AJNR

Use of the Neuroform Atlas Stent or LVIS Jr Stent for Treatment of Unruptured Intracranial Aneurysms in Parent Arteries of <2 mm in Diameter: A Multicenter Experience

Tengfei Li, Shuailong Shi, Qingliang Chen, Chao Jiang, Wenxian Feng, Qi Tian, Shuhai Long, Zhuangzhuang Wei, Jie Yang, Ye Wang, Jianzhuang Ren, Xinwei Han and Ji Ma

AJNR Am J Neuroradiol published online 13 June 2024
http://www.ajnr.org/content/early/2024/06/13/ajnr.A8238

Published June 13, 2024 as 10.3174/ajnr.A8238

Use of the Neuroform Atlas Stent or LVIS Jr Stent for Treatment of Unruptured Intracranial Aneurysms in Parent Arteries of <2 mm in Diameter: A Multicenter Experience

Tengfei Li, Shuailong Shi, Qingliang Chen, Chao Jiang, Wenxian Feng, Qi Tian, Shuhai Long, Zhuangzhuang Wei, Jie Yang, Ye Wang, Jianzhuang Ren, Xinwei Han, and Ji Ma

ABSTRACT

BACKGROUND AND PURPOSE: The Neuroform Atlas stent and the LVIS Jr stent are intracranial microstent systems for the treatment of wide-neck intracranial aneurysms. Hence, this study aimed to compare the efficacy and safety of the Neuroform Atlas stent and the LVIS Jr stent for the treatment of unruptured intracranial aneurysms in parent arteries of <2 mm in diameter.

MATERIALS AND METHODS: From March 2022 to April 2023, the clinical and imaging data of 135 patients with unruptured intracranial aneurysms treated with stent-assisted coiling using the Neuroform Atlas or LVIS Jr stent in parent arteries of <2 mm in diameter were retrospectively analyzed. Stent apposition was evaluated by high-resolution conebeam CT (HR-CBCT). Immediate aneurysm-embolization attenuation and occlusion at 6-month follow-up were evaluated using 2D DSA and the modified Raymond-Roy classification. Adverse events were recorded. Multivariate logistic regression analysis was undertaken to determine the independent factors affecting incomplete stent apposition.

RESULTS: One hundred thirty-five patients (135 aneurysms) underwent stent-assisted coiling (66 Neuroform Atlas stents and 69 LVIS Jr stents). Intraoperative HR-CBCT showed that 1 Neuroform Atlas stent and 11 LVIS Jr stents had incomplete stent apposition at the aneurysm neck ($P < .05$). Perioperative complications occurred in 3 cases (2.22%). These comprised 2 cases of neurologic complications (1 case of distal intracranial vascular embolism and 1 case of cerebral parenchymal hemorrhage) and 1 case of severe postprocedural gastrointestinal hemorrhage. DSA follow-up showed 3 cases of aneurysm recurrence in the LVIS Jr group. Multivariate regression analysis showed that a stent angle of ≥75° (OR, 23.963; $P = .005$) or a parent artery diameter mismatch ratio of ≥1.25 (OR, 8.043; $P = .037$) were risk factors for incomplete stent apposition, especially for the LVIS Jr stent (OR, 20.297; $P = .015$).

CONCLUSIONS: The Neuroform Atlas stent and LVIS Jr stent are efficacious in the treatment of unruptured intracranial aneurysms in parent arteries of <2 mm in diameter. Apposition of the LVIS Jr stent was worse than in the Neuroform Atlas stent at the neck of some aneurysms.

ABBREVIATIONS: FD = flow diverter; HR-CBCT = high-resolution conebeam CT; IA = intracranial aneurysm; ISA = incomplete stent apposition; SAC = stent-assisted coiling

With the widespread application of flow diverters (FDs), stent-assisted coiling (SAC) appears to have been replaced in the treatment of intracranial aneurysms (IAs).[1,2] Despite advances in FD treatment of bifurcation aneurysms, SAC continues to be relevant.[3-5] Traditional intracranial stents, such as the Solitaire AB (eV3), Enterprise (Codman & Shurtleff), and Neuroform EZ (Styker) can be difficult to implant smoothly for the following reasons: 1) tortuous parent arteries; 2) the large angle of the parent arteries at the aneurysm neck due to the large diameter (0.021 or 0.027 inches) of the microcatheter; and 3) poor compliance.[6,7] Traditional stents are not suitable for the treatment of IAs in parent arteries of <2 mm in diameter because they have a thicker metal wall.[8]

Received November 14, 2023; accepted after revision February 11, 2024.

From the Department of Interventional Radiology (T.L., S.S., Q.T., S.L., Z.W., JY., Y.W., J.R., X.H., J.M.), The First Affiliated Hospital of Zhengzhou University, Zhengzhou, China; Interventional Institute of Zhengzhou University (T.L., S.S., Q.T., S.L., Z.W., JY., Y.W., J.R., X.H., J.M.), Zhengzhou, China; Department of Interventional Radiology (Q.C.), The Third People's Hospital of Henan Province, Zhengzhou, China; Department of Neurology (C.J.), The Fifth Affiliated Hospital of Zhengzhou University, Zhengzhou, China; and Department of Interventional Radiology (W.F.), Zhumadian Central Hospital, Zhumadian, China.

TengFei Li and ShuaiLong Shi contributed equally to this article.

This work was supported by the National Natural Science Foundation of China (grant No. 81801806); Henan Provincial Science and Technology Research Project (grant No. KYDZ2020120441 and grant No. YXKC2022029).

Please address correspondence to Ji Ma, MD, Department of Interventional Radiology, The First Affiliated Hospital of Zhengzhou University, Jianshe Rd No. 1, Er qi district, Zhengzhou, Henan, China; e-mail: soulma@126.com

Indicates article with online supplemental data.

http://dx.doi.org/10.3174/ajnr.A8238

The laser cut Neuroform Atlas stent (Styker) and the braided LVIS Jr stent (MicroVention) are new-generation microembolization-assisted stents for IAs that can be released through smaller microcatheters (0.0165 or 0.017 inches). Multiple clinical studies have shown that these stents are more likely to be suitable for IAs in deep, tortuous parent arteries because of their good compliance and conformity.[9-11] However, comparative studies on the efficacy and safety of SAC using the Neuroform Atlas stent and LVIS Jr stent for IAs in parent arteries of <2 mm in diameter are scarce. Moreover, limited by the DSA performance and x-ray visualization of stent trabeculae, observation and evaluation of stent apposition are difficult.[12,13]

In the present study, we compared the safety and efficacy of these 2 stent types to provide guidance on the SAC of unruptured IAs with parent arteries of <2 mm in diameter. Also, high-resolution conebeam CT (HR-CBCT) was used to evaluate the apposition of the Neuroform Atlas stent and LVIS Jr stent in parent arteries of <2 mm in diameter.

MATERIALS AND METHODS

Ethics

The protocol of this retrospective study was approved by the ethics committee (IRB: 2023KY0937) of Zhengzhou university and verified by the ethics department of each participating institution. The protocol complied with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The requirement to obtain informed consent from participants was waived because of the retrospective nature of this study.

Participants

Patients with unruptured IAs in a parent artery of <2 mm in diameter who were treated by SAC with the Neuroform Atlas stent or LVIS Jr stent at 4 centers from March 2022 to April 2023 were identified from the PACS of the hospitals. The inclusion criteria were the following: 1) unruptured IAs diagnosed by clinical evaluation and imaging examination (MRA, CTA, DSA) that were treated by SAC with the Neuroform Atlas stent or LVIS Jr stent; 2) the diameter of the parent artery of <2 mm; 3) intraoperative HR-CBCT of the stent-placement area; and 4) complete clinical follow-up data and DSA follow-up data at 6 months being available. The exclusion criteria were the following: 1) simultaneous use of FDs or multiple overlapping stents or combined with surgical clipping; 2) embolization with coils alone or with embolic material other than coils, such as Onyx (eV3); 3) the diameter of the parent artery of ≥2 mm; 4) blood blister–like aneurysms, pseudoaneurysms, or dissecting aneurysms caused by infection or trauma; 5) intraoperative HR-CBCT not undertaken; and 6) lack of 6-month DSA follow-up data or patient lost to follow-up.

Clinical and Imaging Data

All interventional procedures were undertaken on the Artis Zeego Endovascular Surgical Cath Lab (Siemens) and Allura Xper FD20 Cath/Angio System (Philips Healthcare) with HR-CBCT capability. Postprocessing of images was undertaken on the workstations of these 2 systems. All patients were subjected to pharmacogenetic testing for aspirin and clopidogrel. Patients who were sensitive to both drugs were given aspirin (100 mg/day) and clopidogrel (75 mg/day) ≥5 days before surgery. Patients who were insensitive to one or both drugs could have an increased dose or be switched to ticagrelor (90 mg/day). All interventional procedures were undertaken by experienced senior neurointerventionalists with ≥10 years of experience and an annual volume of ≥300 cases.

During the procedure, the size and shape of the aneurysm and diameter of the parent artery were determined by global cerebral angiography and 3D reconstructed images. Then the type and size of the stent, the size of the bare coil, and the prerelease site of the stent were determined. We choose the Headway-17 microcatheter (MicroVention) to deliver the LVIS Jr stent or the SL-10 and XT-17 microcatheters (Styker) to deliver the Neuroform Atlas stent. The embolization microcatheter was selected with Echelon-10 straight, 45°, or 90° types (Medtronic) based on the morphology of the aneurysm and the relationship between the aneurysm neck and the parent artery. SAC was completed by prestent release or semi-stent release. The specific methods for implantation of the Neuroform Atlas stent and LVIS Jr stent and aneurysm embolization were similar to those described in the literature.[14-16] The immediate attenuation of aneurysm embolization was evaluated, and the angles of stent placement were measured according to 2D DSA in the working position after the procedure.

The clinical and imaging data of enrolled patients were collected, including basic information (eg, sex, age, preoperative complications), parent artery characteristics (eg, mean diameter, diameter ratio), and aneurysm information (eg, location, shape, size). The mean diameter of the parent artery was defined as the average value of the 3 vessels in the aneurysm neck and beyond the neck, 5 mm at both ends. The diameter mismatch ratio of the parent artery was defined as the ratio of the larger vessel diameter to the narrower vessel diameter at the end of the aneurysm neck. The stent angles were defined as the angles formed by the extension lines at the 2 ends of the stent by selecting an appropriate angle to fully deploy the stent. The attenuation of aneurysm embolization was evaluated using the modified Raymond-Roy classification:[17] I, complete obliteration; II, residual neck; IIIa, residual aneurysm with contrast within the coil interstices; and IIIb, residual aneurysm with contrast along the aneurysm wall.

Observation of Stent Apposition

All patients in this study underwent HR-CBCT of the area of stent placement after the procedure to observe whether the stent had been deployed completely and to detect local deformities or distortions. For patients who underwent intraoperative HR-CBCT with diluted contrast media, imaging information was used to reconstruct and observe stent apposition by reduction of metal artifacts at the postprocessing workstation. For patients who did not undergo intraoperative HR-CBCT with diluted contrast media, the HR-CBCT and 3D DSA data of the parent artery were imported into the postprocessing workstation. Then, images of the stent and parent artery were fused and reconstructed by technology for volume imaging and metal artifact reduction for the observation of stent apposition. The parameters and specific operating methods of HR-CBCT with diluted contrast media and

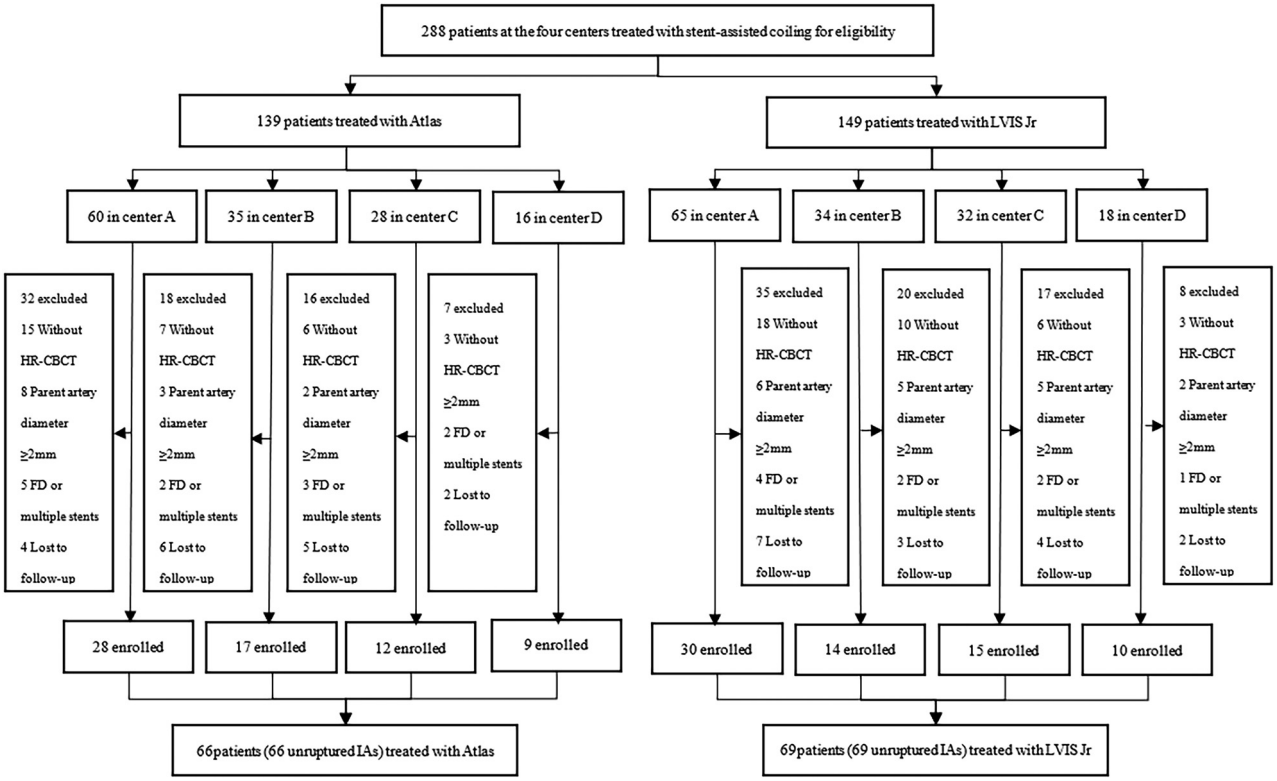

FIG 1. Flow chart of patient selection.

technology for volume reconstruction and metal-artifact reduction by imaging have been described.[18-20]

Stent apposition was evaluated by 2 experienced neurointerventionalists independently. In case of a disagreement, stent apposition was evaluated by a third experienced neuroradiologist. With reference to the criteria of Li et al[19] and Kato et al,[21] incomplete stent apposition (ISA) was defined as the following: I, proximal or distal ISA; II, ISA at the greater or lesser curvature of the "crescent" or "saddle"; and III, incomplete deployment in long stent segments. Patients were divided into a complete apposition group and an incomplete apposition group. On the basis of the literature[22,23] and clinical experience, univariate analysis was undertaken on the factors affecting ISA: aneurysm location, aneurysm size, diameter mismatch ratio of the parent artery, and stent angles. Factors with $P < .05$ were included in multivariate logistic regression analysis to determine the independent factors affecting ISA.

Complications and Follow-Up

Complications during the perioperative period and follow-up were recorded. Serious complications were defined as ischemic stroke caused by acute in-stent thrombosis or embolus dislodgement, parenchymal hemorrhage, or aneurysm rupture in the stent-placement area.

Postoperative follow-up in the outpatient department or over the telephone was undertaken regularly. The mRS score was used to evaluate the improvement of neurologic function at the final follow-up after SAC. Stent patency and the prevalence of complete occlusion of the aneurysm were observed at 6-month DSA follow-up. Aneurysm recurrence was defined as increased visualization of the aneurysm body or neck under DSA, with or without coil compression.

Statistical Analyses

Statistical analyses were performed using SPSS 26.0 (IBM). Quantitative variables with a normal distribution are expressed as the mean (SD) and were compared between groups using the Student *t* test. Quantitative variables with a non-normal distribution are expressed as interquartile ranges and were compared between groups using the Mann-Whitney *U* test. Categoric variables are presented as numbers with percentages and were compared between groups using the χ^2 test or Fisher exact test. Univariate analysis was used to determine the predictors of ISA, and factors with $P < .05$ were included in the multivariate logistic regression analysis. $P < .05$ was considered significant.

RESULTS

Characteristics of the Study Cohort

From March 2022 to April 2023, we screened 288 patients. We excluded 153 patients (68 without HR-CBCT, 31 with a parent artery diameter of ≥ 2mm, 21 with FDs or multiple stents, and 33 lost to follow-up). Eventually, 135 patients (with 135 unruptured IAs) met the inclusion criteria at the 4 centers (Fig 1). They were divided into the Neuroform Atlas group ($n = 66$) and the LVIS Jr group ($n = 69$) depending on the stent type. Among these 135 patients, there were 66 men (48.89%) and 69 women (51.11%), with an average age of 58.78 (SD, 9.60) years. The average size of aneurysms was 4.81 (SD, 1.38) mm. The most common locations of aneurysms were the anterior communicating artery (60/135, 44.44%) and the M1 bifurcation

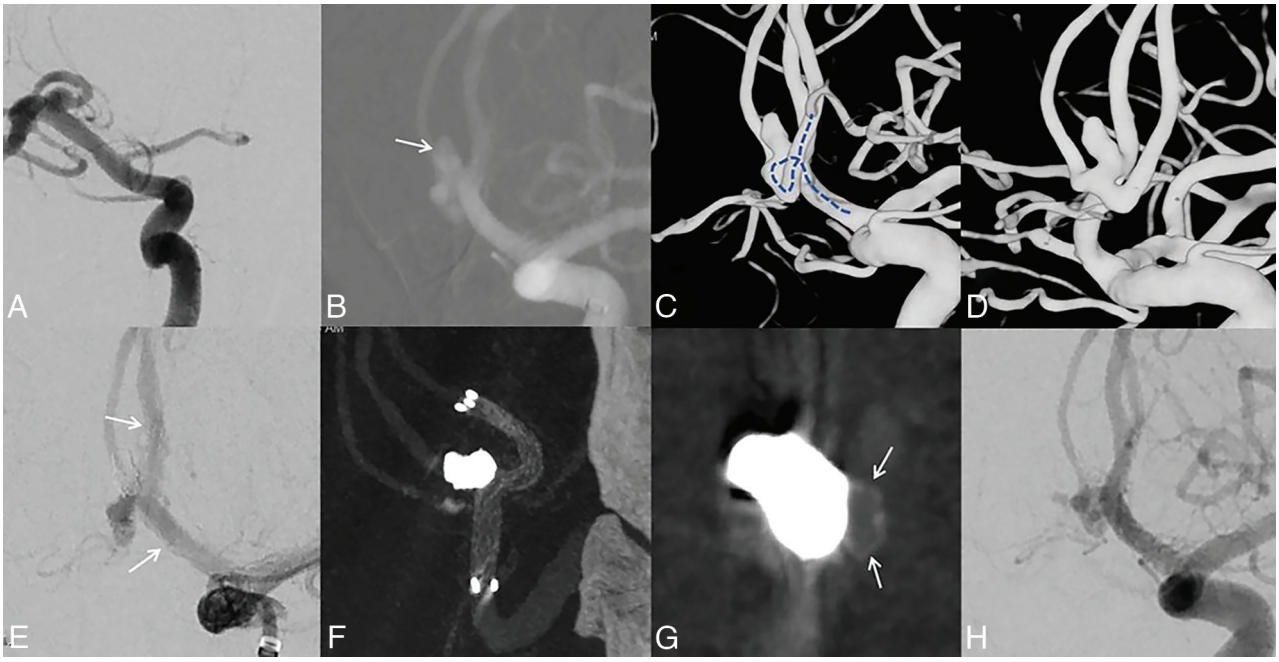

FIG 2. Use of the Neuroform Atlas stent in SAC for the treatment of an unruptured anterior communicating artery aneurysm. *A*, 2D DSA of the right ICA shows the right A1 artery to be slender and the anterior communicating artery to be open. *B*, 2D DSA of the left ICA shows an aneurysm of the anterior communicating artery of 2.2 × 4.5 mm. The anterior communicating artery sends out a median callosal artery and the bilateral A2 arteries together to form a triploid anterior cerebral artery (aneurysm is shown by a *white arrow*). *C* and *D*, 3D DSA shows the position between the 3 A2 arteries and the aneurysms (*blue dashed line* denotes the stent-placement area, the parent artery diameter is 1.91 mm, and the diameter mismatch ratio is 1.09). *E*, SAC using a Neuroform Atlas stent (3.0 × 24 mm) was performed, and the occlusion attenuation of the aneurysm was Raymond-Roy class I (*white arrows* indicate the ends of the stent). *F* and *G*, HR-CBCT with diluted contrast media shows complete stent apposition and satisfactory protection of the coils at the aneurysm neck (the stent wire at the aneurysm neck is indicated by *white arrows*). *H*, DSA follow-up at 6 months shows the stent patency and well-healed aneurysm (Raymond-Roy class I).

(36/135, 26.67%). The morphology of aneurysms was mainly saccular (111/135, 82.22%). There were no significant differences in sex, age, aneurysm size, or parent artery characteristics between the 2 groups (all $P > .05$), but the Neuroform Atlas stent was used more widely than the LVIS Jr stent at the M1 bifurcation ($P = .036$) (Online Supplemental Data).

Outcomes of Interventional Therapy

Implantation of the Neuroform Atlas stent or LVIS Jr stent was successful in all patients. Neuroform Atlas stents were 3 mm in diameter, and 15 mm (20 cases), 21 mm (39 cases), or 24 mm (7 cases) in length. LVIS Jr stents were 2.5 mm in diameter, and 13 mm (8 cases), 17 mm (16 cases), or 23 mm (45 cases) in length. The coils used in this study were all bare coils, and the average number ranged from 2 to 14. 2D DSA images revealed no significant difference in the results for immediate aneurysm occlusion between the 2 groups ($P > .05$) (Online Supplemental Data and Figs 2 and 3).

Complications and Follow-Up Outcomes

During the perioperative period (within 30 days after SAC), 2 neurologic complications (1 distal vascular embolism and 1 cerebral parenchymal hemorrhage) and 1 non-neurologic complication (manifested as severe gastrointestinal bleeding) were observed. One patient with an aneurysm in an anterior communicating artery had an embolic A2 occlusion of the left anterior cerebral artery after implantation of the Neuroform Atlas stent. After evaluation, the occipital branch of the left MCA was fully compensated without special treatment. The other patient with an aneurysm in the M1 bifurcation had a cerebral parenchymal hemorrhage in the non-stent-implantation area 13 hours after implantation of the LVIS Jr stent, and the hemorrhage did not increase after discontinuation of dual antiplatelet therapy. One non-neurologic complication manifested as severe hemorrhage in the upper gastrointestinal tract 4 hours after implantation of the Neuroform Atlas stent. The hemorrhage stopped after emergency embolization of the left gastric artery and right gastroepiploic artery combined with acid-suppression drugs. The mRS scores of the 3 patients before hospital discharge were 0, 1, and 0, respectively. No serious complications (eg, aneurysm rupture, stent migration, coil escape) occurred in the remaining patients during the perioperative period.

All patients were followed up by telephone or examination in the outpatient department. The mean duration of follow-up was 9.44 (SD, 2.27) months. At the final follow-up, residual neurologic symptoms (mRS score = 3–5) or death did not occur in any patient. DSA follow-up at 6 months showed 3 cases of aneurysm recurrence in the LVIS Jr group, and the prevalence of complete occlusion of aneurysms was significantly lower than that in the Neuroform Atlas group (84.1%, 58/69 versus 95.5%, 63/66) ($P = .030$). However, there was no significant difference in the prevalence of in-stent stenosis (2.9%, 2/69 versus 0%, 0/66; $P = .497$). Three patients with recurrent aneurysms and their families refused further treatment, so we conducted only regular follow-up (Online Supplemental Data).

Stent Apposition

Intraoperative HR-CBCT showed that 11 LVIS Jr stents had incomplete apposition at the neck, whereas only 1 Neuroform Atlas stent had incomplete apposition. Patients were divided into the complete-apposition group ($n = 123$) and the incomplete-apposition group ($n = 12$). There were no significant differences in sex, age, preoperative complications, or other clinical data between the 2 groups (all $P > .05$). Univariate analysis showed that aneurysm size, diameter mismatch ratio of the parent artery, stenosis of the parent artery, stent angles, and stent type affected stent apposition (all $P < .05$) (Online Supplemental Data). The facts stated above were included in multivariate logistic regression analysis, after which the stent angles, diameter mismatch ratio of the parent artery, and stent type were found to be independent factors affecting stent apposition. Stent angles of ≥75°or diameter mismatch ratio of the parent artery of ≥1.25 were risk factors for ISA, and apposition of the LVIS Jr stent was worse than that of the Neuroform Atlas stent (Tables 1 and 2).

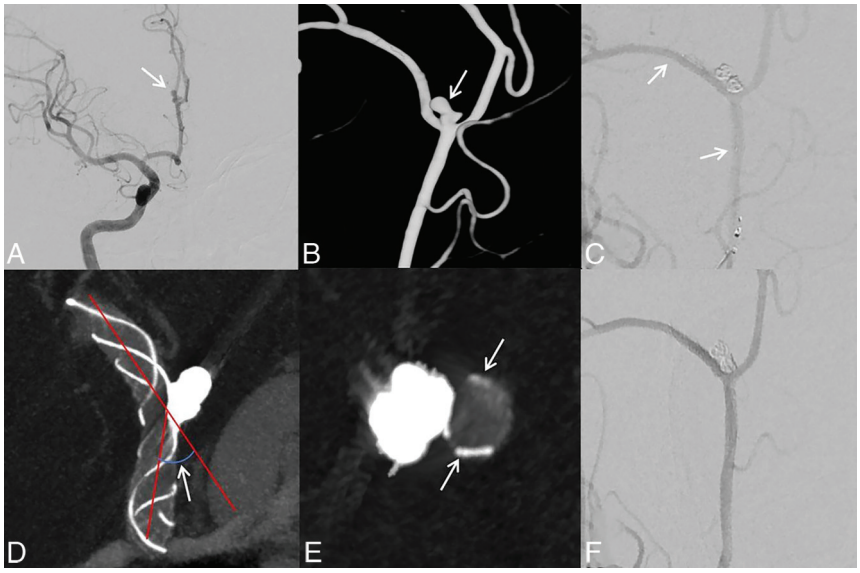

FIG 3. Use of the LVIS Jr stent in SAC for the treatment of an unruptured A2-segment aneurysm. *A* and *B*, 2D DSA and 3D DSA of the right ICA show an A2-segment aneurysm of the right anterior cerebral artery, with an irregular shape and a size of 1.5 × 2.7 mm. The parent artery diameter is 1.79 mm, and the diameter mismatch ratio is 1.15 (aneurysm is shown by a *white arrow*). *C*, SAC using a LVIS Jr stent (2.5 × 13 mm) was performed, and the aneurysm occlusion attenuation was Raymond-Roy class I (*white arrows* indicate the ends of the stent). *D*, HR-CBCT with diluted contrast media shows that the stent was completely deployed and stent angles were 43.34° (the stent angles are indicated by a *white arrow*). *E*, HR-CBCT shows complete stent apposition at the aneurysm neck and the coils protected satisfactorily (stent wire at the aneurysm neck is indicated by *white arrows*). *F*. DSA follow-up at 6 months shows stent patency, and the aneurysm has healed well (Raymond–Roy class I).

Table 1: Included variables and assignment in multivariable regression analysis of incomplete stent apposition[a]

Variable	Name	Assign
Aneurysm dome	X1	Quantitative variable
Aneurysm neck	X2	Quantitative variable
Parent artery diameter mismatch ratio	X3	<1.25 = 0[a], ≥1.25 = 1
Paren artery stenosis	X4	No = 0[a], yes = 1
Stent type	X5	Atlas = 0[a], LVIS Jr = 1
Stent angles	X6	<75°= 0[a], ≥75°= 1

[a] A value of zero was assigned as the reference group.

Table 2: Multivariable logistic analysis of the factors associated with incomplete stent apposition of unruptured intracranial aneurysms treated with Neuroform Atlas or LVIS Jr stents

Variable	OR	95% CI	*P* Value
Aneurysm dome	1.122	0.655∼1.922	.675
Aneurysm neck	1.683	0.936∼3.027	.082
Parent artery diameter mismatch ratio	8.043	1.137∼56.895	.037
Parent artery stenosis	1.794	0.310∼10.369	.514
Stent type	20.297	1.794∼229.636	.015
Stent angles	23.963	2.602∼220.693	.005

DISCUSSION

We showed that the Neuroform Atlas stent and LVIS Jr stent had good clinical outcomes and radiographic follow-up results, and a low recurrence rate in the SAC of unruptured IAs in parent arteries of <2 mm in diameter. It has been reported that the rate of immediate complete occlusion of IAs in SAC using the LVIS Jr stent varied from 42% to 91%,[12,24,25] and for the Neuroform Atlas stent, it varied from 48% to 97%.[13,14,26,27] Those data are basically consistent with the results of immediate aneurysm occlusion in our study: 84.8% for the Neuroform Atlas and 73.9% for the LVIS Jr. In the present study, although the stent was placed in a parent artery diameter of < 2mm, the rate of immediate aneurysm occlusion remained satisfactory, and there was no significant difference between the 2 groups. On the one hand, this scenario results from improvement of the stent design, such as the metal coverage of the Neuroform Atlas stent at only 6%–12%. Due to its hybrid design with distal open and proximal closed cells, the Neuroform Atlas stent can adhere closely to the lesser curvature of the vessel and has good perforation performance in tortuous parent arteries. The LVIS Jr stent has high metal coverage (15%–18%), and the small stent mesh (diameter < 1.5 mm) can prevent escape of the coil during SAC of small IAs to improve the chances of complete occlusion and cure of the aneurysm.

On the other hand, due to rational application of the advantages and characteristics of different stents, such as through the semi-release method of the stent and the "vault" technique, part of the stent at the aneurysm neck can be

herniated into the aneurysm cavity, and a wide-neck aneurysm can be changed into a relatively narrow-neck aneurysm. Therefore, the Neuroform Atlas stent can be used for SAC in small IAs and coils do not escape easily, especially for wide-neck aneurysms at vascular bifurcations (eg, M1 bifurcation, basilar artery tip). This phenomenon aligns with the fact that the Neuroform Atlas stent is used more widely in M1 bifurcated aneurysms than the LVIS Jr stent used in our study.

Studies[9,25,28,29] have reported that the Neuroform Atlas stent and LVIS Jr stent had a prevalence of neurologic perioperative complications of 3.4%–13.6% and 4.9%–19.0%, with ischemic complications of about 1.7%–6.2% and 4.1%–14.0% and bleeding complications of about 0%–3.0% and 2.4%–5.2%, respectively. In the present study, bleeding complications were documented in 2 patients (cerebral parenchymal hemorrhage in the non-stent-implantation area and hemorrhage in an ulcer after stent implantation), but the causes were not related directly to stent implantation. Traditional Neuroform EZ and LVIS stents are not suitable for small parent arteries due to the large diameter of the microcatheter and poor compliance. Also, the prevalence of postoperative ischemic complications (eg, acute in-stent thrombosis and in-stent stenosis) was higher, possibly related to the incomplete apposition of metal stents with a thick wall in small parent arteries. In the present study, although the Neuroform Atlas stent or LVIS Jr stent was implanted into a parent artery of <2 mm in diameter, the prevalence of ischemic complications was not increased significantly (only 1 instance of embolic detachment) and serious events (eg, acute in-stent thrombosis) did not occur. This observation may have been related to the Neuroform Atlas stent and LVIS Jr stent having a relatively thin wall, which aids in easy deployment and complete apposition in the small parent artery.

DSA follow-up at 6 months showed that the prevalence of complete occlusion of aneurysms in the Neuroform Atlas group was significantly higher than that in the LVIS Jr group and that 3 patients (4.3%) had aneurysm recurrence in the LVIS Jr group. This finding is consistent with reports of a prevalence of recurrence of 3.8%–8.3% after SAC using the LVIS Jr stent.[9,12] Intraoperative HR-CBCT showed significant ISA at the aneurysm neck in 11 patients treated with a LVIS Jr stent, but in only 1 patient treated with the Neuroform Atlas stent. Multiple studies have shown that ISA is closely associated with delayed occlusion and recurrence of aneurysms, in-stent thrombosis, and delayed endothelialization.[30,31] For example, Li et al[32] reported that ISA using FDs prolonged the time to endothelialization significantly and caused delayed occlusion of the aneurysm. Use of the lantern method during implantation of the LVIS Jr stent can protect from the escape of coils at the aneurysm neck, but a braided metal stent may cause local stress changes during pushing and pulling, which may lead to ISA.[22,33]

Continuous blood flow into the aneurysm cavity through the gap of the ISA at the aneurysm neck also causes delayed occlusion or recurrence of the aneurysm. This phenomenon may have been the main reason for the lower rate of long-term occlusion and the higher recurrence rate of partial LVIS Jr stents with incomplete apposition. We showed that a stent angle of $\geq 75°$ or a diameter mismatch ratio of the parent artery of ≥ 1.25 were independent risk factors for ISA and that the LVIS Jr stent was more prone to ISA than the Neuroform Atlas stent. These data are in accordance with the results of study by Monteiro et al.[25] They reported that the Neuroform Atlas stent was more suitable for aneurysms in the parent artery with a larger curvature or different diameters than the LVIS Jr stent. This observation suggests that the apposition achieved by the LVIS Jr stent should be highly focused on if the parent artery is too angulated or has a larger diameter mismatch ratio at the aneurysm neck.

Our study had several limitations. First, this was a retrospective study with a small sample size, and its conclusions must be verified in additional large-sample, multicenter, prospective, randomized controlled studies. Second, there were selection biases for stents and coils. Third, despite use of a method to reduce metal artifacts, stent apposition at the neck of some aneurysms was affected by the metal artifact of the coil, which may have affected our results. Fourth, the follow-up period was short, and long-term DSA results after SAC were not observed. Fifth, the operator-assessed imaging, patient selection, and variability (including operation procedures, operator experience, and stent preference) among different institutions may have influenced the study results. Sixth, the limited visibility of the nitinol wires may be a potential limitation in the assessment of stent wall apposition.

CONCLUSIONS

The Neuroform Atlas stent and LVIS Jr stent had good efficacy and a low prevalence of complications in SAC of unruptured IAs in parent arteries of <2 mm in diameter. Apposition of the LVIS Jr stent was worse than that of the Neuroform Atlas stent at the neck of some aneurysms.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

REFERENCES

1. Sciacca S, Bassiouny A, Mansoor N, et al. **Early outcomes of the Pipeline Vantage flow diverter: a multicentre study.** *Clin Neuroradiol* 2023;33:887–96 CrossRef Medline
2. Stahl J, Marsh LM, Thormann M, et al. **Assessment of the flow-diverter efficacy for intracranial aneurysm treatment considering pre- and post-interventional hemodynamics.** *Comput Biol Med* 2023;156:106720 CrossRef Medline
3. Hanel RA, Cortez GM, Jankowitz BT, et al; ATLAS Investigators. **Anterior circulation location-specific results for stent-assisted coiling: carotid versus distal aneurysms: 1-year outcomes from the Neuroform Atlas stent pivotal trial.** *J Neurointerv Surg* 2023 Nov 8 [Epub ahead of print] CrossRef Medline
4. Oishi H, Fujii T, Yatomi K, et al. **Stent-assisted coil embolization of unruptured middle cerebral artery aneurysms using LVIS Jr stents.** *J Clin Neurosci* 2020;80:87–91 CrossRef Medline
5. Zhang X, Wang R, Ding Y, et al. **Embolization of unruptured wide-necked aneurysms at the MCA bifurcation using the Neuroform Atlas stent-assisted coiling: a two-center retrospective study.** *Front Neurol* 2023;14:1199390 CrossRef Medline
6. Daou BJ, Palmateer G, Linzey JR, et al. **Stent-assisted coiling of cerebral aneurysms: head-to-head comparison between the Neuroform Atlas and EZ stents.** *Interv Neuroradiol* 2021;27:353–61 CrossRef Medline

7. Iwakami T, Fujii N, Son J. **Comparison of the physical characteristics of support stents for cerebral aneurysm embolization.** *J Neuroendovasc Ther* 2021;15:778–86 CrossRef Medline
8. Kim YN, Choi JW, Lim YC, et al. **Usefulness of silent MRA for evaluation of aneurysm after stent-assisted coil embolization.** *Korean J Radiol* 2022;23:246–55 CrossRef Medline
9. Gross BA, Ares WJ, Ducruet AF, et al. **A clinical comparison of Atlas and LVIS Jr stent-assisted aneurysm coiling.** *J Neurointerv Surg* 2019;11:171–74 CrossRef Medline
10. Jankowitz BT, Jadhav AP, Gross B, et al. **Pivotal trial of the Neuroform Atlas stent for treatment of posterior circulation aneurysms: one-year outcomes.** *J Neurointerv Surg* 2022;14:143–48 CrossRef Medline
11. Zaidat OO, Hanel RA, Sauvageau EA, et al; ATLAS Investigators. **Pivotal trial of the Neuroform Atlas stent for treatment of anterior circulation aneurysms: one-year outcomes.** *Stroke* 2020;51:2087–94 CrossRef Medline
12. Kim J, Han HJ, Lee W, et al. **Safety and efficacy of stent-assisted coiling of unruptured intracranial aneurysms using low-profile stents in small parent arteries.** *AJNR Am J Neuroradiol* 2021;42:1621–26 CrossRef Medline
13. Ozaki T, Fujinaka T, Kidani T, et al. **Coil embolization of unruptured cerebral aneurysms using stents in small arteries less than 2 mm in diameter.** *Neurosurgery* 2022;90:538–46 CrossRef Medline
14. Dong L, Chen X, Wang J, et al. **Neuroform Atlas stent-assisted coiling of tiny wide-necked intracranial aneurysms.** *Front Neurol* 2022;13:1020785 CrossRef Medline
15. Foo M, Maingard J, Hall J, et al. **Endovascular treatment of intracranial aneurysms using the novel low profile visualized intraluminal support EVO stent: multicenter early feasibility experience.** *Neurointervention* 2021;16:122–31 CrossRef Medline
16. Hanel RA, Yoon N, Sauvageau E, et al. **Neuroform Atlas stent for treatment of middle cerebral artery aneurysms: 1-year outcomes from Neuroform Atlas stent pivotal trial.** *Neurosurgery* 2021;89:102–08 CrossRef Medline
17. Ten Brinck MFM, de Vries J, Bartels R, et al. **Neuroform Atlas stent-assisted coiling: preliminary results.** *Neurosurgery* 2019;84:179–89 CrossRef Medline
18. Kotsugi M, Nakagawa I, Konishi K, et al. **Three-dimensional reconstruction imaging by C-arm computed tomography accurately visualizes in-stent neointimal formation in patients with stent-assisted coil embolization.** *Front Neurol* 2023;14:1131061 CrossRef Medline
19. Li TF, Ma J, Han XW, et al. **Application of high-resolution C-arm CT combined with streak metal artifact removal technology for the stent-assisted embolization of intracranial aneurysms.** *AJNR Am J Neuroradiol* 2019;40:1752–58 CrossRef Medline
20. Li TF, Shi CC, Ma J, et al. **Clinical study of high-resolution C-arm CT in mechanical recanalization and stent implantation for chronic cerebral artery occlusion.** *Neurol India* 2022;70:694–98 CrossRef Medline
21. Kato N, Yuki I, Ishibashi T, et al. **Visualization of stent apposition after stent-assisted coiling of intracranial aneurysms using high-resolution 3D fusion images acquired by C-arm CT.** *J Neurointerv Surg* 2020;12:192–96 CrossRef Medline
22. Kwon MY, Ko YS, Kwon SM, et al. **Evaluation of stent apposition in the Lvis blue stent-assisted coiling of distal internal carotid artery aneurysms: correlation with clinical and angiographic outcomes.** *J Korean Neurosurg Soc* 2022;65:801–15 CrossRef Medline
23. Wu D, Lai N, Zhao X, et al. **Enterprise 2 stent-assisted embolization of paraclinoid aneurysms: a single-center preliminary study.** *Clin Interv Aging* 2022;17:1833–40 CrossRef Medline
24. Martinez-Galdamez M, Orlov K, Kadziolka K, et al. **Safety and efficacy of intracranial aneurysm embolization using the "combined remodeling technique:" low-profile stents delivered through double lumen balloons—a multicenter experience**. *Neuroradiology* 2019;61:1067–72 CrossRef Medline
25. Monteiro A, Cortez GM, Aghaebrahim A, et al. **Low-Profile Visualized Intraluminal Support Jr braided stent versus Atlas self-expandable stent for treatment of intracranial aneurysms: a single-center experience.** *Neurosurgery* 2021;88:E170–78 CrossRef Medline
26. Dong L, Wang J, Chen X, et al. **Stent-assisted coiling using the Neuroform Atlas stent for treatment of aneurysms that recur after coil embolization.** *Front Neurol* 2022;13:967942 CrossRef Medline
27. Sweid A, Herial N, Sajja K, et al. **Early multicenter experience with the Neuroform Atlas stent: feasibility, safety, and efficacy.** *Neurosurgery* 2020;87:E321–35 CrossRef Medline
28. Choo YS, Kim EJ, Sung SM, et al. **Additional rescue stenting with Neuroform Atlas stents during stent-assisted coiling of saccular aneurysms.** *Clin Neurol Neurosurg* 2023;230:107777 CrossRef Medline
29. Liu C, Guo K, Wu X, et al. **Utility of Low-Profile Visualized Intraluminal Support (LVIS) stent for treatment of acutely ruptured bifurcation aneurysms: a single-center study.** *Front Neurol* 2023;14:1050369 CrossRef Medline
30. Ando H, Nakano Y, Sawada H, et al. **Diagnostic performance of high-resolution intravascular ultrasound for abnormal post-stent findings after stent implantation: a comparison study between high-resolution intravascular ultrasound and optical coherence tomography.** *Circ J* 2021;85:883–90 CrossRef Medline
31. Wang N, Lu Y, Feng L, et al. **Identifying risk factors for in-stent restenosis in symptomatic intracranial atherosclerotic stenosis: a systematic review and meta-analysis.** *Front Neurol* 2023;14:1170110 CrossRef Medline
32. Li J, Gong W, Li D, et al. **Evaluation of the apposition in unruptured aneurysms treated with flow diverters by optical coherence tomography: preliminary clinical experience.** *Front Neurol* 2022;13:1029699 CrossRef Medline
33. Zhang H, Gao X, Liang H, et al. **Incomplete stent apposition of Low-Profile Visualized Intraluminal Support stents in the treatment of cerebral aneurysms.** *J Neurointerv Surg* 2020;12:591–97 CrossRef Medline