Combination of Multicatheter Plus Stent or Balloon for Treatment of Complex Aneurysms

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ABSTRACT

BACKGROUND AND PURPOSE: Coiling of complex aneurysms is still difficult even with current adjuvant techniques. This study sought to evaluate the safety and effectiveness of a combination of multicatheter plus stent or balloon for the treatment of complex aneurysms.

MATERIALS AND METHODS: All complex aneurysms that underwent coiling with the combination technique were identified from prospectively maintained neurointerventional data bases. “Complex aneurysm” was defined as a wide-neck aneurysm with branch incorporation into or a deep lobulation of the sac. The clinical and angiographic outcomes were retrospectively analyzed.

RESULTS: Sixty-two complex aneurysms (12 ruptured, 50 unruptured) in 62 patients (mean age, 57 years; male/female ratio, 12:50) were treated with a combination technique by using a multicatheter plus stent (n = 42, 3 ruptured) or balloon (n = 20, 9 ruptured). Treatment-related morbidity (grade 3 hemiparesis) occurred in 1 patient (1.6%). Except for 1 patient who had treatment-related morbidity, none of the other patients with unruptured aneurysms developed new neurologic symptoms at discharge. Nine of the 12 patients with ruptured aneurysms had good outcomes (Glasgow Outcome Score, 4 or 5) at the latest follow-up (mean, 32 months; range, 6–72 months), and 1 patient died from an initial SAH. Posttreatment control angiograms revealed complete occlusion in 27, neck remnant in 34, and incomplete occlusion in 1 aneurysm. At least 1 follow-up catheter or MR angiogram was available in 80.6% (n = 50) (mean, 21 months; range, 6–65 months). There were 4 minor and 3 major recurrences (14.0%).

CONCLUSIONS: In this case series, the combination technique by using multicatheter plus stent or balloon seemed safe and effective for the treatment of complex aneurysms.

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Technical advances with devices such as catheters, balloons, and stents have widened the indications and improved the outcomes of coiling for the treatment of intracranial aneurysms. A wide-neck, branch incorporation into the sac and a lobulated sac are well-known anatomic features of aneurysms that make the conventional coiling procedure difficult. These complicated anatomic features increase the risk of incomplete coiling, complications such as compromise of the parent vessel or branching artery, and posttreatment recurrence. Some case series have already reported the feasibility of adjunctive techniques for aneurysms with difficult anatomic characteristics and have presented good procedural outcomes. However, the coiling procedure of an aneurysm with a wide neck plus an incorporated branch and/or lobulated sac still remains a technical challenge. In this regard, those aneurysms should be defined as “complex aneurysms.” On the other hand, a simple combination of already well-known techniques can make it easy to coil such complex aneurysms. To our knowledge, however, the feasibility and clinical and angiographic outcomes of combination techniques for these complex aneurysms have not yet been demonstrated. In this study, we evaluated the safety and effectiveness of a combination technique such as multicatheter plus stent or balloon for complex aneurysms.

MATERIALS AND METHODS

All complex aneurysms that underwent coiling with the combination technique were identified from prospectively maintained neurointerventional data bases in 2 academic tertiary referral hospitals between July 2007 and June 2014. A “complex aneurysm” was defined as a wide-neck aneurysm with an incorporated branch into and/or a deep lobulation (more than one-third of the aneurysm height) of the sac; “wide neck” meant that the neck diameter was ≤4 mm or the dome-to-neck ratio was ≤1.5.
During the study period of 7 years, 1307 patients with 1423 aneurysms were treated with coiling in the 2 hospitals. One hundred twenty-one (8.5%) of the 1423 aneurysms met the definition of complex aneurysms in this study. Patient informed consent was obtained before treatment. The institutional review board approved this retrospective study with a waiver of informed consent for study inclusion. All relevant clinical and imaging data were obtained from electronic medical charts, PACSs, and a prospectively registered neurointerventional data base. The clinical and angiographic outcomes were retrospectively analyzed.

**Coiling with the Combination Technique**

All patients with unruptured aneurysms who were scheduled for stent-assisted coil embolization received premedication with dual antiplatelet medication (aspirin, 100 mg, and clopidogrel, 75 mg) for at least 5 days. Dual antiplatelet medication was maintained for at least 3 months and then was changed to aspirin monotherapy. For patients with ruptured aneurysms who underwent stent placement, a bolus of dual antiplatelet medication (aspirin, 100–500 mg, and clopidogrel, 300 mg) was given just after completion of the procedure. After the introduction of a guiding catheter, a bolus of heparin, 3000 IU, was injected and then heparin, 100–500 mg, and clopidogrel, 600 mg, was given as a booster every hour. For anterior circulation complex aneurysms, a 6F Shuttle guide sheath (Cook, Bloomington, Indiana) was placed in the relevant internal carotid artery. For posterior circulation complex aneurysms, a single 6F Shuttle sheath was placed in the dominant vertebral artery or 2 Envoy guiding catheters of 5F or 6F diameter (Codman & Shurtleff) and Neuroform (Stryker) stents. The stents used in this study included Enterprise (Codman, Kalamazoo, Michigan) and Scepter C balloons (MicroVention). The adjunctive balloons in this study were HyperForm/HyperGlide (Covidien, Irvine, California) and Scepter C balloons (MicroVention). The stents used in this study included Enterprise (Codman & Shurtleff) and Neuroform (Stryker) stents.

**Outcome Measures**

“Treatment-related morbidity” was defined as the development of any new neurologic deficit due to treatment-related complications that were still present at discharge. “Treatment-related mortality” was defined when the patient died from treatment-related complications during clinical follow-up. The clinical outcomes of the patients with subarachnoid hemorrhage were evaluated by the Glasgow Outcome Score. A good outcome was defined as a Glasgow Outcome Score of 4 or 5. The clinical outcome at the latest follow-up was defined as the final outcome. If the latest clinical follow-up was >3 months at the point of the analysis of this study, a telephone interview was obtained to determine the patient’s clinical status.

Immediate postcoiling angiographic outcome was analyzed according to the Raymond scale. Follow-up angiographic outcome was classified into 3 categories: improved/stable, minor recurrence when the recurred aneurysm did not require retreatment, and major recurrence when the recurred aneurysm required retreatment. The need for retreatment was determined on the basis of a discussion among 2 neurointerventionists and 3 vascular neurosurgeons in a weekly neurovascular conference.

**RESULTS**

The Table summarizes the characteristics of complex aneurysms and the results of the combination technique by using the multicatheter plus stent or balloon.

| Type of complex aneurysms | No. of patients | Presentation (No.) | Male/female | Location of complex aneurysm | Immediate angiographic outcome | Follow-up angiograms (No.) | Complete | Incomplete | Follow-up results | Improved or stable | Minor recurrence | Major recurrence |
|---------------------------|----------------|--------------------|-------------|-----------------------------|------------------------------|---------------------------|-----------|------------|----------------------|------------------|----------------|-----------------|
| Wide neck plus branch incorporated | 41 | 12 (99.4%) | 50 (80.6%) | Anterior cerebral artery | 27 (43.6%) | 50 (80.6%) | 43 (86.0%) | 4 (8.0%) | 3 (6.0%) |
| Wide neck plus deep lobulation | 16 | 12 (99.4%) | 50 (80.6%) | Middle cerebral artery | 34 (54.8%) | 50 (80.6%) | 43 (86.0%) | 4 (8.0%) | 3 (6.0%) |
| Wide neck plus both | 5 | 12 (99.4%) | 50 (80.6%) | Basilar artery | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |

The Table summarizes the characteristics of complex aneurysms and the results of the combination technique by using the multicatheter plus stent or balloon. Sixty-two complex aneurysms (12 ruptured and 50 unruptured) in 62 patients (mean age, 57; male/female ratio = 12:50) were treated with a combination technique either multicatheter plus stent (n = 42, 3 ruptured) or balloon (n = 20, 9 ruptured). Treatment-related morbidity occurred in 1 patient (1.6%) who had a grade 3 right hemiparesis due to an embolic occlusion of the incorporated left anterior choroidal artery, but there was no treatment-related mortality. Except for that patient, no other patient with an unruptured aneurysm developed a new neurologic symptom. Nine of the 12 patients with ruptured aneurysms exhibited

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**Summary of complex aneurysms and the results of the combination technique using multicatheter plus stent or balloon**

| No. of patients | Age (yr) (mean) | Male/female | Presentation (No.) | Ruptured | Unruptured | Type of complex aneurysms | Immediate angiographic outcome | Follow-up angiograms (No.) | Complete | Incomplete | Follow-up results | Improved or stable | Minor recurrence | Major recurrence |
|----------------|----------------|-------------|--------------------|----------|-----------|--------------------------|------------------------------|---------------------------|-----------|------------|-----------------|------------------|----------------|-----------------|
| 62 | 54.0 ± 12.0 | 12 (99.4%) | 50 (80.6%) | 12 (99.4%) | 50 (80.6%) | Wide neck plus branch incorporated | 27 (43.6%) | 50 (80.6%) | 43 (86.0%) | 4 (8.0%) | 3 (6.0%) |
| 62 | 16 (25.8%) | 5 (8.1%) | 8 (12.9%) | 20 (32.2%) | 1 (1.6%) | Wide neck plus deep lobulation | 34 (54.8%) | 50 (80.6%) | 43 (86.0%) | 4 (8.0%) | 3 (6.0%) |
| 62 | 5 (8.1%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | Wide neck plus both | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |

| Sac diameter (mm) (mean) (range) | Neck diameter (mm) (mean) (range) | Location of complex aneurysm | Immediate angiographic outcome | Follow-up angiograms (No.) | Complete | Incomplete | Follow-up results | Improved or stable | Minor recurrence | Major recurrence |
|-------------------------------|----------------------------------|-----------------------------|------------------------------|---------------------------|-----------|------------|----------------------|------------------|----------------|-----------------|
| 8.7 ± 3.4 (3.5–19.0) | 6.0 ± 3.3 (2.2–14.0) | Internal carotid artery | 29 (46.8%) | 27 (43.6%) | 5 (8.1%) | 8 (12.9%) | 20 (32.2%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) |
| Middle cerebral artery | 5 (8.1%) | 34 (54.8%) | 50 (80.6%) | 43 (86.0%) | 4 (8.0%) | 3 (6.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Anterior cerebral artery | 8 (12.9%) | 20 (32.2%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Basilar artery | 20 (32.2%) | 1 (1.6%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |

| Type of combination technique | Multicatheter plus stent (No.) | Multicatheter plus balloon (No.) | Treatment-related morbidity | Treatment-related mortality | Immediate angiographic outcome | Follow-up angiograms (No.) | Complete | Incomplete | Follow-up results | Improved or stable | Minor recurrence | Major recurrence |
|-------------------------------|-------------------------------|-------------------------------|---------------------------|---------------------------|------------------------------|---------------------------|-----------|------------|-----------------|------------------|----------------|----------------|
good outcomes (Glasgow Outcome Score of 4 or 5) at the last follow-up (mean, 32 months; range, 6–72 months), and 1 patient died as a consequence of the initial subarachnoid hemorrhage. Posttreatment control angiograms showed complete occlusion in 27, neck remnants in 34, and incomplete occlusion in 1 aneurysm. At least 1 follow-up angiogram was available in 80.6% (n = 50; mean, 21 months; range, 6–65 months). Seven (14%) of the 50 patients were followed by MR angiography alone. Recurrence occurred in 7 aneurysms (14.0%), including 4 minor and 3 major recurrences.

DISCUSSION
Endovascular coiling has been increasingly used for wide-neck aneurysms due to rapid advances in devices and techniques.1-12 However, if wide-neck aneurysms have an incorporated branch and/or deeply lobulated sac, coiling is more difficult and there is potentially an increased risk of incomplete coiling, a thromboembolic event, or branching occlusion and posttreatment recurrence. The unique configuration of this aneurysm usually demands a more elaborate coiling technique and can be recognized as a complex and difficult aneurysm in view of the coiling procedure.

To some extent, the multicatheter technique can handle the wide-neck aneurysm via interleaving 2 or 3 coils or locking the first or second coil to make a stabilizing coil basket, and it is useful for accessing the lobulated sac by separating the catheter positions.5,6,8,13 In a recent case series, treatment-related morbidity and mortality with a dual-microcatheter technique were 1% and 2%, respectively.5 This technique can also intentionally protect the incorporated branch by placing 1 catheter or coil into the branch.6,11,12,14 Although balloons and stents were originally designed for preventing coil prolapse and enhancing coil-packing attenuation, slight overinflation of a compliant balloon or “gator backing” of open cell stent struts can additionally protect the branch incorporated with the parent artery of a wide-neck aneurysm.6,7,15

A combination technique is intended to provide the advantages of both the multicatheter technique and a stent or balloon technique. In the combination technique, a balloon or stent is used to protect the aneurysm neck, and multicatheters are used to form and stabilize the coil basket to preserve the incorporated branch and/or to uniformly pack the lobulated sac with coils (Fig 2).16 This approach may be a relatively complex procedure, even though it uses already known devices. There may also be complications associated with additional instruments, such as an increase in thromboembolic events and device-related problems. For these reasons, in this study, treatment via the combination technique was initially planned in only one-third of the complex aneurysms, while in two-thirds of the aneurysms, a conventional multicatheter, balloon-, or stent-assisted technique was initially attempted. For the complex aneurysms initially treated with the combination technique, it was anticipated that the multicatheter, balloon, or stent alone could not achieve preservation of an incorporated branch or stability of the coil basket due to a wide neck with incorporated branches and/or deep lobulation (Fig 3).
FIG 2. A 27-year-old woman with underlying Moyamoya disease and an unruptured basilar tip aneurysm. A, The 3D reconstruction image shows an unruptured basilar tip aneurysm with a deep lobulation. B, A spot image shows coil placement after positioning 2 microcatheter tips (arrows) in the large and small lobes of the sac, respectively, and horizontal stent placement (arrows) via the posterior communicating artery. C, Completion control angiogram shows uniform coil packing of the lobulated sac, resulting in complete occlusion of the aneurysm.

Given the accumulation of experience since the previously reported cases series, the complexity of the technique used has not limited the ability to obtain satisfactory results. In the cases focused on preserving an incorporating branch, interleaving 2 coils stabilized the initial coil basket to preserve the incorporated branch, while the overinflated balloon prevented coils from moving toward the incorporated branch (Fig 1). In other cases with a very wide neck and a shallow aneurysm with an acute-angled incorporating branch, a multicatheter-plus-stent system was a more reliable choice than a multicatheter-plus-balloon system (Fig 3). Overall, stents (67.7%) have been used more than balloons (32.3%) for covering the wide neck, but in ruptured cases, balloons (75.0%) were preferred because stents may be associated with hemorrhagic complications. For cases with a very wide neck and deep lobulation, each lobe of the aneurysm was selected by using 2 microcatheters that had different distal tip shapes (preshaped or steam-shaped). Each lobe could be completely embolized with different coils suitable for the respective shape and size during the protection of the parent artery from coil protrusion by the stent (Fig 2).

When using the combined technique for a branch-incorporated aneurysm, the embolizing coil size was matched to the aneurysm depth, rather than the largest or mean diameter of the aneurysm, with an oversized stent or a supercompliant balloon (HyperForm). When the incorporated branch was intended to be protected with a coil, the appropriate preshaped or steam-shaped catheter was used for facing the origin of the incorporated branch (Fig 3 and On-line Fig 1). Usually, for facing the catheter tip to the origin of an ophthalmic artery or an acutely angled middle cerebral artery branch, a preshaped S (Stryker Neurovascular, Fremont, California) or steam-shaped S catheter was useful. As a protection coil for a small incorporated branch, a helical coil with size matched to or slightly greater than the size of the origin of the incorporated branch was chosen (Fig 3 and On-line Fig 1). The complex or 3D coil was occasionally useful for protection of a relatively larger incorporated branch such as a fetal-type posterior cerebral artery. For the deeply lobulated and shallow aneurysm without an incorporated branch, the appropriate preshaped or steam-shaped catheters were chosen for facing each catheter tip to the respective lobe of the aneurysm. Then each coil size was matched to or slightly greater than the largest size of each lobe. If possible, the stent size was matched to the parent artery size. The balloon was not overinflated, with room for coil placement. Thus, most often 2 coils were packed in each lobe partially intermingling at the confluence of each lobe (Fig 2). After we made a stable coil basket, smaller helical coils were always used for further coil packing without breaking the initial shape of the coil basket.

A major concern about the combination technique for coiling of a complex aneurysm is a possibly increased risk of treatment-related complications resulting from unfavorable aneurysm geometry and the use of additional instruments. The overall incidence of treatment-related complications was reported to be 7.9%–17.1% and 9.4%–12.2% with balloon- and stent-assisted techniques, respectively. The multicatheter technique also ranged from 0% to 13.3%.

Notably, in our series, treatment-related morbidity occurred in only 1 patient (1.6%), which is acceptable in comparison with the reported results from the literature focusing only on wide necks and is also remarkable because adding an adjunctive device may lead to an increase in adverse events like thromboembolism and intra-procedural rupture.

Another concern is a possible increase in the recanalization rate after frequent incomplete coiling due to the complicated characteristics of the aneurysm. However, through the combination technique, only 1 incomplete coiling occurred in our study. Although there was a 14% recurrence (3 major and 4 minor recurrences) on follow-up imaging (mean, 21 months), this recurrence rate is favorably comparable with the results reported in the literature.

An intentional dog-ear remnant in coiling of a branch-incorporated aneurysm cannot be helped, though a dog-ear remnant may be a risk factor for recurrence. There was, however, no significant predictor of recurrence in this study. It may be due to the small number of cases included. Another explanation is that because an incorporated branch was mostly a small or tiny branch except for the posterior communicating artery, hemodynamic stress due to the incorporated branch might also be a little increased and less likely to affect the recurrence rate. In addition, in the case series of coiling of a branch-incorporated aneurysm, the recurrence rate was not greater than those in the literature.

Finally, all 3 major recurrent aneurysms were successfully retreated by additional coiling without any complications.

A flow diverter may be an effective alternative to coiling for complex aneurysms. Unfortunately, no type of flow diverter was launched in our country until November 2014, so it was not available during the study period.

Our series demonstrated that the combination technique is not related to a higher complication rate than a single adjunctive device for the treatment of complex aneurysms. Furthermore, the combination strategy for complex aneurysms had a safety and effectiveness favorably comparable with the single adjunctive endovascular techniques in previous studies.

Our study had several limitations due to its retrospective design and the relatively small number of cases. Therefore, the se-
lection bias was inevitable, but it might be somewhat lowered because our data of endovascular treatment were consecutively and prospectively registered. Second, although we preferred balloons to stents in ruptured cases on the basis of the literature, we were not able to demonstrate which device was better for complex aneurysms. Third, angiographic follow-up was not available in all cases; therefore, this lack of follow-up may have somewhat underestimated the recurrence rate. In addition, 7 of the 50 patients who underwent follow-up imaging were followed by MR angiography alone. This type of follow-up might underestimate the recurrence rate a little further.

Finally, this study did not have a control group. Many of the aneurysms might be coilable by using balloon remodeling or stent assistance, and even a single microcatheter. Actually, Kim et al reported a case series about the coiling of a branch-incorporated aneurysm by using multicatheter, balloon, or stent.6 Also, a lobulated aneurysm can be coilable by using a multicatheter or single catheter plus a balloon or stent. However, in our experience, this type of coiling took longer and was technically more demanding. In our own experience, the longer it took for coiling, the more frequently procedure-related (especially thromboembolic) complications occurred. Furthermore, in a few cases in which the aneurysm was shallow and had a wide neck and a branch incorporated, it was very difficult to complete coiling by using a single catheter plus balloon/stent or multicatheter. In our own cases in this study, we thought that a combination of multicatheter plus balloon or stent made the coiling time shorter and the procedure easier than multicatheter, balloon-remodeled, or stent-assisted technique alone. Therefore, despite these limitations, because this study showed satisfactory results in terms of safety and effectiveness, the combination technique described here may provide helpful information in daily practice.

CONCLUSIONS
In this small case series, the combination technique by using a multicatheter plus stent or balloon had very low morbidity and an acceptable recurrence rate for the treatment of a complex aneurysm with a wide neck and an incorporated branch or deep lobulation. The combination technique may be a viable option for coiling of complex aneurysms.

Disclosures: Dong Joon Kim—UNRELATED: Payment for Lectures (including service on Speakers Bureaus): Covidien, Comments: lectures on acute stroke management.

REFERENCES
1. Shapiro M, Babb J, Becak T, et al. Safety and efficacy of adjunctive balloon remodeling during endovascular treatment of intracranial aneurysms: a literature review. AJNR Am J Neuroradiol 2008;29:1777–81 CrossRef Medline
2. Gentric JC, Biondi A, Piotin M, et al; French SENAT Investigators. Safety and efficacy of Neuroform for treatment of intracranial aneurysms: a prospective, consecutive, French multicentric study. AJNR Am J Neuroradiol 2013;34:1203–08 CrossRef Medline
3. Fargen KM, Hoh BL, Welch BG, et al. Long-term results of Enterprise stent-assisted coiling of cerebral aneurysms. Neurosurgery 2012;71:239–44; discussion 244 CrossRef Medline
4. Starke RM, Durst CR, Evans A, et al. Endovascular treatment of
unruptured wide-necked intracranial aneurysms: comparison of dual microcatheter technique and stent-assisted coil embolization. J Neurointerv Surg 2015;7:256–61 CrossRef Medline
5. Durst CR, Starke RM, Gaughrn JR Jr, et al. Single-center experience with a dual microcatheter technique for the endovascular treatment of wide-necked aneurysms. J Neurosurg 2014;121:1093–101 CrossRef Medline
6. Kim BM, Park SI, Kim DJ, et al. Endovascular coil embolization of aneurysms with a branch incorporated into the sac. AJNR Am J Neuroradiol 2010;31:145–51 CrossRef Medline
7. Lubicz B, Lefranc F, Levivier M, et al. Endovascular treatment of intracranial aneurysms with a branch arising from the sac. AJNR Am J Neuroradiol 2006;27:142–47 Medline
8. Baxter BW, Rosso D, Lownie SP. Double microcatheter technique for detachable coil treatment of large, wide-necked intracranial aneurysms. AJNR Am J Neuroradiol 1998;19:1176–78 Medline
9. Rho MH, Kim BM, Suh SH, et al. Initial experience with the new double-lumen scepter balloon catheter for treatment of wide-necked aneurysms. Korean J Radiol 2013;14:832–40 CrossRef Medline
10. Kim BM, Kim DJ, Kim DI. Stent application for the treatment of cerebral aneurysms. Neurointervention 2011;6:53–70 CrossRef Medline
11. Kim BM, Kim DI, Park SI, et al. Coil embolization of unruptured middle cerebral artery aneurysms. Neurosurgery 2011;68:346–53; discussion 353–54 CrossRef Medline
12. Ihn YK, Kim BM, Suh SH, et al. Coil-protected embolization technique for a branch-incorporated aneurysm. Korean J Radiol 2013;14:329–36 CrossRef Medline
13. Kim DJ, Kim BM, Park KY, et al. Coil embolization of wide-necked unruptured intracranial aneurysms with double microcatheter technique. Acta Neurochir (Wien) 2014;156:839–46 CrossRef Medline
14. Cho YD, Kang HS, Kim JE, et al. Microwiggedwire protection of wide-necked aneurysms incorporating orifices of tortuous acute-angled vessels: a novel approach. Neuoradiology 2014;56:553–59 CrossRef Medline
15. McLaughlin N, McArthur DL, Martin NA. Use of stent-assisted coil embolization for the treatment of wide-necked aneurysms: a systematic review. Surg Neurol Int 2013;4:43 CrossRef Medline
16. Nakahara T, Kutsuna M, Yamanaka M, et al. Coil embolization of a large, wide-necked aneurysm using a double coil-delivered microcatheter technique in combination with a balloon-assisted technique. Neuroradiology 1999;16:324–26 Medline
17. Bodily KD, Cloft HJ, Lanzino G, et al. Stent-assisted coiling in acutely ruptured intracranial aneurysms: a qualitative, systematic review of the literature. AJNR Am J Neuroradiol 2011;32:1232–36 CrossRef Medline
18. Pierot L, Spelle L, Leclere X, et al. Endovascular treatment of unruptured intracranial aneurysms: comparison of safety of remodeling technique and standard treatment with coils. Radiology 2009;251:846–55 CrossRef Medline
19. Pierot L, Cognard C, Anxionnat R, et al; CLARITY Investigators. Remodeling technique for endovascular treatment of ruptured intracranial aneurysms had a higher rate of adequate postoperative occlusion than did conventional coil embolization with comparable safety. Radiology 2011;258:546–53 CrossRef Medline
20. Nishido H, Piotin M, Bartolini B, et al. Analysis of complications and recurrences of aneurysm coiling with special emphasis on the stent-assisted technique. AJNR Am J Neuroradiol 2014;35:339–44 CrossRef Medline
21. Shapiro M, Becske T, Sahlein D, et al. Stent-supported aneurysm coiling: a literature survey of treatment and follow-up. AJNR Am J Neuroradiol 2012;33:159–63 CrossRef Medline
22. Chung EJ, Shin YS, Lee CH, et al. Comparison of clinical and radiologic outcomes among stent-assisted, double-catheter, and balloon-assisted coil embolization of wide neck aneurysms. Acta Neurochir (Wien) 2014;156:1289–95 CrossRef Medline
23. Kwon OK, Kim SH, Oh CW, et al. Embolization of wide-necked aneurysms with using three or more microcatheters. Acta Neurochir (Wien) 2006;148:1139–45; discussion 1145 CrossRef Medline
24. Szuzewski M, van Rooij WJ, Beute GN, et al. Balloon-assisted coil embolization of intracranial aneurysms: incidence, complications, and angiography results. J Neurosurg 2006;105:396–99 CrossRef Medline
25. Consoli A, Vignoli C, Renieri L, et al. Assisted coiling of saccular wide-necked unruptured intracranial aneurysms: stent versus balloon. J Neurointerv Surg 2014 Nov 26. [Epub ahead of print] CrossRef Medline
26. Geyik S, Yavuz K, Yurttutan N, et al. Stent-assisted coiling in endovascular treatment of 500 consecutive cerebral aneurysms with long-term follow-up. AJNR Am J Neuroradiol 2013;34:2157–62 CrossRef Medline
27. Becske T, Kallmes DF, Saatci I, et al. Pipeline for uncoilable or failed aneurysms: results from a multicenter clinical trial. Radiology 2013;267:858–68 CrossRef Medline