Safety and efficacy of complete versus near-complete coiling in treatment of intracranial aneurysms

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ABSTRACT

Objective: This study aimed to evaluate the clinical and angiographic outcomes of aneurysms that were completely or near-completely embolized and ascertain whether complete embolization is important in the stent-assisted coiling (SAC) of intracranial aneurysms.

Methods: This retrospective study enrolled 390 patients (417 aneurysms). Among them, complete (100%) or near-complete (>90%) angiographic obliteration of the aneurysms on immediate angiography was accomplished. Baseline characteristics, complications, angiography follow-up results, and clinical outcomes were analyzed.

Results: Cumulative adverse events occurred in 30 patients (7.7%), including thromboembolic complications in 17 (4.4%), intraoperative rupture in 10 (2.6%), and others in 3 (0.8%). Statistical analyses revealed an increased intraprocedural rupture rate in the initially completely occluded aneurysms (5.6% compared with 1.0%). The incidence of cumulative adverse events was higher in patients with completely occluded aneurysms (11.1%) than in those with near-completely occluded aneurysms (5.5%). Angiography follow-up was available for 173 aneurysms. Aneurysm occlusion status at follow-up was correlated with stent placement ($p = 0.000$, odds ratio = 5.847), size ($p = 0.000$, odds ratio = 6.446 for tiny aneurysms; and $p = 0.001$, odds ratio = 5.616 for small aneurysms), and initial aneurysm occlusion status ($p = 0.001$, odds ratio = 3.436). Complete occlusion at follow-up was seen in 82.6% of the initially complete occlusion group versus 63.0% of the initially near-complete occlusion group. Complete occlusion at follow-up was higher in the initially completely occluded aneurysms with SAC (100%) than in the initially completely occluded aneurysms without SAC (65.2%).

Conclusions: Initial complete treatment may lead to higher complication rates and good clinical outcomes at follow-up. Stent placement may enhance progressive aneurysm occlusion. Initial complete occlusion with SAC can provide durable closure at follow-up.

Introduction

With advances in endovascular techniques, endovascular coil embolization of intracranial aneurysms has become a valid alternative to surgical clipping.1–3 Aneurysm recanalization is a major shortcoming of endovascular coiling techniques, as some aneurysms are incompletely embolized. Studies focusing on the outcomes of completely and near-completely coiled intracranial aneurysms are limited. Some scholars described that the use of stent-assisted technology for the treatment of aneurysms facilitates a higher coil packing density and more stable aneurysm neck sealing.4–8 Neurointerventionists wonder how densely to pack a stented aneurysm in daily practice. Here we conducted a retrospective single-center analysis of the short- and mid-term clinical and angiographic outcomes of completely or near-completely embolized aneurysms. We also aimed to ascertain whether complete embolization is important in stent-assisted coiling (SAC) of intracranial aneurysms.

Materials and methods

Patient characteristics

The study was approved by the local institutional review board and ethics committee. We retrospectively reviewed 451 patients who underwent endovascular treatment in our institution between July 2004 and June 2015, in whom a total of 481 intracranial aneurysms were intervened. Among them, complete (100%) or near-complete (>90%) angiographic obliteration of the aneurysms on immediate angiography was accomplished in 417 aneurysms (390 patients) (Fig. 1).
Results

The patient characteristics and aneurysm features are summarized in Table 1. The cohort consisted of 160 males (41.0%) and 230 females (59.0%) with a median age of 57 years (range, 16–82 years). Of the 417 aneurysms, 259 (62.1%) were ruptured and 158 (37.9%) remained unruptured. The 2 groups were similar in all baseline characteristics.

Initial angiography manifestations

The aneurysm size was up to 3 mm in 78 aneurysms (18.7%), 3–10 mm in 314 aneurysms (75.3%), 11–25 mm in 22 aneurysms (5.3%), and more than 25 mm in 3 aneurysms (0.7%). The aneurysms were located in the internal carotid artery (n = 215), middle cerebral artery (n = 50), anterior communicating artery (n = 104), and other arteries (n = 48).

Stents used in treatment

Among the 417 aneurysms, 197 were treated with SAC using the Enterprise stent in 24, the Solitaire stent in 119, and the Neuroform stent in 54.

Adverse events and mortality

Adverse events are summarized in Table 2. Thromboembolic complications were seen in 17 patients (4.4%). Intraoperative rupture occurred in 10 patients (2.6%). Other adverse events occurred in 3 patients (one case each of gastrointestinal bleeding, coil stretching, and coil migration). Cumulative adverse events occurred in 30 patients (7.7%). Nineteen patients (4.9%) had a permanent disabling neurologic deficit (mRS 3–6). The overall mortality rate was 0.8% (3/390).

The statistical analysis revealed an increased rate of intra-procedural rupture in initial completely occluded aneurysms (5.6% versus 1.0%, p = 0.010). The incidence of cumulative adverse events was higher in patients with completely occluded aneurysms (11.1%) than in those with near-completely occluded aneurysms (5.5%) (p = 0.042).

Follow-up outcomes

Follow-up data were available for 299 patients (Table 3). During a median follow-up period of 30 months (range, 3–124 months), one case
SAH, subarachnoid hemorrhage.

Unless indicated otherwise, data are number of cases with percentages in parentheses.

* χ² test or Fisher’s exact test.

b Because of treatment-related complications, complications of SAH, or unfavorable evolution of SAH.

### Table 2

| Initial aneurysm occlusion status | Total | P value |
|----------------------------------|-------|---------|
| Complete (n = 126) | Near-complete (n = 291) |
|-------------------------------|------------------------|
| Ischemic events | 7 (5.6) | 10 (3.4) | 17 | 0.315a |
| Introporative rupture | 7 (5.6) | 3 (1.0) | 10 | 0.010b |
| Other adverse events | 0 (0) | 3 (1.0) | 3 | 0.557b |
| Cumulative adverse events | 14 (11.1) | 16 (5.5) | 30 | 0.042a |
| Permanent disabling | 9 (7.1) | 10 (3.4) | 19 | 0.096b |
| Neurologic deficit | 1 (0.8) | 2 (0.7) | 3 | 1.000b |

### Table 3

Potential risk factors related to follow-up results.

| Good outcome | Poor outcome | Total | P value |
|--------------|--------------|-------|---------|
| Median age, years | 57 | 56 | 0.918b |
| Sex | 162 (92.0) | 14 (8.0) | 176 |
| Female | 118 (95.9) | 5 (4.1) | 123 |
| Male | 176 (92.6) | 14 (7.4) | 190 |
| Rupture status | 104 (95.4) | 5 (4.6) | 109 |
| Location | 144 (96.6) | 5 (3.4) | 149 |
| Internal carotid artery | 33 (97.1) | 1 (2.9) | 34 |
| Middle cerebral artery bifurcation | 74 (90.2) | 8 (9.8) | 82 |
| Anterior communicating artery | 29 (85.3) | 5 (14.7) | 34 |
| Other | 144 (94.7) | 8 (5.3) | 152 |
| Stent placement | 136 (92.5) | 11 (7.5) | 147 |
| Initial occlusion status | 82 (91.1) | 8 (8.9) | 90 |
| Complete | 198 (94.7) | 11 (5.3) | 209 |
| Near-complete | 17 (77.3) | 5 (22.7) | 22 |
| Adverse events | 263 (94.9) | 14 (5.1) | 277 |

### Table 4

Predictors of aneurysm obliteration at last follow-up.

| Follow-up aneurysm occlusion status | Complete (n = 118) | P value | Logistic regression p value |
|-------------------------------------|-------------------|---------|---------------------------|
| Near-complete or incomplete (n = 55) | 57 | 54 | 0.211c |
| Median age, years | 69 (69.0) | 31 (31.0) | 0.793b |
| Sex | 49 (67.1) | 24 (32.9) | 0.040b |
| Rupture status | 56 (76.7) | 17 (23.3) | 0.0005 |
| No | 62 (62.0) | 38 (38.0) | 0.0005 |
| Size | 78 (83.9) | 15 (16.1) | 0.000 (3.847) |
| Large or giant | 45 (67.2) | 22 (32.8) | 0.001 (5.616) |
| Initial occlusion status | 38 (82.6) | 8 (17.4) | 0.001 (3.436) |
| Complete | 80 (63.0) | 47 (37.0) | 0.001 (3.799) |

### Table 5

Initial and follow-up angiography outcomes of aneurysms treated with coil embolization.

| Initial occlusion status | Follow-up aneurysm occlusion status | Complete (n = 23) | Near-complete or incomplete (n = 70) | P value |
|--------------------------|------------------------------------|------------------|------------------------------------|---------|
| Complete | 15 (65.2) | 8 (34.8) | 0.084c |
| Near-complete | 25 (43.9) | 32 (56.1) |
| Complete treated with SAC (n = 23) | 23 (100) | 0 (0) | 0.004c |
| Near-complete treated with SAC (n = 70) | 55 (78.6) | 15 (21.4) | 0.004c |

SAC, stent-assisted coiling.

Unless indicated otherwise, data are number of cases with percentages in parentheses.

a Mann-Whitney U test.
b χ² test or Fisher’s exact test.
c Numbers in parentheses are odds ratios. Numbers in brackets are 95% confidence intervals. P values were obtained using binary logistic regression.

of rebleeding occurred (initial near-complete occlusion status). The statistical analysis demonstrated that clinical outcomes were correlated with adverse events (p = 0.008) and aneurysm location (p = 0.032).

Angiographic follow-up data were available for 173 aneurysms (163 patients) with a median follow-up period of 6 months (range, 3–14 months) (Table 4). Follow-up angiograms showed complete occlusion in 118 aneurysms (68.2%) and near-complete or incomplete occlusion in 55 aneurysms (31.8%). Follow-up aneurysm occlusion status was correlated with stent placement (p = 0.000, odds ratio = 5.847), size (p = 0.000, odds ratio = 6.446 for tiny aneurysms; p = 0.001, odds ratio = 5.616 for small aneurysms) and initial aneurysm occlusion status (p = 0.001, odds ratio = 3.436).

Initial and follow-up angiography outcomes are summarized in Table 5. Complete occlusion at follow-up was seen in 82.6% (38/46) of the initial complete occlusion group versus 63.0% (80/127) of the initial near-complete occlusion group (p = 0.014). In the SAC condition, complete occlusion at follow-up was seen in 100% (23/23) of the initial complete occlusion group versus 78.6% (55/70) of the initial near-complete occlusion group (p = 0.018). In the non-SAC condition, complete occlusion at follow-up was seen in 65.2% (15/23) of the initial complete occlusion group versus 43.9% (25/57) of the initial near-complete occlusion group (p = 0.084). The incidence of complete occlusion at follow-up was higher in the initial near-completely occluded aneurysms treated with SAC (78.6%) than in the initial near-completely occluded aneurysms treated with non-SAC (43.9%) (p = 0.000). The incidence of complete occlusion at follow-up was higher in the initial completely occluded aneurysms treated with SAC (100%) than in the initial completely occluded aneurysms treated with non-SAC (65.2%) (p = 0.004).

In the SAC condition, follow-up angiography data were available for 93 aneurysms; among them, there were 2 cases (2.2%) of severe in-stent stenosis, both of which were asymptomatic.
Discussion

The International Subarachnoid Aneurysm Trial suggested that incompletely coiled aneurysms may be more likely to re-rupture than completely coiled aneurysms, although the overall re-rupture rate after coiling is low. However, not all aneurysms can be completely occluded in the first treatment. In a systematic review of 8161 coiled aneurysms, initial complete occlusion was reported in 4355 (62.3%), near-complete occlusion in 2065 (29.5%), and incomplete occlusion in 571 (8.2%). At present, few studies have compared the outcomes of initial near-completely occluded aneurysms with those of initial completely occluded aneurysms.

In our study, 291 aneurysms (69.8%) had initial near-complete occlusion status. Complete occlusion at follow-up was seen in 82.6% of the initial complete occlusion group versus 63.0% of the initial near-complete occlusion group (p = 0.014). These findings suggest that near-complete initial treatment cannot provide durable closure at follow-up.

The introduction of stent technology has led to a conceptual shift in the management of intracranial aneurysms. Previous clinical studies reported conflicting efficacy results for SAC and non-SAC. Some scholars demonstrated that SAC facilitated a higher coil packing density and more stable aneurysm neck sealing. A recent meta-analysis revealed an immediate occlusion rate of SAC of 57.7% (range, 20.2–89.2%) and 48.7% (range, 31.7–89.2%) for coiling only; progressive thrombosis was significantly more likely in SAC (29.9%) than in coiling only (17.5%). However, Hwang et al. noted that stent placement provided no better long-term angiography outcomes for aneurysms with unfavorable configurations for coiling.

In the initial near-complete occlusion group, the complete obliteration rate was 78.6% (55/70) in SAC versus 43.9% (25/57) in non-SAC at follow-up (p = 0.000). This finding suggests that stent placement may enhance progressive aneurysm occlusion despite initial unsatisfactory angiography results (Fig. 2).

Embolized aneurysms can develop worse closure despite complete initial occlusion. Choi et al. reported a recanalization rate of 26.4% in a retrospective study of 91 completely coiled aneurysms. Xavier et al. reported a recanalization rate of 24% in a retrospective study of 83 completely coiled aneurysms. Nevertheless, Chalouhi et al. found that overpacking aneurysms with coils when a stent is used does not confer any advantage in obliteration rates. Neurointerventionists wonder how densely to pack a stented aneurysm.

Follow-up angiography demonstrated a significant difference in the incidence of complete occlusion between SAC and non-SAC of initial completely coiled aneurysms (Table 5, Figs. 3 and 4). Among the stented patients, all 23 aneurysms (100%) demonstrated occlusion. In the non-stented patients, 15 of 23 aneurysms (65.2%) were occluded (p = 0.004). These findings suggest that SAC can provide durable closure for initial completely occluded aneurysms (Fig. 4). Complete occlusion is important in SAC of intracranial aneurysms.

In this study, we noted a comparable complication rate (7.7%) to those of previously studies. Pierot et al. reported a total complication rate of 13.5% in a retrospective study of 1088 aneurysms. Song et al. reported a total complication rate of 3% in a retrospective study of 606 unruptured aneurysms.

In our study, the statistical analysis revealed an increased rate of intraprocedural rupture in initial completely occluded aneurysms (5.6% versus 1.0%). The incidence of cumulative adverse events was higher in patients with completely occluded aneurysms (11.1%) than in those with near-completely occluded aneurysms (5.5%) (p = 0.042). The clinical outcomes did not significantly differ between the 2 groups at follow-up. Good clinical outcomes (mRS of 0–2) at follow-up were seen in 82 patients (91.1%) with initial completely occluded aneurysms and in 198 patients (94.7%) with initial near-completely occluded aneurysms (p = 0.238). A possible explanation for this is that the majority of patients can survive without severe sequelae if managed appropriately after intraoperative aneurysm rupture. These findings suggest that initial complete treatment may lead to higher complication rates and good clinical outcomes at follow-up. The excessive pursuit of an angiographically perfect coil embolization might increase the risk of aneurysm rupture, especially in cases of rupture.
Fig. 3. Coiling of a ruptured aneurysm in a 47-year-old man. Cerebral angiography showed an aneurysm of the basilar artery (A). Angiography performed immediately after coiling revealed complete aneurysm occlusion (B). Angiography performed at 64 months after embolization revealed aneurysm recanalization (C).

Fig. 4. Coiling of an unruptured aneurysm in a 57-year-old woman. Cerebral angiography showed an aneurysm of the left carotid artery (A). The aneurysm was treated with stent-assisted coiling (Solitaire). Angiography performed immediately after coiling revealed complete aneurysm occlusion (B). Angiography performed at 5 months after embolization revealed complete aneurysm occlusion (C).
Limitations

This study has several limitations. First, its retrospective design and single-center setting have inherent demerits. Second, some patients did not undergo long-term follow-up. Third, the morphologies of the enrolled aneurysms were not absolutely the same in the SAC and non-SAC groups. Fourth, other kinds of stents such as the LVIS and Leo stents were not used in this study.

Conclusions

Initial complete treatment may lead to higher complication rates and good clinical outcomes at follow-up. Stent placement may enhance the progressive occlusion of aneurysms despite the initial unsatisfactory angiography results. Our results suggest that initial complete occlusion with SAC can provide durable closure at follow-up.

Patient consent

Witten informed consent was obtained from patients for publication of these case reports and any accompanying images.

Declaration of competing interest

The authors declare that they have no conflicts of interests to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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