Article

Single Stent-Assisted Coiling for the Treatment of Complex, Acute-Angled Wide-Necked Intracranial Bifurcation Aneurysms Using the Bulging Technique with the Neuroform Atlas Stent

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AIM: Protecting both bifurcation branches with a single device is challenging when the neck of an intracranial aneurysm is centered at a bifurcation and forms an acute angle. This study aimed to evaluate the efficacy of the bulging technique using a single Neuroform Atlas stent to protect two branches in complex, acute-angled, wide-necked bifurcation aneurysms (WNBAs).
METHODS: We retrospectively reviewed patients with complex, acute-angled WNBAs who underwent single stent-assisted coiling using the bulging technique with a Neuroform Atlas stent between August 2020 and July 2024. Technical feasibility, procedure-related complications, and angiographic and functional outcomes were evaluated.
RESULTS: A total of 52 eligible patients were enrolled, including 22 (42.3%) with acutely ruptured aneurysms. The bulging technique was successfully implemented in all cases. Initial angiographic assessment demonstrated complete occlusion in 33 (63.5%) cases, neck remnants in 14 (26.9%) cases, and residual aneurysms in 5 (9.6%) cases. Angiographic follow-up was available for 48 (92.3%) patients, with a median follow-up duration of 6.4 months. Follow-up angiography demonstrated complete occlusion in 42 (87.5%) patients and neck remnants in 6 (12.5%) patients. Procedure-related complications occurred in 2 (3.8%) patients and consisted of ischemic events. Favorable functional outcomes (modified Rankin Scale score, 0–2) were achieved in 48 (92.3%) patients during follow-up. No cases of permanent procedure-related morbidity or mortality were observed.
CONCLUSIONS: The bulging technique using a single Neuroform Atlas stent appears to be a feasible and safe treatment for complex, acute-angled WNBAs, with satisfactory short-term angiographic and clinical outcomes. However, further studies with longer follow-up durations are warranted to establish its long-term efficacy.

Keywords: stent-assisted coiling; Neuroform Atlas; bulging technique; wide-necked bifurcation aneurysm; intracranial aneurysm

Introduction

Stent-assisted coiling can effectively treat wide-necked intracranial aneurysms by preventing coil protrusion into the parent artery [1]. However, the treatment of complex wide-necked bifurcation aneurysms (WNBAs) remains challenging when the aneurysm neck is centered at the bifurcation of two branches [2]. Double-stent-assisted coiling using various stent configurations, such as X- and Y-stents, has recently been developed for the treatment of WNBAs [3,4]. Nevertheless, Y-stenting is associated with procedure-related complications and technical difficulties. The T-stent-assisted technique is a modified Y-stenting approach; however, T-stent-assisted coiling is technically demanding because it requires the simultaneous placement of three microcatheters within a single vessel and precise positioning of the stent in the daughter branch [4]. Published studies have demonstrated the promising efficacy of several novel endovascular devices for the treatment of WNBAs, including intrasaccular flow-disruption and neck-bridging devices [5–7]. Nevertheless, the safety of these newer devices and the durability of aneurysm occlusion require further validation.

The stent bulging technique is a novel approach for the treatment of bifurcation aneurysms because it enables neck coverage with a single compacted stent while avoiding double-stent placement [8–11]. Most studies investigating the bulging technique have been limited to low-profile braided stents. However, a single braided stent may be insufficient to protect both branches in complex, acute-angled bifurcation aneurysms and may carry a risk of stent kinking. The Neuroform Atlas stent (Stryker Neurovascular, Fremont, CA, USA) has been widely used in the treatment of intracranial aneurysms because of its excellent deliverability through a low-profile 0.0165-inch microcatheter [12]. Due to its open-cell design, the Neuroform Atlas

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stent provides sufficient space for stent struts to prolapse into the aneurysm orifice through a push-pull maneuver. This mechanism is theoretically similar to the shelf technique used with closed-cell braided stents and may facilitate preservation of side-branch arteries in complex bifurcation aneurysms. Moreover, its open-cell architecture allows the application of the bulging technique, enabling stent strut prolapse into the aneurysm orifice while preserving side-branch patency. Furthermore, its excellent conformability makes the bulging technique particularly suitable for aneurysms with acute vessel angulation.

However, the literature regarding the use of the bulging technique with a single Neuroform Atlas stent for WNBAs remains limited. Therefore, this study aimed to evaluate the feasibility, safety, and therapeutic efficacy of the bulging technique using a single Neuroform Atlas stent for the treatment of complex, acute-angled WNBAs.

Methods

Patients

The interventional database of Affiliated Hangzhou First People's Hospital, School of Medicine of Westlake University was retrospectively reviewed to identify patients with intracranial aneurysms treated between August 2020 and July 2024. The inclusion criteria were as follows: (1) complex, acute-angled WNBAs; (2) treatment with the bulging technique using a Neuroform Atlas stent; and (3) availability of complete clinical and imaging data. The exclusion criteria were as follows: (1) treatment with dual-, T-, or half-T-stent placement, or balloon-assisted remodeling techniques; and (2) use of the bulging technique with low-profile braided stents.

WNBAs were defined as aneurysms on digital subtraction angiography (DSA) with a dome-to-neck ratio <2 or a neck width ≥ 4 mm. Complex, acute-angled WNBAs were defined as bifurcation aneurysms involving more than one branch, with an angle between the daughter branch and the parent vessel of $<90°$. Treatment strategies were determined at the discretion of the treating neurointerventional specialists based on aneurysm characteristics, including aneurysm size, morphology, and the anatomy of the parent vessels and branch vessels. The bulging technique using the Neuroform Atlas stent was prioritized for the treatment of complex, acute-angled WNBAs.

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Affiliated Hangzhou First People's Hospital, School of Medicine of Westlake University (NO. 2025ZN320-1). Since anonymized patient data were used, written informed consent was waived. All clinical information was retrospectively collected and de-identified in compliance with institutional ethical guidelines.

Data Assessment

Clinical and aneurysm characteristics, technical feasibility, procedure-related complications, and angiographic and clinical outcomes were evaluated. The angles between the daughter branch and the parent vessel were measured using three-dimensional rotational angiography reconstructions in Siemens Syngo X Workplace software (version VD10, Siemens Healthineers), and the smaller angle was defined as the alpha angle. Fig. 1 illustrates the key procedural steps of the bulging technique, stent configuration, and angle measurements.

Angiographic outcomes were evaluated using DSA, and the degree of aneurysm occlusion was determined according to the Raymond-Roy (RR) classification. Imaging data were independently reviewed by two experienced neuroradiologists who were blinded to the clinical outcomes. In cases of disagreement, a consensus was reached with the assistance of a third neuroradiologist.

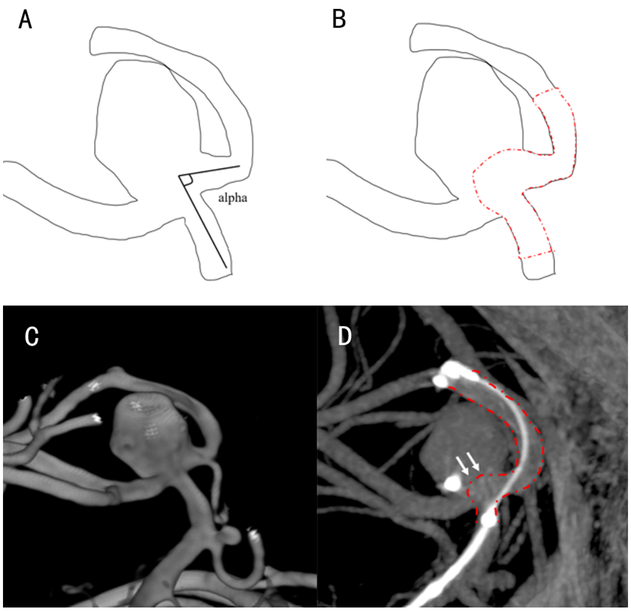

Fig. 1. Schematic illustration of the bulging technique. (A,B) The schematic diagrams illustrating angle measurement and stent placement using the bulging technique (red dotted line). (C,D) Deployment of a single Neuroform Atlas stent in a complex, acute-angled, wide-necked bifurcation aneurysm demonstrates formation of a bulging "shelf" (red dotted and white arrows) covering at least three-quarters of the aneurysm neck, which helps prevent coil prolapse.

Procedure

All endovascular procedures were performed under general anesthesia. A 6-French (Fr) guiding catheter was used in a standard coaxial configuration. Systemic heparin (70 U/kg) was administered intravenously, followed by an additional 1000 IU/h during the procedure to maintain the activated

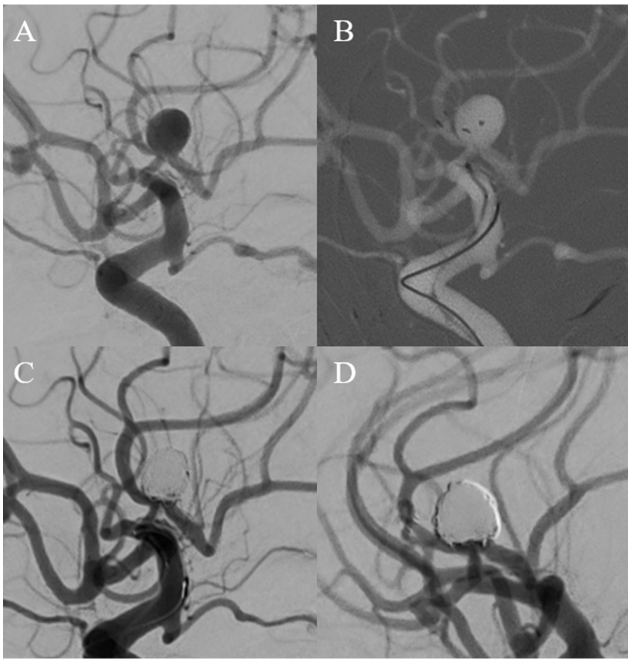

Fig. 2. Representative case illustrating the clinical treatment workflow and outcomes. (A) A patient with a complex, acute-angled, wide-necked anterior communicating artery aneurysm was diagnosed by digital subtraction angiography. (B) Stent-assisted coiling was performed using the bulging technique with a single Neuroform Atlas stent. (C) Immediate postprocedural DSA demonstrated Raymond-Roy class 2 occlusion with minimal neck filling. (D) Six-month follow-up DSA demonstrated complete aneurysm occlusion. DSA, digital subtraction angiography.

clotting time at approximately 2.0–2.5 times the baseline value. All procedures were performed by neuroradiologists with at least 10 years of operative experience.

A microcatheter (SL-10/XT-17, Stryker Neurovascular) was advanced over a microwire and navigated to a distal branch beyond the bifurcation. The stent was generally deployed within the main branch involved in the aneurysm neck. Subsequently, a second microcatheter (Headway 17, MicroVention/Terumo, Tustin, CA, USA, or Echelon 10, eV3) was positioned to facilitate deployment of the Neuroform Atlas stent across the aneurysm neck.

The delivery wire and microcatheter were advanced, and the microcatheter distal marker was withdrawn to the aneurysm neck. The stent was partially deployed under forward tension to allow expansion at the aneurysm neck, thereby creating a shelf that prevented coil prolapse and maintained the branch orifice. Following bulging stent placement, aneurysm coiling was performed through a pre-shaped jailed microcatheter. The coil frame was adjusted to ensure patency of the jailed branch. If branch patency was uncertain during coiling, the stent was fully deployed, and the SL-10 or XT-17 microcatheter was navigated into the opposite branch of the bifurcation to prepare for rescue Y-stent placement. If the coil frame remained stable and branch patency was preserved, the delivery microcatheter could be advanced through the stent cells for additional coil embolization.

A stent diameter 0.5–1.0 mm larger than that of the parent artery was selected to ensure adequate coverage of the aneurysm neck and dome. The stent was required to extend at least 8 mm beyond the aneurysm neck, with a minimum of 4 mm coverage of the parent vessel on each side of the neck to achieve adequate anchoring and neck coverage. Technical success was defined as successful deployment of the stent and embolization of the aneurysm, without the occurrence of procedure-related complications.

Antiplatelet Regimen

In our clinical practice, the intravenous tirofiban (loading dose, 5 μg/kg) was administered to patients with acutely ruptured aneurysms immediately after stent placement, followed by a maintenance infusion of 0.1 μg/kg/min for 24 hours. Aspirin (100 mg) and clopidogrel (300 mg) were administered 20 hours after the endovascular procedure, with tirofiban continued for an additional 4 hours as a bridging regimen. Thereafter, aspirin (100 mg/day) and clopidogrel (75 mg/day) were initiated on the second postoperative day. Patients with unruptured aneurysms received dual antiplatelet therapy consisting of aspirin (100 mg/day) and clopidogrel (75 mg/day) for at least 7 days before the procedure. Given the excellent conformability and low metal coverage of the single Neuroform Atlas stent, patients continued aspirin (100 mg/day) and clopidogrel (75 mg/day) for 3 months after discharge, followed by aspirin (100 mg/day) for 1 year.

Thromboelastography was routinely performed after 1 week of dual antiplatelet therapy to evaluate drug responsiveness and guide adjustment of the antiplatelet regimen.

Follow-Up

DSA was performed for the first angiographic follow-up 6 months after discharge. Magnetic resonance angiography (MRA) was performed 1 year after the first angiographic follow-up and every 2 years thereafter. Disease recurrence as deterioration in the Raymond-Roy (RR) classification on follow-up imaging, while progressive aneurysm occlusion was defined as improvement in the RR classification during follow-up (Fig. 2). Functional outcomes at the last follow-up were assessed using the modified Rankin Scale (mRS). A favorable outcome was defined as an mRS score $\leq$2. Follow-up mRS scores were obtained during outpatient clinic visits or through telephone interviews. Procedure-related complications, including ischemic and hemorrhagic events occurring during or after the endovascular procedure, were also recorded.

Results

Baseline Characteristics

A total of 52 patients with 52 complex, acute-angled WNBAs met the eligibility criteria. Baseline characteristics are summarized in Table 1. The mean age was 64.9 years (standard deviation [SD], 5.2 years), and 34 (65.4%) patients were female. Twenty-two (42.3%) patients presented with ruptured aneurysms. Among these patients, 72.7% had Hunt-Hess grades I–II, while 27.3% had grades III–IV. Additionally, 68.2% had modified Fisher grades I–II, and 31.8% had grades III–IV. Thirty (57.7%) patients had unruptured aneurysms. No patients had a personal history of subarachnoid hemorrhage or previous coil embolization. All patients had a baseline mRS score of 0–2.

The most common aneurysm location was the middle cerebral artery, accounting for 63.5% of cases. The mean aneurysm size, neck width, and dome-to-neck ratio were 6.1 mm (SD, 2.4), 4.3 mm (SD, 1.3), and 1.4 (SD, 0.4), respectively. The mean diameters of the parent artery and stented branch were 2.9 mm (SD, 0.5) and 2.5 mm (SD, 0.4), respectively. The mean alpha angle of the aneurysm was 71.2° (SD, 9.2°).

Table 1. Baseline patient and aneurysm characteristics.

Variable	Total (n = 52)
Female, n (%)	34 (65.4)
Age (years), mean ± SD	64.9 ± 5.2
Hypertension, n (%)	34 (65.4)
Diabetes mellitus, n (%)	5 (9.6)
Coronary artery disease, n (%)	3 (5.8)
Smoking history, n (%)	10 (19.2)
Family history of SAH, n (%)	3 (5.8)
Clinical presentation, n (%)	
Subarachnoid hemorrhage	22 (42.3)
Incidentally discovered unruptured aneurysm	30 (57.7)
Hunt-Hess grade*, n (%)	
I–II	16 (72.7)
III–IV	6 (27.3)
Modified Fisher scale*, n (%)	
I–II	15 (68.2)
III–IV	7 (31.8)
Baseline mRS score 0–2, n (%)	52 (100)
Multiple aneurysms, n (%)	12 (23.1)
Aneurysm location, n (%)	
Middle cerebral artery	33 (63.5)
Anterior communicating artery	10 (19.2)
Pericallosal artery	4 (7.7)
Basilar apex	5 (9.6)
Aneurysm size (mm), mean ± SD	6.1 ± 2.4
<3 mm, n (%)	5 (9.6)
3–10 mm, n (%)	42 (80.8)
>10 mm, n (%)	5 (9.6)
Neck width (mm), mean ± SD	4.3 ± 1.3
Dome-to-neck ratio, mean ± SD	1.4 ± 0.4
Parent-artery diameter (mm), mean ± SD	2.9 ± 0.5
Stented branch diameter, mean ± SD	2.5 ± 0.4
Alpha angle (°), mean ± SD	71.2 ± 9.2

Abbreviations: SAH, subarachnoid hemorrhage; mRS, modified Rankin Scale.

*Data were available for the 22 patients presenting with SAH.

Immediate Angiographic Results and Complications

The treatment outcomes are summarized in Table 2. Successful stent placement was achieved in all cases. In one case, the coiling procedure was initially challenging, and an additional microcatheter was deployed into the side branch to prepare for potential Y-stent implantation if necessary. Ultimately, the coiling procedure was completed using the stent bulging technique without Y-stent deployment. Immediate postprocedural angiography demonstrated complete occlusion (RR class 1) in 33 (63.5%) cases, neck remnants (RR class 2) in 14 (26.9%) cases, and residual aneurysms (RR class 3) in 5 (9.6%) cases.

Procedure-related ischemic complications occurred in 2 (3.8%) patients, both of whom presented with acutely ruptured aneurysms. One patient developed acute in-stent thrombosis during the procedure and received intra-arterial infusion of tirofiban, resulting in complete recanalization. The patient remained asymptomatic throughout the perioperative period. Another patient developed contralateral weakness within 12 hours after the coiling procedure. Emergency angiography revealed in-stent thrombosis, and the patient received intra-arterial tirofiban infusion, resulting in complete thrombus resolution. Neurological recovery was achieved on the second day after endovascular treatment, and the patient was discharged with an mRS score of 0. No hemorrhagic or delayed complications were observed in either case.

Follow-Up Outcomes

Forty-eight (92.3%) patients underwent angiographic follow-up, with a median follow-up duration of 6.4 months (range, 5–16 months). The remaining four patients did not undergo DSA follow-up because of factors such as financial constraints or limited mobility. The first follow-up angiography demonstrated complete occlusion in 42 (87.5%) patients and neck remnants in 6 (12.5%) patients. Thirty patients with complete initial embolization maintained stable angiographic results during follow-up. Eighteen patients with incomplete initial embolization (13 cases with RR class 2 and 5 cases with RR class 3) underwent follow-up angiography. Among these patients, 14 aneurysms exhibited progressive occlusion after a median of 6.8 months (range, 5–8 months), while the remaining 4 remained unchanged (Table 3). The aneurysms demonstrating progressive occlusion exhibited relatively narrower necks compared with those that remained unchanged. No patient exhibited deterioration in RR classification during follow-up.

Table 2. Treatment and clinical outcomes.

Variable	Total (n = 52)
Technique success, n (%)	52 (100.0)
Immediate Raymond-Roy classification, n (%)	
Class 1	33 (63.5)
Class 2	14 (26.9)
Class 3	5 (9.6)
Follow-up Raymond-Roy classification, n (%)	
Class 1	42 (87.5)
Class 2	6 (12.5)
Class 3	0 (0)
Retreatment, n (%)	0 (0)
Procedure-related complications, n (%)	
Ischemic events	2 (3.8)
Hemorrhagic events	0 (0)
Procedure-related permanent morbidity, n (%)	0 (0)
Procedure-related mortality, n (%)	0 (0)
Follow-up mRS score, n (%)	
0–2	48 (92.3)
3–6	4 (7.7)

No significant in-stent stenosis (defined as >50% stenosis of the parent artery) or occlusion of the jailed branch was observed in the included cases. Forty-six patients underwent serial MRA examinations after the initial DSA follow-up, and no evidence of aneurysm recurrence was detected.

A favorable functional outcome was achieved in 48 patients (92.3%) during a median follow-up duration of 12.4 months. The rates of permanent morbidity and mortality were 7.7% and 0%, respectively. Four patients had unfavorable outcomes at the last follow-up, including three patients with an mRS score of 3 and one with an mRS score of 4. Despite successful endovascular treatment, these patients did not achieve neurological recovery during follow-up because of severe preoperative neurological deficits associated with extensive subarachnoid hemorrhage.

Discussion

The present study evaluated the outcomes of endovascular treatment for complex, acute-angled WNBAs using the bulging technique with a single Neuroform Atlas stent. The procedure-related complication rate was low, and the durability of aneurysm occlusion was acceptable during follow-up. To our knowledge, this is the largest study investigating the use of the bulging technique with a single Neuroform Atlas stent for the treatment of complex, acute-angled WNBAs.

The application of double-stent configurations, including "Y-", "X-", and "T-stents", for the treatment of complex wide-necked intracranial bifurcation aneurysms has been reported to yield promising results [3,4]. Nevertheless, Bartolini *et al*. [3] reported a complication rate of 19.6% and a permanent procedure-related morbidity rate of 10% in patients with complex WNBAs treated with Y- or X-stent-assisted coiling. The T-stent-assisted coiling technique was introduced by Cho *et al*. [13] as an alternative to the Y-stent technique, avoiding stent overlapping and the associated safety concerns of Y-stent-assisted coiling. However, the simultaneous placement of three microcatheters within a small-caliber artery may increase the risk of ischemic complications. The use of a single braided stent for the treatment of bifurcation aneurysms has also been proposed as an alternative to Y-stent placement and has been described as the "shelf technique" [9–11], the "barrel technique" [14], and the "herniation technique" [15]. However, complete expansion of braided stents may be difficult to achieve in aneurysms with acute angles between the daughter vessels and parent vessel, potentially increasing the risk of thrombotic complications.

In the present study, we used the bulging technique with a single Neuroform Atlas stent to treat complex, acute-angled WNBAs. Due to its open-cell design, the Neuroform Atlas stent provides sufficient space for stent struts to prolapse into the aneurysm orifice, thereby preserving the incorporated branch. Additionally, the Neuroform Atlas stent is compatible with low-profile microcatheters and can be navigated through small, tortuous vessels with excellent compliance, making it particularly suitable for cases involving acute branch angulation and broad bifurcations. Notably, compared with angles approaching 90°, extremely acute angles (e.g., <45°) may pose significant challenges for microcatheter navigation and increase the risk of device deformation or kinking, thereby requiring greater procedural precision. In the present study, the bulging technique using a Neuroform Atlas stent was successfully performed in all patients without significant technical complications.

Compared with the braided stent, the Neuroform Atlas stent exhibits favorable vascular compliance, excellent stability, and a low incidence of thromboembolic events involving branch vessels. The present study reported a complication rate of 3.8%, which was comparable to the rates reported in two systematic reviews and meta-analyses evaluating the Neuroform Atlas stent for the treatment of intracranial aneurysms (6.0 and 6.2%) [16] and in other studies investigating the shelf technique with braided stents [9–11]. Furthermore, none of our patients developed permanent treatment-related morbidity. Du *et al*. [9] reported that 25% (2/8) of patients treated with the LVIS Jr 'shelf' technique experienced technical complications; however, no treatment-related morbidity or mortality was observed. Maus *et al*. [10] presented their experience with the shelf technique using the LVIS EVO stent for the treatment of WNBAs and reported a treatment-related morbidity rate of 7% (1/15). Çay *et al*. [11] evaluated the therapeutic efficacy of the shelving technique using the LEO Baby stent in bifurcation aneurysms and reported a complication rate of 8.3% (3/36). In the present study, both ischemic complications occurred in patients with acutely ruptured aneurysms, possibly because subarachnoid hemorrhage is associated with

Table 3. Evolution of aneurysm occlusion status at first angiographic follow-up.

Initial Raymond-Roy classification	Total (n, %)	Follow-up (n, %)			
		Completed follow-up	Class 1	Class 2	Class 3
Class 1	33 (63.5)	30 (90.9)	30 (100.0)	0 (0)	0 (0)
Class 2	14 (26.9)	13 (92.9)	9 (69.2)	4 (30.8)	0 (0)
Class 3	5 (9.6)	5 (100.0)	3 (60.0)	2 (40.0)	0 (0)
Total cases	52 (100.0)	48 (92.3)	42 (87.5)	6 (12.5)	0 (0)

a hypercoagulable state and an increased risk of thrombosis [17]. In patients with subarachnoid hemorrhage, the use of this bulging technique combined with a more aggressive perioperative heparin protocol or a modified tirofiban regimen may help reduce ischemic complications; however, further clinical studies are required to validate this potential benefit.

Previous studies have reported variable immediate occlusion rates for aneurysms treated using the bulging technique. Du *et al*. [9] reported immediate RR class 2 and RR class 3 occlusion rates of 62.5% (5/8) and 37.5% (3/8), respectively, in aneurysms treated with the LVIS Jr shelf technique. Maus *et al*. [10] observed an initial complete occlusion rate of 93% (14/15) in their case series treated using the shelf technique with the LVIS EVO stent. Çay *et al*. [11] reported an immediate complete occlusion rate of 66.7 (24/36) in patients treated with the shelf technique using the LEO Baby stent. In the current study, immediate complete occlusion was achieved in 33 (63.5%) cases. However, the complete occlusion rate increased to 87.5% at the first DSA follow-up, which was comparable to the rates reported in previous studies using the shelf technique (62.5–91.0%). This rate was also similar to those reported following Y-stent-assisted coiling (85.8–95.7%) [3,18]. The progressive thrombosis observed in our cohort was likely attributable to hemodynamic flow diversion and re-endothelialization after stent placement [19].

Several novel devices have also been introduced as alternative treatment options for complex WNBAs, including flow-diverter stents, the pCONus device, and the Woven EndoBridge (WEB). Flow-diverter stents may represent a feasible treatment option with favorable aneurysm occlusion rates; however, they have been associated with an increased risk of ischemic events and jailed branch occlusion [20,21]. A systematic review and meta-analysis provided moderate-strength evidence supporting the safety and effectiveness of the pCONus device for the treatment of WNBAs [22]. The Barrel Vascular Reconstruction Device has also demonstrated promising outcomes, although a study with larger sample sizes and longer follow-up periods are warranted to validate its efficacy [23]. Recent studies have shown encouraging results with the WEB device for the treatment of WNBAs, but additional device-assisted techniques may still be required in cases with irregular aneurysm morphology [5,6,24]. With ongoing advances in new devices in interventional neuroradiology, further studies are necessary to determine the optimal indications and comparative advantages of these treatment modalities and to facilitate individualized therapeutic decision-making.

Several limitations of this study should be acknowledged. First, this was a non-randomized, retrospective study. Second, no control group was included to compare the safety and efficacy of different treatment techniques or devices, which may limit the strength of our findings. Third, we acknowledged that the study may be subject to selection bias, and the inclusion of both ruptured and unruptured aneurysms may have influenced the interpretation of the results. Fourth, the use of different antiplatelet regimens for ruptured and unruptured aneurysms may have affected clinical outcomes; stratified analyses by rupture status would be valuable in future investigations. Furthermore, because the findings were derived from a single center, their generalizability may be limited. Finally, the present study included a relatively small sample size and a short follow-up duration; therefore, studies with larger patient cohorts and longer follow-up periods are required to further validate the safety and efficacy of this treatment strategy.

Conclusions

In conclusion, the findings of this study suggest that the bulging technique with a single Neuroform Atlas stent is a feasible and safe treatment option for complex, acute-angled WNBAs, with favorable short-term angiographic and clinical outcomes. However, its long-term efficacy and durability require further validation in larger patient populations with extended follow-up.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

HN, XG, CY, LZ, WX, and HH contributed to the study conception and design. HN, XG, CY, LZ, WX, and HH performed material preparation, data collection, and analysis. The first draft of the manuscript was written by HN. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to

be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Affiliated Hangzhou First People's Hospital, School of Medicine of Westlake University (NO. 2025ZN320-1). This study was conducted in accordance with the Declaration of Helsinki. Since anonymized patient data were used, written informed consent was waived.

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Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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