a proximal arterial branch can be successfully treated with intraarterial thrombolysis, as occurred in one of our patients. Distal branch occlusions are best treated with full systemic heparinization and volume expansion. Most centers are now performing GDC embolizations under full systemic heparinization, even in patients with acute subarachnoid hemorrhage, to prevent these small emboli from forming. Heparinization may be continued for up to 48 hours and long-term aspirin therapy has been advocated (5). Careful attention must be paid to all catheter flushing solutions to prevent air emboli (17).

Particular care must be taken as packing of the aneurysmal lumen approaches the neck. Coils must not compromise the parent artery. It is desirable to occlude as much of the neck as possible to prevent aneurysmal regrowth. It is impossible, however, to control the amount of thrombus formation at the base of the coils adjacent to the parent vessel. There is evidence that the coils induce an inflammatory response leading to organization of intraluminal clot and eventual neointimal formation in some cases (12, 13); however, this is a more chronic phenomenon and in the acute stage there is no protection for the parent vessel. Even in the long term, intraluminal clot may remain friable and neointima may be absent from the aneurysmal neck (16, 17). Aneurysmal packing with a protective nondetachable balloon at the base may result not only in better obliteration of wide-necked aneurysms (18) but may afford some immediate protection from distal clot embolization.

## Conclusion

We have documented a relatively high prevalence of thromboembolic events (28%) during or immediately after otherwise uneventful GDC coiling of intracranial aneurysms. These are presumably due to distal embolization of friable thrombus originating from either the lumen or neck of the aneurysm. Radiologic findings may be minimal and most patients recover completely; we found only a 5% frequency of permanent stroke. The procedures should be performed under full heparinization with careful attention to catheterization technique and flushing solutions. In most cases, conservative treatment with anticoagulation, volume expansion, and hypertension will be adequate, with thrombolysis reserved for patients with proximal branch occlusions.

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