Intracranial hemorrhage associated with stent-assisted coil embolization of cerebral aneurysms: a cautionary report

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Object. The introduction of the Neuroform microstent has facilitated the embolization of complex cerebral aneurysms, which were previously not amenable to endovascular therapy. Typically, the use of this stent necessitates the administration of dual antiplatelet therapy to minimize thromboembolic complications. Such therapy may increase the risk of hemorrhage in patients who require concurrent external ventricular drainage and/or subsequent permanent cerebrospinal fluid diversion.

Methods. The authors’ neurosurgical database was queried for all patients who underwent stent-assisted coil embolization for cerebral aneurysms and who required an external ventricular drain (EVD) or ventriculoperitoneal (VP) shunt placement for management of hydrocephalus.

Results. Thirty-seven patients underwent stent-assisted coil embolization for intracranial aneurysms at the authors’ institution over a recent 2-year period. Seven of these patients required placement of an EVD and/or a VP shunt. Three of the 7 patients suffered an immediate intraventricular hemorrhage (IVH) associated with placement or manipulation of an EVD; 1 experienced a delayed intraparenchymal hemorrhage and an IVH; 1 suffered an aneurysmal rehemorrhage; and the last patient had a subdural hematoma (SDH) that resulted from placement of a VP shunt. This patient required drainage of the SDH and exchange of the valve.

Conclusions. The necessity of dual antiplatelet therapy in the use of stent-assisted coil embolization increases the risk of intracranial hemorrhage and possibly rebleeding from a ruptured aneurysm. This heightened risk must be recognized when contemplating the appropriate therapy for a cerebral aneurysm and when considering the placement or manipulation of a ventricular catheter in a patient receiving dual antiplatelet therapy. Further study of intracranial procedures in patients receiving dual antiplatelet therapy is indicated. (DOI: 10.3171/JNS/2008/108/6/1122)

Key Words • aneurysm • endovascular therapy • external ventricular drain • intracranial hemorrhage • Neuroform microstent

The introduction of the Neuroform microstent (Boston Scientific Neurovascular) has increased the ability of interventionalists to treat certain intracranial aneurysms that were previously outside the realm of endovascular therapy.1,3,5,11,17–20 Specifically intended for aneurysms with low dome/neck ratios (< 2), such stents use a Nitinol alloy that allows for a high degree of elasticity, facilitating navigation through the tortuous intracranial vessels that lie beyond the carotid siphon.6,14,15,23 The self-expanding nature of this stent further aids in its delivery and use. Nevertheless, this increased capability is weighed against any stent’s inherent thrombogenicity, which in most cases necessitates dual antiplatelet therapy.2,7,9,10 This prerequisite has to some extent limited our use of the Neuroform stent in the therapy of acutely ruptured aneurysms.

We report our experience treating 7 patients in whom the configuration of the aneurysm required stent-assisted coil embolization and in whom external ventricular drainage or permanent CSF diversion was required for management of the hydrocephalus. Hemorrhagic complications were analyzed and the relevant literature was reviewed. Based on our experience, we have identified an increased hemorrhagic risk in the setting of stent-assisted endovascular therapy and concurrent ventricular access. Although the majority of complications that occur during intracranial endovascular procedures are thromboembolic,2,7,10 the requirement for dual antiplatelet therapy also increases the risk of intracranial hemorrhage in those patients requiring both stent-supported coil embolization and ventricular drainage.

Clinical Materials and Methods

Patient Population

In a retrospective review of the neurosurgical database
at our institution, we identified 37 patients who underwent stent-assisted coil embolization for either a ruptured or an unruptured aneurysm over a 2-year period between September 2003 and September 2005. Institutional review board permission was sought and approved to review all outpatient, inpatient, procedural, anesthesia, and radiographic data in these 37 patients. The demographic characteristics of this group were as follows: 25 were female, 12 were male, and the mean age was 58.8 years. Twenty-six of the treated aneurysms were unruptured and 11 were ruptured. Seven of these patients required external ventricular drainage before or after a stent-assisted coil embolization of an intracranial aneurysm. No hemorrhagic complication was identified in the remaining 30 patients who did not require CSF diversion.

**Treatment Methods**

All patients in our series were given a loading dose of 325 mg aspirin and 375 mg clopidogrel prior to undergoing common femoral artery sheath placement and diagnostic angiography. During the procedure, heparin was used for anticoagulation. Activated clotting times were maintained between 250 and 300 seconds, and anticoagulation was maintained in all patients throughout the procedure with hourly maintenance doses of heparin. Neuroform stents were introduced into all patients through an appropriate guiding catheter, navigated into position, and then unsheathed without complication. Stent-assisted coil embolization was accomplished with a variety of framing, hybrid expansile, and platinum coils. At the end of each procedure, control angiography studies demonstrated complete or near complete obliteration of the aneurysm and normal filling of the surrounding cerebral vasculature, except in 1 patient in whom the parent vessel was sacrificed. There was no evidence of thrombus formation on or in the vicinity of the coil mass. The patients were maintained on daily doses of aspirin (325 mg) and clopidogrel (75 mg).

**Results**

The 7 patients ranged in age from 41 to 74 years (mean age 53 years). All 7 patients had intracranial aneurysms; 6 of the lesions were acutely ruptured and one presented electively. Six patients had posterior circulation aneurysms (4 in the BA terminus, one in the PCA, and 1 in the PICA). There was only 1 anterior circulation lesion, a giant proximal ICA aneurysm. All patients required EVDs, which were placed prior to the procedure in 5 of the patients and after the procedure in 2. Three patients experienced IVH as a result of initial EVD placement or its subsequent replacement. One patient suffered rebleeding from an incompletely coil-occluded aneurysm, with associated IPH and intraventricular extension 2 weeks after the procedure. One patient experienced a rehemorrhage during the endovascular procedure, and the last patient with complications developed an SDH following VP shunt placement. There was 1 patient in this series who experienced no hemorrhagic complication as a result of dual antiplatelet therapy. The mean mRS score for patients in this series was 4 (Table 1).

**Case Reports**

*Case 1*

This 51-year-old man presented with Hunt and Hess Grade V SAH from a 5 × 5 × 8-mm right BA–SCA aneurysm with a 5-mm neck, and he successfully underwent stent-assisted coil embolization with > 95% angiographically confirmed occlusion (Fig. 1). An EVD was placed for management of hydrocephalus prior to endovascular intervention. The patient was started on dual antiplatelet therapy. After failure to wean him from the EVD, the patient underwent VP shunt placement with a medium-pressure valve. The risk of thromboembolic events prompted the continuation of dual antiplatelet therapy, despite the fact that he was undergoing a surgical procedure. Several days after the procedure, a neurological decline was noted. A CT scan demonstrated a right-sided SDH with 9 mm of right-to-left shift. The patient was returned to the operating room for drainage of the SDH and placement of a programmable valve. His platelet function assays were normalized prior to surgery with a platelet transfusion, and antiplatelet therapy was restarted the day after surgery. The patient had no thromboembolic complication. He was discharged on a regimen of clopidogrel only and eventually made a recovery to an mRS score of 3.

*Case 2*

This 74-year-old woman presented with a Hunt and Hess...
Grade III SAH from a right-sided PCA aneurysm. The patient underwent ventriculostomy 1 day prior to endovascular intervention. A near complete obliteration of the right-sided PCA aneurysm was accomplished using stent-assisted coil embolization, with > 95% angiographically confirmed occlusion and without angiographic evidence of stent thrombus or flow-limiting complications (Fig. 2). The patient was successfully weaned from her EVD and discharged on a regimen of aspirin and clopidogrel after 25 days in the hospital. She achieved an mRS score of 1 over the next 14 months. There were no hemorrhagic complications.

Case 3

This 41-year-old man presented with a Hunt and Hess Grade V SAH from a giant left-sided ICA aneurysm. Despite EVD placement (without hemorrhagic complication) and aggressive resuscitation, the patient remained moribund. The configuration of the aneurysm precluded its complete occlusion despite stent-assisted coil embolization (50–75% angiographically confirmed occlusion was achieved). Definitive surgical management was deferred until the patient’s neurological recovery was optimized. The patient was successfully weaned from his EVD over several weeks and he was discharged after a prolonged hospital stay to a rehabilitation facility on a regimen of aspirin and clopidogrel; his mRS score was 4. Prior to surgical intervention, he returned with IPH and IVH 3 months after his initial hemorrhage. Ventriculostomy placement was further complicated with IVH, which was probably related to dual antiplatelet therapy. He eventually died of his illness despite aggressive critical care. The likely cause of the hemorrhage was the partially coil-occluded aneurysm.

Case 4

This 48-year-old woman presented with a Hunt and Hess Grade III SAH from a 10 × 8 × 7-mm BA terminus aneurysm with a 6-mm neck. External ventricular drainage was established 1 day prior to her endovascular procedure for management of hydrocephalus. Successful stent-assist-
ed coil embolization was achieved, with 100% angiographically confirmed occlusion (Fig. 3). While receiving dual antiplatelet therapy, she required exchange of her EVD, which had become occluded with debris. This was complicated by IVH, requiring prolonged drainage prior to permanent CSF diversion (Fig. 3D). After successful VP shunt placement without hemorrhagic complication, she was discharged and eventually recovered to an mRS score of 2.

Case 5

This 45-year-old woman harboring an unruptured 6 × 6–mm BA terminus aneurysm with a 5.5–mm neck presented for elective coil embolization. The patient received a loading dose of clopidogrel and aspirin prior to undergoing stent-assisted coil embolization, with which 100% occlusion was achieved (Fig. 4). Throughout the procedure, no hemodynamic fluctuation or angiographic evidence of hemorrhage was noted. Nevertheless, the patient awoke from anesthesia with a severe headache and meningismus. A head CT scan obtained without contrast material confirmed SAH and hydrocephalus. Unfortunately, the patient’s prolonged hospital course was marked by repeated IPHs from EVD placement and exchange. This occurred despite preprocedural platelet transfusion. She eventually developed bacterial ventriculitis and died of IPH/IVH/ventriculitis–induced cerebral edema.

Case 6

This 64-year-old man presented with a Hunt and Hess Grade I SAH from a 15 × 13 × 12–mm multilobulated BA terminus aneurysm with a 9-mm neck. The patient underwent stent-assisted coil embolization, resulting in 90–95% obliteration of the aneurysm. After the procedure the patient was noted to be more lethargic. An unenhanced CT scan of the head demonstrated hydrocephalus. Several hours after uneventful placement of a ventriculostomy, bright red blood was noted to be coming from the EVD. On repeated imaging there was clear evidence of IVH from the EVD insertion site, with worsening hydrocephalus. This prompted placement of another catheter in the left ventricle. Despite these efforts, the patient’s condition deteriorated, and brain death was declared.

Case 7

This 50-year-old woman presented with a Hunt and Hess Grade IV acute SAH from a right-sided PICA aneurysm, which had reruptured 3 days prior to the patient’s arrival at our institution. She underwent EVD placement prior to endovascular intervention. Subsequent neurological decline prompted CT angiography, which revealed vasospasm without IVH or further SAH. In light of this, intervention was planned to treat both the vasospasm and the ruptured aneurysm. Appropriate dual antiplatelet therapy was administered, but prior to the delivery of the Neuroform stent, control angiography demonstrated extravasation of contrast agent from the aneurysm, and bright red blood from the ventriculostomy was identified. This prompted immediate positioning of the stent across the aneurysm neck, followed by immediate coil embolization of the aneurysm. Because of our inability to arrest bleeding completely by coil occlusion of the aneurysm, the VA was sacrificed (Fig. 5). The patient was successfully weaned from her EVD over the following 12 days, and she was transferred to a rehabilitation facility 22 days after her initial aneurysm rupture, where she eventually recovered to an mRS score of 4.

Discussion

The use of an inherently thrombogenic stent in the intracranial circulation requires complete neutralization of platelet aggregation to minimize thromboembolic complications. However, patients with ruptured aneurysms...
may often require further neurosurgical intervention after coil embolization, specifically insertion of an EVD and VP shunt placement. To minimize the hemorrhagic complications resulting from these procedures, coagulation parameters and platelet function must be normalized, even though, in the patient who has undergone stent-assisted coil embolization, the restoration of platelet function is fraught with thromboembolic events, which in fact account for the majority of complications associated with endovascular treatment of intracranial aneurysms. Under these circumstances, there is no therapeutic balance to reconcile the paradox of complete neutralization of platelet aggregation for intracranial stent placement with normalization of platelet aggregation for surgery. In light of this conundrum, we have retrospectively reviewed our experience in patients who have undergone stent-assisted coil embolization and internal or external CSF diversion. A more comprehensive review of our experience with the Neuroform stent will be the topic of a future manuscript.

The collective reports in the literature reviewing series of stent-assisted coil embolizations have included both ruptured and unruptured aneurysms. Nevertheless, reports of hemorrhagic complications from EVD and VP shunt placement procedures among the patient population with SAH alone have been limited. More frequently noted are hemorrhagic complications such as gastrointestinal bleeding, retroperitoneal hematomas, and pseudoaneurysm formation. In a report reviewing their preliminary experience with 50 aneurysms, Lylyk et al. treated a total of 24 ruptured aneurysms with stent-assisted coil embolization. There was no mention of the number of patients who required either EVD or VP shunt placement, limiting the

![Fig. 3. Case 4. Angiograms (A–C) and CT scan (D) demonstrating a wide-necked, bilobed BA terminus aneurysm that was successfully embolized with stent assistance. Exchange of a nonfunctioning EVD resulted in IVH.](image)
ability to assess whether the dual antiplatelet therapy increased the risk of such adjunctive neurosurgical interventions.

Benitez et al. reviewed 48 patients who underwent stent-assisted coil embolization, 16 of whom had ruptured aneurysms. These authors recognized the theoretical risk of hemorrhagic complications associated with EVD placement in the context of dual antiplatelet therapy, and they addressed this concern with preprocedural placement of EVDs in patients noted to have early hydrocephalus. Among the patients with ruptured aneurysms and stent-assisted coil embolization, these authors reported no hemorrhagic complications as a result of ventriculostomy; however, there is no mention of the number of patients who actually underwent ventriculostomy or when the need for subsequent permanent CSF diversion arose under antiplatelet conditions.

In this report, we have identified a significant hemorrhagic complication rate in 6 patients presenting with wide-necked ruptured aneurysms that required stent assistance for coil insertion as well as 1 patient harboring an unruptured wide-necked aneurysm. There were a total of 6 hemorrhagic complications (3 of them fatal) among 37 patients who underwent stent-assisted coil embolization. The patient in Case 1 suffered a hemorrhagic complication as a result of a VP shunt being placed while antiplatelet therapy was being given; the patients in Cases 3–6 suffered hemorrhages from placement of the EVD; and the patient in Case 7 suffered from a repeated hemorrhage prior to a definitive treatment. The extent of these hemorrhages was probably worsened by the platelet inhibition. The patient in Case 2 was the only one on dual antiplatelet therapy with ventriculostomy who had no hemorrhagic complication.

The risk of hemorrhage in patients undergoing endovascular aneurysm coil insertion and ventriculostomy has been previously reported. The largest series includes 119 patients who underwent EVD placement followed by anticoagulation with heparin and endovascular therapy. These authors furthermore report on 251 patients who underwent EVD placement without heparinization or endovascular intervention. The symptomatic hemorrhagic complication rates among patients in these 2 groups were reported as 0.08 and 1.2%, respectively. The reports of hemorrhagic complications in patients receiving dual antiplatelet therapy who have undergone EVD or CSF shunt placement are limited. Although the historic data set is not fully congruent with the clinical scenarios of our patient population, it does represent a relative point of reference. The main distinction is that 4 of our 6 hemorrhagic complications resulted from placement or exchange of a ventricular catheter.

![Image](https://www.neurosurgery.org/assets/images/1083252419.png)

**Fig. 4.** Case 5. A 3D reconstruction (A) of the unruptured wide-necked BA terminus aneurysm in this patient, with the planned path of the Neurostent marked by *gray lines*. Anteroposterior (B) and lateral (C) angiographic views of the positioned stent and framing coils. Angiogram (D) demonstrating technically successful embolization of the aneurysm. *Arrows* indicate the position of the stent within the vessel crossing the aneurysm. Axial CT scans (E and F) demonstrating SAH and hydrocephalus the day after the procedure, which required an EVD. This was complicated by further IVH.
in a patient who was receiving full dual antiplatelet therapy after endovascular therapy. Collectively, our experience with the Neuroform stent has resulted in an overall 16.2% hemorrhagic complication rate, and an 85% hemorrhagic complication rate in patients who require both stent-assisted coil embolization and external ventricular drainage.

More recent reports have begun to address strategies for the use of stent-assisted coil embolization. In their review of 64 cases, Fiorella et al. describe their experience with 8 patients who had ruptured aneurysms. These authors recommend a staged procedure, in which the aneurysm is incompletely occluded with coils until all issues related to CSF management are resolved. At that point, according to their strategy, the patient may be pretreated with antiplatelet agents and then receive embolization with stent assistance during a delayed second stage. Yet another strategy recommended by Benitez et al. for patients with SAH who are being considered for stent-assisted coil embolization is placement of an EVD prior to the procedure in patients exhibiting early hydrocephalus. Although these protocols may lower the risk of hemorrhagic complications, they remain suboptimum in certain clinical scenarios: patients who may eventually need an EVD for management of intracranial pressure cannot always be identified at the time of endovascular intervention (Case 6 in our series, for instance). Furthermore, the relative efficacy of incomplete coil embolization to protect from rerupture remains debatable. We consider a single definitive intervention superior to a staged intervention, especially in the management of lesions in patients with higher-grade SAH, who are already destined to have a prolonged hospital course.

Application of these treatment strategies retrospectively to the patients in our series further demonstrates the inherent limitation in preventing hemorrhagic events. Five of the 7 patients in our series had preprocedural EVD placement as recommended by Benitez et al., but 4 of them still suffered hemorrhagic events from subsequent replacement of EVDs or VP shunt placement. Of the 2 patients in whom an EVD was placed after the procedure, the patient in Case 6 had no evidence of hydrocephalus on her admission CT scan and a clinical presentation of Hunt and Hess Grade I. Despite a technically successful embolization, the patient required an EVD for hydrocephalus, and this was complicated by IVH.

There is a scarcity of evidence-based data regarding the reversal of dual antiplatelet therapy and safe neurosurgical intervention in patients with intracranial stents. Typically the urgent need for intervention coupled with the thromboembolic risks associated with intracranial stents preclude clinicians from waiting for normalization of platelet aggregation over a period of 5–7 days. Thus, in these clinical scenarios, rapid improvement in platelet function can only be accomplished by platelet transfusion. At our institution, we now withhold dual antiplatelet therapy for 24 hours and normalize platelet function assays, adenosine diphosphate, and epinephrine aggregometry, with platelet transfusion performed prior to intervention whenever possible. In emergency settings, intervention follows rapid transfusion of platelets with normalization of platelet function assays. Patients are continued on dual antiplatelet therapy in the postoperative period.

At our institution, as in many others, the approach to patients with SAH is multidisciplinary. The decision to proceed with endovascular or surgical therapy in patients with aneurysmal SAH is typically made at the completion of the diagnostic angiogram in consultation with the neurosurgical team. Should the anatomy of the ruptured aneurysm require the use of stent assistance for successful emboliza-
Intracranial hemorrhage and stent-supported coil embolization

tion, surgical intervention may be judged as a more viable option in light of the significant hemorrhage risks described in this series.

Conclusions

The necessity of dual antiplatelet therapy in the use of stent-assisted coil embolization significantly increases the risk of intracranial hemorrhagic complications and possible rebleeding from an incompletely treated aneurysm. This heightened risk must be recognized when selecting the initial therapy for wide-necked ruptured intracranial aneurysms and also when contemplating placement of a ventricular catheter in a patient who is receiving dual antiplatelet therapy. Initial surgical therapy may be preferred, especially in patients with higher-grade SAH who are more likely to require such interventions.

Disclaimer

No financial support and no grant assistance was received for the generation of this study. We have no financial interest in the materials mentioned in this paper.

Acknowledgments

We are grateful for the editorial assistance rendered by Andrea J. Porter and Rhonda Everett.

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