A comparison of Atlas and Leo Baby stents-assisted coiling of intracranial aneurysms with small parent vessels

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Background: Some studies have reported the efficacy and safety of the Atlas stent and the Leo Baby stent-assisted coiling (SAC) of intracranial aneurysms arising from small cerebral vessels. The authors aimed to compare the clinical performance of the Atlas and the Leo Baby stents in small parent arteries.

Methods and materials: Between January 2019 and November 2022, 56 patients at our centre were treated using either Atlas or Leo Baby SAC of intracranial aneurysms arising from small parent vessels (< 2 mm). The clinical and angiographic imaging data of the two cohorts were retrospectively collected and comparatively analyzed.

Results: A total of 56 patients were included in this study. Thirty-two patients were treated with the Atlas SAC, and 24 patients were treated with the Leo Baby SAC. The mean age of the Atlas stent cohort was older, and the mean aneurysm size was smaller than the Leo Baby stent. The immediate complete occlusion rate was 68.6% in the Atlas stent cohort and 62.5% in the Leo Baby stent cohort. The mean angiographic follow-up time for Atlas stent cohort was 8.9 ± 2.5 months, and the final aneurysm complete occlusion rate was 81.0%. The mean follow-up time for Leo Baby stent cohort was 18.9 ± 6.0 months, and the final aneurysm complete occlusion rate was 83.3%.

Conclusions: At the final follow-up, the Atlas or the Leo baby stent SAC of intracranial aneurysms with small parent vessels resulted in favourable angiographic results and clinical outcomes, with a low rate of associated complications.

Keywords: aneurysm occlusion rate, atlas stents, intracranial aneurysms, leo baby stents, small vessels

Introduction

In the past several decades, with the advancement of micro-catheter technology and the development of embolic devices and materials, previous challenging or uncoilable lesions have become treatable[1,2]. The introduction of the stent device has allowed neurointerventionalists to treat wide-neck aneurysms using stent-assisted coiling (SAC) safely and effectively[3–5]. However, there are still many challenges remaining for the SAC of intracranial aneurysms arising from small parent vessels less than 2 mm in diameter, primarily because the small cerebral vessels make delivery of large delivery microcatheters (0.021 or 0.027 inch) difficult[6]. In earlier studies, Turk *et al.*[7] attempted to use the

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HIGHLIGHTS

- There are still many challenges remaining for the stent-assisted coiling of intracranial aneurysms arising from small parent vessels less than 2 mm in diameter, primarily because the small cerebral vessels make delivery of large delivery microcatheters (0.021 or 0.027 inch) difficult.
- In this study, we compared the efficacy and safety of the Atlas and the Leo baby stent in small vessels less than 2.0 mm in luminal diameter.
- Coil embolization of intracranial aneurysms using Atlas or Leo Baby stents in small arteries less than 2 mm in diameter is safe and effective.

Neuroform stent in distal small cerebral vessels. Fortunately, all devices were successfully deployed, and all patients accepted positive short-term and intermediate-term results. However, it also increased the incidence of intraprocedural thromboembolism.

Recently, several low-profile micro-stents, including the Atlas and the Leo Baby, have gained increasing attention and great success in intracranial aneurysms originating from small parent vessels due to being compatible with smaller (0.0165 inch) microcatheters[8–10]. The Neuroform Atlas stent (Stryker Neurovascular) is a self-expandable stent constructed from laser-cut nitinol. Unlike previous cell designs, it poses a hybrid cell design with open-cell and closed-cell structures[11]. The Leo Baby stent (Balt) is also a self-expandable stent with a sliding-strut design constructed from braided mesh nitinol wires[12]. Although

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some studies have confirmed the efficacy and safety of these two stents, the results varied greatly. In addition, currently, few studies report the efficacy and safety of the Atlas or the Leo Baby SAC of intracranial aneurysms in parent vessels smaller than 2.0 mm. Furthermore, no study has formally compared the clinical performance of these stents. Therefore, this study compares the clinical performance of these two stents in intracranial aneurysms with small parent vessels less than 2.0 mm.

Methods and materials

Study design

The study was approved by the Institutional Review Board (IRB) of hospital (no. Kelun-2017005) and written informed consent was not required from every patient before treatment due to retrospective design.

Patients population

The Atlas and the Leo Baby stents are both commercially available. All consecutive patients were treated with SAC using either the Atlas stents or the Leo Baby stents at our centre between January 2019 and June 2021. The diameter of the parent vessel was measured, and all intracranial aneurysms with a parent artery diameter of less than 2 mm were included. The indication of SAC is that the age of the patient is younger than 85 years. Indications for stent use include wide neck (tumour neck larger than 4 mm or body-to-neck ratio < 1.5). Patient were not associated with other serious diseases that could lead to rapid deterioration or death. After digital subtraction angiography (DSA) angiography, small parent vessels less than 2.0 mm. At the same time, no other surgical treatments were performed in patients with ruptured aneurysms or patients without ruptured aneurysms. Aneurysms clipped and treated with shunt stents (FD) were excluded. Finally, we included a total of 56 patients, of which 32 used the Atlas stent and 24 used the Leo Baby stent. Patient and aneurysm characteristics, immediate and follow-up angiography data, discharge and follow-up clinical outcome, and device-related complications were obtained and evaluated.

Antiplatelet protocol and interventional procedures

The final treatment options were determined together by neurosurgeons and neurointerventionalists via consensus. All patients with unruptured aneurysms needed to receive a standard dual antiplatelet regime (100 mg aspirin and 75 mg clopidogrel) for at least 5 days and were evaluated for platelet aggregation rate using the Verify Now test before the procedure. For patients with ruptured aneurysms, tirofiban was administered upon an intravenous bolus of 5 μg/kg over three minutes as soon as the stent was deployed, and then tirofiban continuous infusion by a maintenance infusion of 0.06–0.08 μg/kg/min for 24 h. After the tirofiban continuous infusion, a 300 mg loading dose of aspirin or a 300 mg loading dose of clopidogrel was administered. Dual antiplatelet therapy was overlapped with half the tirofiban dose for 2 h before finishing the infusion of tirofiban. Whether patient experienced unruptured aneurysms or ruptured aneurysms, daily doses of 75 mg clopidogrel were administered for three months and 100 mg/day of aspirin was given indefinitely.

All procedures were performed under general or local anaesthesia with conscious sedation by an experienced interventional neuroradiologist. All patients underwent surgery using the femoral artery approach. The choice of device and technique applied was at the discretion of the operator.

Study variables

The degree of aneurysm embolization was evaluated by the Raymond scale, in which Classes 1, 2, and 3 represent complete occlusion, residual neck, and residual aneurysm, respectively. All patients underwent postoperative angiography immediately after the operation. Moreover, follow-up angiographic results were obtained by DSA. All angiographic images were independently evaluated by two neurointerventionists.

The clinical outcome was evaluated by the modified Rankin Scale (mRS). A mRS score of 0–2 indicated a good clinical outcome, and a mRS score of 3–6 indicated a poor clinical outcome. The clinical outcome of all patients was evaluated at discharge, and the clinical outcome of all patients was obtained through an outpatient visit or telephone interview at follow-up.

Statistical analysis

Data analyses were carried out using the SPSS software (SPSS 26.0). Categorical variables were presented using numbers and percentages, and continuous data were expressed using mean ± SD values. χ^2 and Fisher exact tests were used to compare categorical variables. A Student's t-test was used to compare continuous data for normally distributed data, and a Mann–Whitney U test was used to compare continuous data for non-normally distributed variables. P less than 0.05 indicated a statistical difference.

Statement

The work has been reported in line with the PROCESS criteria.

Results

Baseline characteristics

In the current study, 56 patients with aneurysms were treated with SAC using either the Atlas or the Leo Baby stents. The Atlas and the Leo Baby stents were engaged in 32 (57.1%) and 24 (42.9%) instances, respectively. Overall, the majority of the patients were female (64.9%, $n = 37$), and the mean age was 58.5 ± 11.1 years. Clinical comorbidities were as follows: hypertension, 44 (77.2%); diabetes, 5 (8.8%); history of stroke, 14 (24.0%); and smoking, 18 (31.6%). More than half of the patients had favourable outcomes at admission.

The most common aneurysm location was the basilar artery tip ($n = 14$, 25.0%), followed by the anterior communicating artery ($n = 14$, 25.0%). The ruptured intracranial aneurysms accounted for 39.3% ($n = 22$) of all intracranial aneurysms. The mean aneurysm size was 5.7 ± 4.2 mm, and the mean neck diameter was 3.5 ± 2.6 mm. The mean parent artery diameter was 1.68 ± 0.27 mm. Notably, the mean age of the Atlas cohort was older than that of the Leo Baby cohort ($P = 0.009$), and the mean aneurysm size of the Atlas cohort was larger than that of the Leo Baby cohort ($P = 0.047$). The demographic characteristics and aneurysm characteristics are presented in Table 1 and Table 2.

Table 1

Comparison of baseline characteristics.

Variables	All	Atlas	Leo Baby	P value
Cases	56	32	24	
Age (years)	58.5 (10.8)	61.7 (9.5)	55.2 (12.2)	0.009*
Female, n (%)	36/56 (64.3)	21/32 (65.6)	15/24 (62.5)	0.809
Hypertension, n (%)	43/56 (76.8)	26/32 (81.3)	17/24 (70.8)	0.361
Diabetes, n (%)	5/56 (8.9)	3/32 (9.4)	2/24 (8.3)	1.000
Stroke, n (%)	14/56 (25.0)	8/32 (25.0)	6/24 (25.0)	1.000
Smoking, n (%)	18/56 (32.1)	12/32 (37.5)	6/24 (24.0)	0.322
Fisher grade, n (%)				
Fisher 0	35/56 (62.5)	22/32 (68.8)	13/24 (54.2)	0.265
Fisher 1	3/56 (5.4)	1/32 (3.1)	2/24 (8.3)	0.571
Fisher 2	8/56 (14.3)	3/32 (9.4)	5/24 (20.8)	0.268
Fisher 3	7/56 (12.5)	4/32 (12.5)	3/24 (12.5)	1.000
Fisher 4	3/56 (5.4)	2/32 (6.3)	1/24 (4.2)	1.000
Clinical outcomes at admission, n (%)				
mRS 0–2	33/56 (58.9)	20/32 (62.5)	13/24 (54.2)	0.530
mRS 3–6	23/56 (41.1)	12/32 (37.5)	11/24 (45.8)	0.530

*indicated $P < 0.05$.
mRS, modified Rankin Scale.

Immediate and follow-up angiographic results

Table 3 shows the immediate and follow-up angiographic results. All patients received an angiography immediately after the procedure. The compete occlusion rate was 68.8% (22/32) and 62.5% (15/24) in the Atlas and the Leo Baby cohorts, respectively. There were no statistically significant differences in the immediate angiographic results ($P = 0.823$).

Angiographic follow-up with DSA was available for 21 (65.6%) patients and 19 (79.2%) patients in the Atlas and the Leo Baby cohorts, respectively. There were no statistically significant differences in the follow-up angiographic results ($P = 1.000$). The compete occlusion rate was 81.0% (17/21) and 78.9% (15/19) in the Atlas and the Leo Baby cohorts, respectively. The near-complete occlusion rate was 14.3% (3/21) and

Table 2

Aneurysm characteristics.

Variables	All	Atlas	Leo Baby	P value
Aneurysms	56	32	24	
Ruptured, n (%)	22/56 (39.3)	10/32 (31.3)	12/24 (50.0)	0.155
Location, n (%)				
ACA	5/56 (8.9)	3/32 (9.4)	2/24 (8.3)	1.000
MCA	12/56 (21.4)	9/32 (28.1)	3/24 (12.5)	0.200
PCA	4/56 (7.1)	1/32 (3.1)	3/24 (12.5)	0.303
AcoA	14/56 (25.0)	8/32 (25.0)	6/24 (25.0)	1.000
BA tip	14/56 (25.0)	6/32 (18.8)	8/24 (33.3)	0.232
SCA	1/56 (1.8)	1/32 (3.1)	0/24 (0)	1.000
AICA	1/56 (1.8)	1/32 (3.1)	0/24 (0)	1.000
PICA	5/56 (8.9)	3/32 (9.4)	2/24 (8.3)	1.000
Anterior circulation, n (%)	31/56 (55.4)	20/32 (62.5)	11/24 (45.8)	0.214
Posterior circulation, n (%)	25/56 (44.6)	12/32 (37.5)	13/24 (54.2)	0.214
Aneurysm size (mm)	5.7 (4.2)	4.6 (2.6)	7.1 (5.5)	0.047*
Neck size (mm)	3.5 (2.7)	3.1 (1.8)	4.1 (3.4)	0.206
Parent artery (mm)	1.68 (0.27)	1.70 (0.26)	1.65 (0.29)	0.504

*indicated $P < 0.05$.
ACA, anterior cerebral artery; AcoA, anterior communicating artery; AICA, anterior inferior cerebellar artery; BA tip, basilar artery tip; MCA, middle cerebral artery; PCA, posterior cerebral artery; PICA, posterior inferior cerebellar artery; SCA, superior cerebellar artery.

Table 3

Comparison of immediate and follow-up angiographic results.

Characteristics	All	Atlas	Leo Baby	P value
Initial occlusion class, n (%)				0.823
Raymond 1	37/56 (66.1)	22/32 (68.8)	15/24 (62.5)	0.625
Raymond 2	14/56 (25.0)	7/32 (21.9)	7/24 (29.2)	0.533
Raymond 3	5/56 (8.9)	3/32 (9.4)	2/24 (8.3)	1.000
Follow-up occlusion class, n (%)				1.000
Raymond 1	32/40 (80.0)	17/21 (81.0)	15/19 (78.9)	1.000
Raymond 2	6/40 (15.0)	3/21 (14.3)	3/19 (15.8)	1.000
Raymond 3	2/40 (5.0)	1/21 (4.8)	1/19 (5.3)	1.000

15.8% (3/19) in the Atlas and the Leo Baby cohorts, respectively. The rate of Raymond 3 was 4.8% (1/21) and 5.3% (1/19) in the Atlas and the Leo Baby cohorts, respectively.

Clinical outcomes at discharge and follow-up

Table 4 shows the clinical outcomes at discharge and follow-up. The clinical outcome of all patients was evaluated using the mRS score at discharge. Overall, 81.3% (26/32) of patients had a good clinical outcome (mRS 0–2) in the Atlas cohort, and 91.7% (22/24) of patients had a good clinical outcome (mRS 0–2) in the Leo Baby cohort. There was no statistically significant difference in the clinical outcomes at discharge ($P = 0.444$). However, three patients in the Atlas cohort died at discharge, and no patient in the Leo Baby cohort died at discharge. The three patients presented with ruptured intracranial aneurysms and had a poor clinical outcome (mRS $\geq$ 4).

Clinical follow-up was available for all 32 patients in the Atlas cohort over a mean period of 8.9 months and for all 24 patients in the Leo Baby stent cohort over a mean period of 18.9 months. Overall, 75.0% (24/32) of patients had a good clinical outcome (mRS 0–2) in the Atlas cohort, and 87.5% (21/24) of patients had a good clinical outcome (mRS 0–2) in the Leo Baby cohort. There was no statistically significant difference in the clinical outcomes at the last follow-up ($P = 0.319$). Four patients in the Atlas cohort and two patients in the Leo Baby cohort died at the final follow-up. Among them, intraoperative aneurysm ruptures occurred in

Table 4

Comparison of initial and follow-up clinical outcomes.

Results	All	Atlas	Leo Baby	P value
Clinical outcome at discharge, n (%)				
Good clinical outcome (mRS 0–2)	48/56 (85.7)	26/32 (81.3)	22/24 (91.7)	0.444
Poor clinical outcome (mRS 3–6)	8/56 (14.3)	6/32 (18.8)	2/24 (8.3)	0.444
All-cause mortality at discharge	3/56 (5.4)	3/32 (9.4)	2/24(0)	0.252
Clinical outcome at follow-up				
Follow-up period	13.5 ± 6.7	8.9 ± 2.5	18.9 ± 6.0	< 0.0001
Good clinical outcome (mRS 0–2), n (%)	49/56 (87.5)	27/32 (84.4)	22/24 (91.7)	0.686
Poor clinical outcome (mRS 3–6), n (%)	7/56 (12.5)	5/32 (15.6)	2/24 (8.3)	0.686
All-cause mortality at follow-up, n (%)	6/56 (10.7)	4/32 (12.5)	2/24(8.3)	0.691

mRS, modified Rankin Scale.

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Table 5

Comparison of stent-related complication.

Results	All, n (%)	Atlas, n (%)	Leo Baby, n (%)	P value
Intraprocedural aneurysm rupture	4/56 (7.1)	2/32 (6.3)	2/24 (8.3)	1.000
Intraprocedural thrombus formation	0/56 (0)	0/32 (0)	0/24 (0)	1.000
Postoperative early rebleeding	1/56 (1.8)	1/32 (3.1)	0/24 (0)	1.000
Postoperative ischaemia	7/56 (12.5)	3/32 (9.4)	4/24 (16.7)	0.447
In-stent stenosis	2/56 (3.6)	0/32 (0)	2/24 (8.3)	0.179

one patient in the Atlas cohort, who died soon after discharge. Two patients in the Leo Baby cohort died at follow-up. One of the patients was diagnosed with moyamoya disease by DSA.

Procedure and complication

Table 5 shows the stent-related complications. Deployment of the Atlas and the Leo Baby stents was successful in all cases (100%). Two patients in the Atlas cohort and two patients in the Leo Baby cohort each used two stents. An intraprocedural aneurysm rupture occurred in one patient out of the 32 patients in the Atlas cohort and one patient out of the 24 patients in the Leo Baby cohort. Intraoperative thromboembolic complications were not observed in either the Atlas or the Leo Baby stent cohorts. One case in the Atlas cohort presented a postoperative early rebleeding on computed tomography imaging. There were no statistically significant differences in postoperative ischaemia ($P = 0.268$). In the Leo Baby cohort, in-stent stenosis was observed in 2 of the 24 patients undergoing the Leo Baby stent. There were no statistically significant differences in the in-stent stenosis.

Representative cases of Atlas and Leo Baby stent

Case 1 of atlas stent

The patient was a 72-year-old man with a right middle cerebral artery (MCA) bifurcation aneurysm (Fig. 1). The minimum vessel diameter was 1.20 mm (right M2 portion). A Neuroform Atlas stent (3.0 × 21 mm) was deployed from the right MCA M2 portion to the M1 portion. The postembolization angiogram showed near-complete aneurysm obliteration without obvious complications. At the final follow-up, complete occlusion was achieved.

Case 2 of leo baby stent

The patient was a 45-year-old woman with a basilar tip aneurysm (Fig. 2). The Leo Baby stent (2.5 × 25 mm) was deployed from the right posterior cerebral artery portion to the basilar artery. The minimum vessel diameter was 1.45 mm (posterior cerebral artery portion). Complete obliteration was achieved, and neurological deficit was not observed during the procedure. However, at the final follow-up, we observed an in-stent stenosis in the parent artery and parent artery stenosis greater than 50%.

Discussions

In terms of intracranial aneurysms, especially ruptured aneurysms, surgical clipping was the most common treatment of choice in the past[13]. Since the international subarachnoid aneurysm trial, SAC has been widely used to treat intracranial aneurysms[14]. Studies have found that SAC has many advantages over coiling alone, such as improving aneurysm occlusion rate and recanalization[15,16]. Self-expanding stents can remodel the aneurysm neck by acting as anatomic barriers, thus providing a mechanical support to prevent coil protrusion and enhance coil-mass stability. In addition, it can achieve parent artery reconstruction and redirection of blood flow away from the aneurysm[17]. However, stent placement in the small diameter vessels remains challenging, mainly because earlier stents could only be delivered via a 0.021-inch or 0.027-inch microcatheter, which cannot easily reach the distal small vessel[18,19]. In recent years, several low-profile mini-stents, such as the Atlas and the Leo Baby stents, have grown in popularity for use in small arteries. Mini-stents can be delivered through 0.0165-inch microcatheters to reach the target region and then embolize the target aneurysm[20].

The Neuroform Atlas stent is a recently introduced low-profile device. This stent is a laser-cut, self-expanding nitinol device that combines open-cell design and closed-cell design[21]. This hybrid design provides adaptability in the artery walls and enhances stability when the microcatheter is crossing the mesh for coiling[22]. The Atlas stent can be delivered through a 0.0165-inch microcatheter to reach the small vessels. However, it should be noted that the stent can only be seen at both ends and cannot be retrieved once deployed[23].

The Leo baby stent is a low-profile braided stent, with a hybrid design. The Leo Baby stent can be delivered through a 0.0165-inch microcatheter and can be re-sheathable and repositioned, despite its length, up to 95% of the time[24]. The Leo baby stent has three different diameters 2.0, 2.5, and 3.0 mm, and is suggested for cerebral arteries with diameters from 1.5 to 3.1 mm[25]. Currently, the Leo Baby stent is the only self-expandable stent recommended for cerebral vessels with a diameter of less than 2 mm[6].

In this study, we compared the efficacy and safety of the Atlas and the Leo baby stent in small vessels less than 2.0 mm in luminal diameter. The overall results showed that SAC treatment using either the Atlas or the Leo baby stent leads to good immediate and long-term angiographic results and clinical outcomes, decreases recurrence and retreatment, and does not increase the device-related complications. In addition, we observed few differences in outcomes between the groups. These results suggested that both these stents are safe and effective.

For the single Atlas stent, a recent meta-analysis of 14 studies, including 593 intracranial aneurysms, demonstrated that the technical success of the Atlas stent procedure was 100%, and the long-term complete occlusion rate was 78.5% (95% CI 71–86%)[26]. For the single Leo baby stent, recent studies have reported that the rate of technical success varied from 89.4 to 100%, the rate of initial complete occlusion varied from 24.7
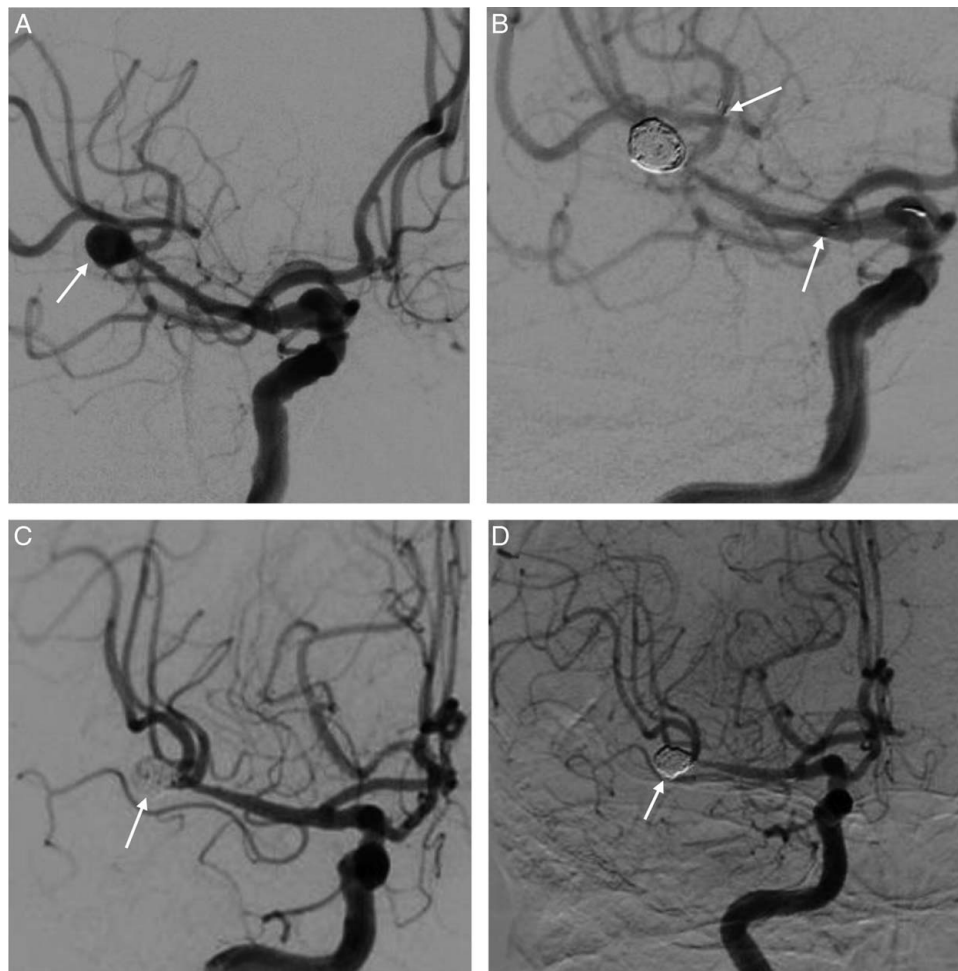
Figure 1. Representative case of Atlas stent group. (A) Angiogram showing wide-necked right MCA bifurcation aneurysm. (B) Native image from DSA showing the Neuroform Atlas stent deployment from the right MCA M2 portion to the M1 portion. (C) Postembolization angiogram showing near-complete aneurysm obliteration (arrow). (D) Follow-up angiogram after 6 months showing complete aneurysm obliteration and patency of the stent. DSA, digital subtraction angiography; MCA, middle cerebral artery.

to 83.3%, and the follow-up complete occlusion ranged from 76 to 93%[10,12,27–29]. These findings are similar to our results. The stent placement may have some advantages, while it can increase the risk of thromboembolic complications and haemorrhagic complications due to the use of a dual antiplatelet regimen[30]. A meta-analysis by Ryu *et al.*[31] reported that the rate of thromboembolic complications of SAC was 11.2%. In the current study, the overall procedure-related complication rate is considerably lower than that of many previous studies. On the one hand, it benefits from the dual antiplatelet regimen and rigorous evaluation of the response in thrombocyte aggregation level. On the other hand, the relatively small number of patients may affect results. In the current study, the final mortality is 10.7%. Several reasons beside procedure and stent might be accounted for these results. First, rupture aneurysms accounts for a large proportion of all intracranial aneurysms and most of patients with ruptured aneurysms had a worse clinical outcome. Second, some patients had serious comorbidities. One of the patients had moyamoya disease and died soon after bypass surgery. Thirdly, giant aneurysms were still a unique and complex challenge. One patient with giant aneurysm of the basilar apex presented obvious

occupying effect and worse neurological outcome. The acute hydrocephalus occurred soon after procedure and dies with several months. Fouth, One patient died due to a ruptured abdominal aneurysm prior to first radiological follow-up moment. Fifth, Due to the fixed follow-up time and considering the emotional factors of the patients' families, the other places of death of the patients were outside the hospital, and the specific cause of death was unknown. In this study, the overall incidence of ischaemia after both stents was 7/57 (12.5%). Stroke due to delayed cerebral ischaemia leading to permanent neurological deficit occurred in 1 case. One patients, ischaemic stroke was confirmed (in 1 case, the M2 branch of the right MCA in which the distal part of the stent had been placed was occluded). One patient experienced transient neurological deficit due to an ischaemic stroke around after 5month after treatment. In 1 patient, a clinically silent ischaemic stroke was discovered through MRA. Transient ischaemic attacks were experienced by two patients. One was highly likely related to the switch from dual antiplatelet therapy to ASA solely 11 days prior to the occurrence of the transient ischaemic attacks. One patients developed
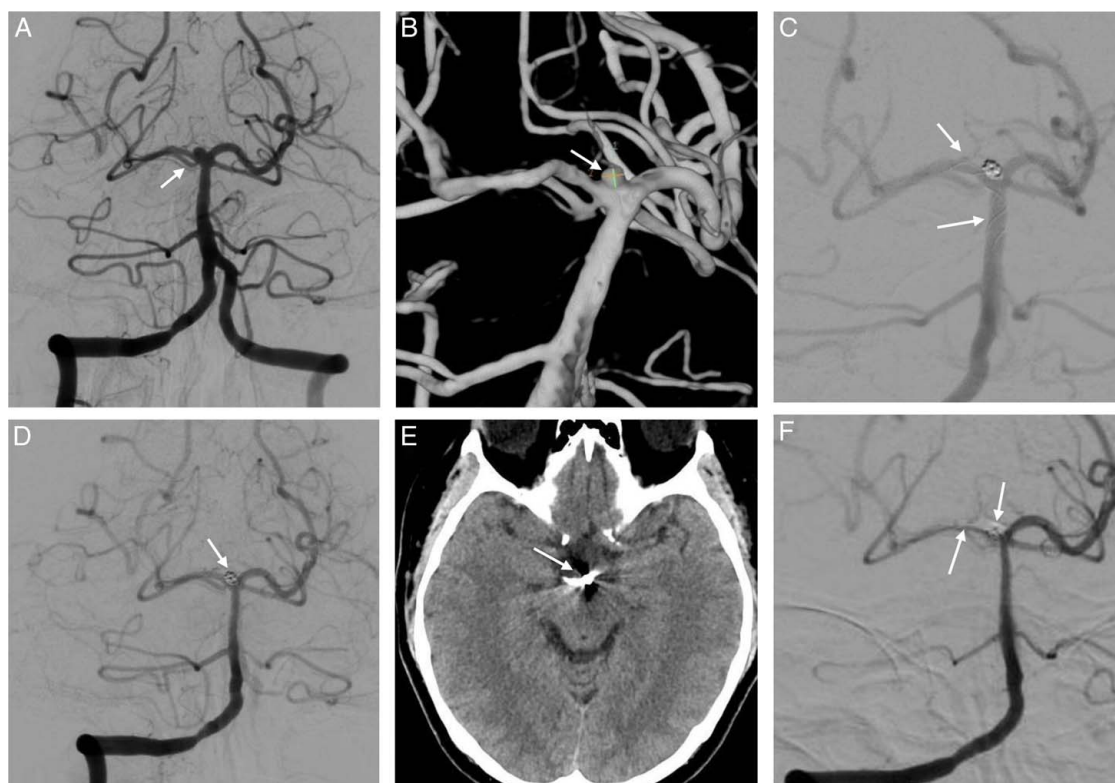
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Figure 2. Representative case of Leo Baby group. (A) Angiogram showing a wide-necked basilar-PCA aneurysm. The arrow shows the minimum vessel diameter in the stent deployment lesion. (B) Three-dimensional reconstructed image of rotational DSA. The arrow shows the basilar-PCA aneurysm. (C) Image from DSA showing Neuroform Atlas deployed from right PCA to basilar artery. (D) Postembolization angiogram showing complete obliteration. (E) Computer tomography image 1 day postoperatively showing no intracranial abnormalities. (F) Follow-up angiogram after 3 months showing maintenance of complete obliteration, but severe in-stent of the parent artery. DSA, digital subtraction angiography; PCA, posterior cerebral artery.

neurological deficits and/or ischaemic hypodense lesions on computed tomgraphy scan.

The similar clinical performance between the Atlas and the Leo Baby stents observed in this study is not difficult to explain. In the in vitro model, stenting alone cannot achieve the ideal effect of aneurysm obliteration after the SAC procedure, which is a result of both thrombosis of the coil and the flow diversion of the stent working together. In the absence of coils, the effect of thrombosis completely disappeared in the stent-only simulations. As the number of coils increased, the thrombosis within the aneurysmal SAC became faster and more durable, and the role of stenting became more marginal. In contrast, as the number of coils decreased, thrombosis had less of an effect, and stenting played a much larger role[32]. When an aneurysm was densely embolized with a coil, even exceeding a certain threshold, the role of the stent deployment, regardless of stent type, was significantly reduced, which may be why we did not observe a significant difference between the two stents. Monteiro *et al.*[33] recently found that the Atlas and the LVIS Jr SAC procedures have a similar immediate and cumulative outcome. Therefore, in clinical use, it is essential to thoroughly recognize each stent's different characteristics, strengths, and weaknesses and thus select the most appropriate stent to address existing clinical conditions.

Inevitably, this study has certain limitations. First, as a retrospective observational study, it lacks a randomized comparison of the two stents. Therefore, selection bias is inevitable. Second, this study involves a relatively small sample size

of intracranial aneurysms located in distal small vessels, and the data come from a single centre. Third, for the two stents, the operation experience of the operators was greater with the Atlas stent, as it was introduced earlier. Another limitation was that some patients lacked long-term follow-up. Therefore, more randomized controlled studies with a larger sample size are needed to assess the comparative treatment effect of these stents in the future.

Conclusions

At the final follow-up, the Atlas stent or Leo Baby SAC of intracranial aneurysm with small parent vessels result in favourable angiographic results and clinical outcomes, with low rate of associated complication. These results suggest that coil embolization of intracranial aneurysms using Atlas or Leo Baby stents in small arteries less than 2 mm in diameter is safe and effective. In the future, we need to conduct more high quality, prospective randomized controlled trials to confirm our results.

Contribution to the field statement

In recent years, some studies have reported the efficacy and safety of the Atlas stent or Leo Baby stent-assisted coiling of intracranial aneurysms. However, few studies have explored the efficacy and safety of the Atlas stent or Leo Baby stent in small parent vessels

less than 2 mm in diameter. Until now, no study has formally compared the clinical performance of the two stents. In the current study, we aimed to clinical performance of the Atlas and the Leo Baby stent-assisted coiling of intracranial aneurysms in small parent arteries (< 2 mm in diameter). We find that Atlas and the Leo Baby stent both can result in favourable clinical outcomes and angiographic results. Meanwhile, there is no statistic difference in clinical outcomes, angiographic results and overall procedure-related complication between the two stents. Currently, this is the first study to compare clinical performance of the two stents.

Ethical approval

Ethical approval for this study was provided by the Institutional Review Board (IRB) of Zhongnan hospital Wuhan University, Wuhan, China on 12 February 2023. Ethical number : Kelun-2017005. Address: No. 169 Donghu road, Wuchang district, Wuhan city, Hubeiprovince. Coordinate: 30.553497,114.352844.

Consent

Written informed consent was not required from every patient before treatment due to retrospective design. This article submitted a request for informed consent for exemption to the Ethics Committee. The data are anonymous, and the requirement for informed consent was therefore waived.

Author contribution

M.S. took responsibility for the integrity of the data and the accuracy of the data analysis. M.S. and Q.T. contributed significantly to data analysis, data acquisition, and manuscript preparation. M.S., Q.T., Y.F. and C.Z. made critical revision of the manuscript for important intellectual content. W.Z. guided the research and contributed to supervision. All authors contribute to the conception, design, analysis, and interpretation of data of the study and approved the submitted version.

Conflicts of interest disclosure

The authors declare that there are no potential conflicts of interests.

Research registration unique identifying number (UIN)

Registry used: Research Registry registration ID:17371409183 username:1398657426@qq.com Password:Tqw812799384 Unique Identifying number : researchregistry8870 https://www. researchregistry.com/browse-theregistry#home/registrationde tails/643ffe89c620490028b937fb/

Guarantor

Wen-yuan Zhao.

Data sharing statement

All data generated and analyzed during the current study will be available at publication from the corresponding author on reasonable request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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