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Case Report

# Stent Migration during Coil Embolization with an Open Cell Stent: A Report of Three Cases

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**Objective:** Among 36 cerebral aneurysm cases of stent-assisted coil embolization with the Neuroform Atlas since April 2017, there were three cases of stent migration during the operation. The status of stent deployment, cause of trouble, results of coil embolization, and complications were assessed.

**Case Presentations:** There were two cases with trouble during stent deployment, a case of internal carotid artery aneurysm, and a case of middle cerebral artery (MCA) aneurysm. The proximal marker of the stent was advanced during stent deployment with the simple pull maneuver, then a part of the stent migrated to the aneurysm sac in both cases. Stent migration to the aneurysm sac during microcatheter navigation by the trans-cell technique occurred in another MCA aneurysm case. No postoperative complications were observed, and a volume embolization ratio (VER) of 24.1%–33% was achieved in these three cases.

**Conclusions:** The Neuroform Atlas is a safe and convenient stent system. However, stent advancement during deployment and migration during trans-cell microcatheter navigation can occur.

**Keywords** ▶ Stent, Neuroform atlas, trouble

## Introduction

The Neuroform Atlas microstent (Stryker Neurovascular, Kalamazoo, MI, USA) was developed by improving the Neuroform stent. It has a hybrid structure consisting of open and closed cells, but primarily has characteristics of an open cell stent; therefore, it can be readily deployed, facilitating kinking or twisting even in tortuous blood vessels or at the site of bifurcation. Furthermore, this microstent is characterized by a low profile and low metal-to-artery ratio (6%–12%). It can be readily delivered even to a distal area. In addition, it may reduce the risk of thromboembolism.[1–6] However, once this microstent is deployed, it cannot be recaptured or replaced. Furthermore, it is structurally weaker than the previous Neuroform stent due to its low profile and low metal-to-artery ratio. We examined three patients with stent migration during or after deployment among those in whom a Neuroform Atlas was used at our hospital.

## Case Report

Of 36 patients in whom a Neuroform Atlas was used for coil embolization of cerebral aneurysms at our hospital after April 2017 (total number of patients: 162, number of patients with unruptured aneurysms: 104) (stent-assisted coil embolization: 45 patients), we report three with unruptured cerebral aneurysms in whom stent migration occurred during or after stent deployment. Our criteria for the use of a stent during coil embolization of cerebral aneurysms include wide-neck aneurysms and patients in whom the risk of intraoperative/postoperative coil deviation when adopting other techniques was evaluated as high through discussion by ≥2 specialists in neuroendovascular treatment. In patients with unruptured cerebral aneurysms, an aneurysmal size of ≥5 mm is targeted. Concerning the use of antiplatelet drugs before surgery, double antiplatelet

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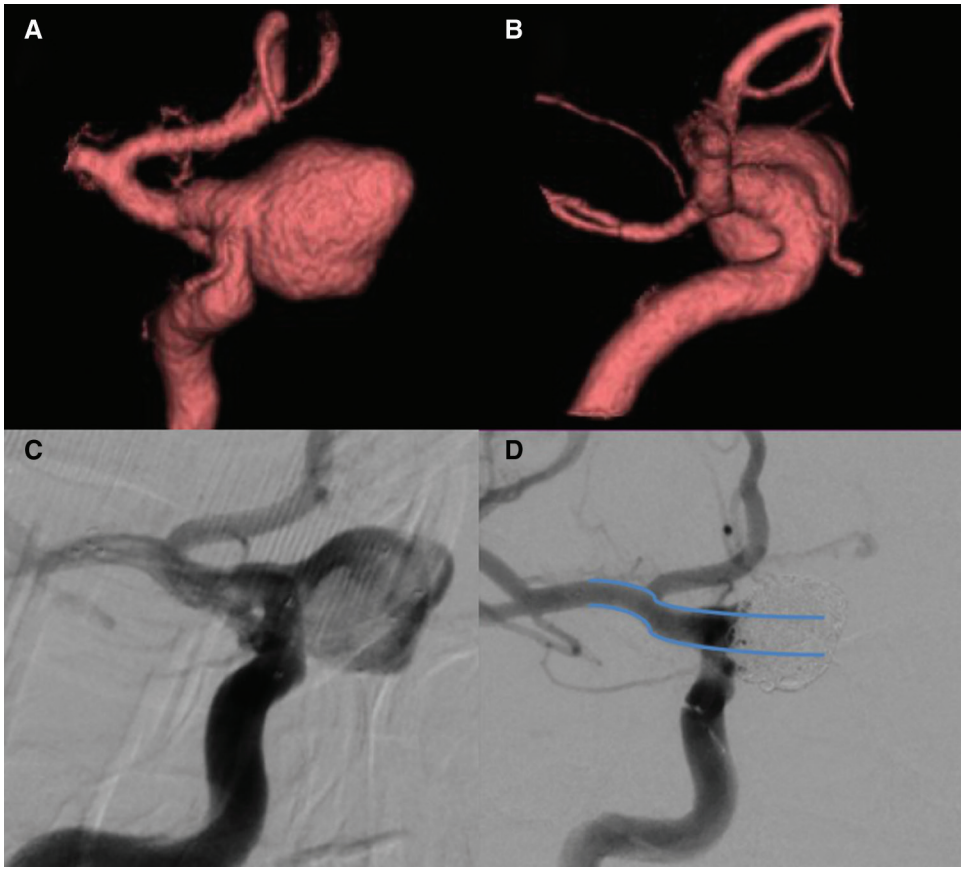


**Fig. 1** An unruptured large right parasellar internal carotid artery aneurysm (medial type). The aneurysmal dome measured 17 mm, and the transverse diameter was 13 × 12.5 mm. The neck measured 8 mm. (**A**) Working angle-like 3DRA image. (**B**) Lateral view. (**C**) The proximal end of a Neuroform Atlas 4.5 mm × 30 mm fell into the aneurysm, and deployment was performed. (**D**) The blue line indicates the position of Neuroform Atlas deployment. Both the outside and inside of the intra-aneurysmal stent were embolized with a coil, and the VER was 27.4%, with a neck remnant. VER: volume embolization ratio

therapy (DAPT) with aspirin at 100 mg/day and clopidogrel at 75 mg/day was performed for all patients from 14 days before surgery. In patients in whom the concentration of either drug had not reached its therapeutic range on "verify-now" platelet function assessment the day before surgery, cilostazol at 200 mg/day was added from the day before surgery. When the PRU level was low (≤90) the day before surgery, surgery was performed as scheduled, but the dose of clopidogrel was reduced from the day of surgery. Prior to the publication of this report, an ethical application was approved by the Ethics Review Board of Mihara Memorial Hospital (No. 094-08).

Of the 36 patients, problems occurred during the deployment of a Neuroform Atlas in two patients during the relatively initial phase; one had a large internal carotid artery aneurysm, and the other had a middle cerebral artery (MCA) aneurysm. In the two patients, the proximal marker of the stent migrated to a distal area during deployment with simple unsheath (simple pull) operations, leading to intra-aneurysmal migration of the proximal end of the stent.

Case 1: A 45-year-old female with an unruptured large right parasellar internal carotid artery aneurysm (medial type). The aneurysmal dome measured 17 mm, and the transverse diameter was 13 × 12.5 mm. The neck measured 8 mm (**Fig. 1A** and **1B**). In April 2017, coil embolization using a Neuroform Atlas 4.5 mm × 30 mm was performed. Initially, an Echelon 14 for coil embolization (Medtronic, Minneapolis, MN, USA) was guided into the aneurysm. Subsequently, the Neuroform Atlas was deployed through an Excelsior XT-17 (XT-17) (Stryker Neurovascular, Kalamazoo, MI, US). However, the proximal end of the stent migrated during stent deployment with simple pull operations, falling into the aneurysm (**Fig. 1C**) (Movie 1, the movies are available online.). In the present case, neck bridge stenting was unable to be performed, but the aneurysm was embolized using the double-catheter technique by combining the jailing technique

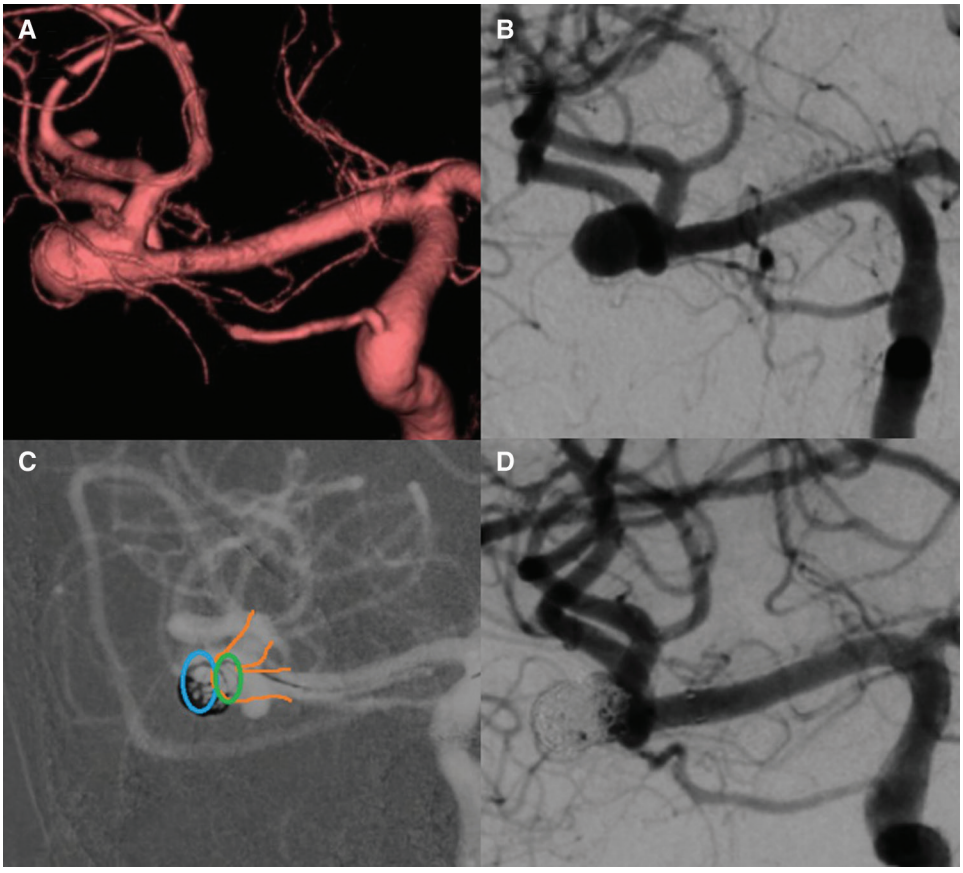


**Fig. 2** An unruptured right MCA aneurysm. The aneurysmal dome measured 6.3 mm, and the transverse diameter was 5.3 × 5.8 mm. The neck measured 4.5 mm. (**A**) Working angle-like 3DRA image. (**B**) Working angle. (**C**) After the deployment of a Neuroform Atlas 3 mm × 21 mm. The orange line indicates the intussusception of the Neuroform Atlas. The blue-line area indicates the site of embolization of the outside of the intra-aneurysmal stent, and the green-line area indicates the site of embolization of the inside of the intra-aneurysmal stent. (**D**) Body filling was partially noted after coil embolization, with a VER of 33%. 3DRA: three dimention rotational angiography; MCA: middle cerebral artery; PRU: P2Y12 reaction unit; VER: volume embolization ratio

with the trans-cell technique. Both the outside and inside of the intra-aneurysmal stent were embolized, and the volume embolization ratio (VER) was 27.4%, with a neck remnant (**Fig. 1D**). There were no postoperative complications. After treatment, the administration of aspirin at 100 mg and clopidogrel at 75 mg was continued. Follow-up examination 6 months after treatment confirmed recanalization. Additional treatment was required thereafter.

Case 2: A 69-year-old female with a right MCA aneurysm. The aneurysmal dome measured 6.3 mm, and the transverse diameter was 5.3 × 5.8 mm. The neck measured 4.5 mm (**Fig. 2A** and **2B**). In the present case, we considered radical treatment to be possible by clipping under craniotomy, but coil embolization was selected based on the patient's wishes. In August 2018, coil embolization using a Neuroform Atlas 3.0 mm × 21 mm was performed. Initially, an Echelon 10 for coil embolization was guided into the aneurysm. Subsequently, an XT-17 was guided into the M2 superior trunk, and the Neuroform Atlas was deployed with simple pull operations. When pulling the XT-17, the proximal marker of the Neuroform Atlas migrated (Movie 2). As a result, the stent proximal to the aneurysm migrated, leading to intra-aneurysmal intussusception of the folded stent (**Fig. 2C**). At this point, the system was pulled, but the stent was unable to be returned smoothly, and it was deployed involving the M1 region with simple pull operations. Although there was stent intussusception at an area adjacent to the intra-aneurysmal neck, embolization of the inside and outside of the intra-aneurysmal stent using the Echelon 10 (Medtronic), which had been jailed, and XT-17, which had been guided using the trans-cell technique, led to a VER of 33%, and body filling was partially noted (**Fig. 2D**). There were no postoperative complications. In the present case, the administration of aspirin at 100 mg and clopidogrel at 75 mg was continued for 1 year after treatment. There were no embolic complications. There was no recurrence on follow-up after 1 year.

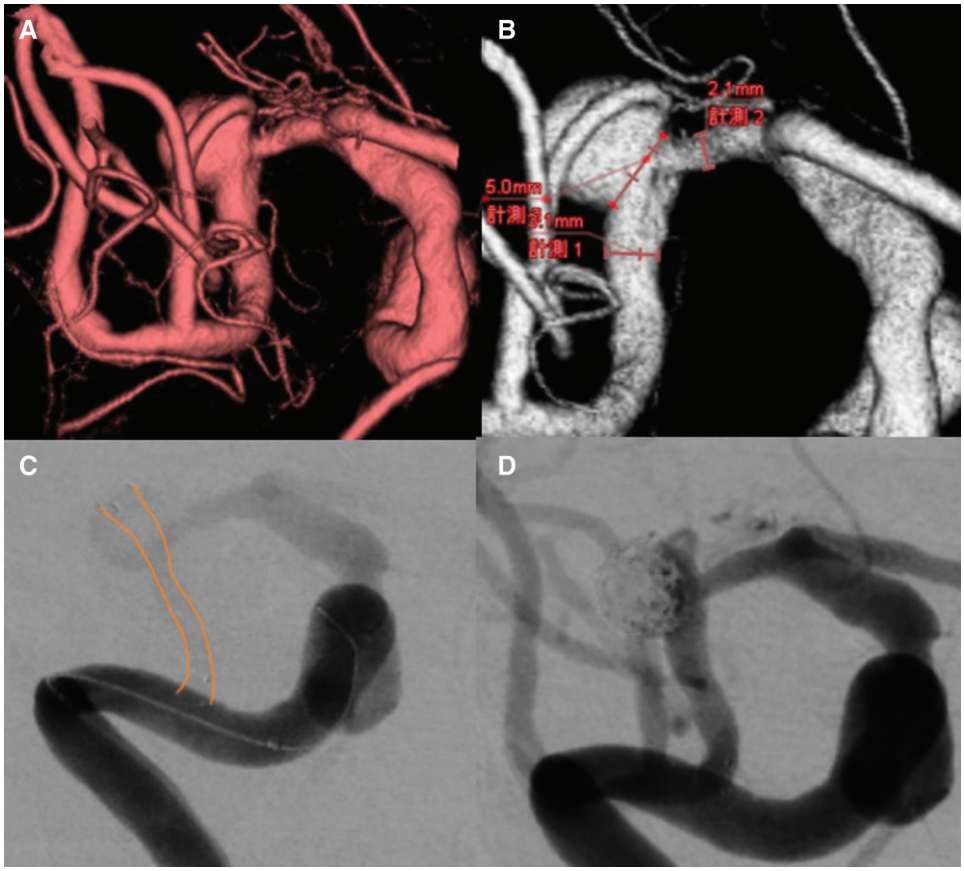


**Fig. 3** An unruptured right MCA aneurysm. The aneurysmal dome measured 6.6 mm, and the transverse diameter was 8.2 × 7.7 mm. The neck measured 5 mm. (**A**) Working angle-like 3DRA image. (**B**) Stenosis (diameter: approximately 2.1 mm) was observed in the M1 region proximal to the aneurysm. (**C**) While guiding a microcatheter using the trans-cell technique after stent deployment, the proximal side of the stent migrated into the aneurysm. The orange line indicates its position after migration. (**D**) Body filling was noted after coil embolization, with a VER of 24.1%. 3DRA: three dimention rotational angiography; MCA: middle cerebral artery; VER: volume embolization ratio

Case 3: An 80-year-old female with a MCA aneurysm. The aneurysmal dome measured 6.6 mm, and the transverse diameter was 8.2 × 7.7 mm. The neck measured 7 mm. Stenosis (diameter: 2.1 mm) was observed in the M1 distal region adjacent to the aneurysmal neck (**Fig. 3A** and **3B**). On preoperative examination, several penetrating vessels adhered to the aneurysmal dome were noted. Therefore, stent-assisted coil embolization using a Neuroform Atlas 4.0 mm × 21 mm was selected considering the risk of penetrating vessel disorder under craniotomy, short M1 artery, and treatment at an advanced age. Initially, an Echelon 10 was guided into the aneurysm, and an XT-17 was guided into the M2 inferior trunk. The Neuroform Atlas was deployed involving the M1 area. The XT-17 was guided into the aneurysm using the trans-cell technique in addition to the Echelon 10, which had been jailed, to accomplish selective, stent-assisted, double-catheter intra-aneurysmal embolization involving preservation of the superior trunk origin. However, while guiding the XT-17 into the aneurysm using the trans-cell technique, the proximal end of the Neuroform Atlas was pushed into the aneurysm by the U-shaped end of a microguidewire, resulting in intra-aneurysmal stent migration (Movie 3). The proximal end of the Neuroform Atlas migrated into the superior trunk orifice, comprising a horizontal stenting-like shape. Therefore, selective coil embolization using the Echelon 10, which had been jailed, and XT-17 newly guided into the aneurysm was possible (**Fig. 3C**). After double-catheter coil embolization, the VER was 24.1%, and body filling was noted. However, a target site involving the dome end was able to be embolized (**Fig. 3D**). There were no postoperative complications. The administration of aspirin at 100 mg and clopidogrel at 75 mg was continued. There were no embolic complications until 1 year after treatment. There has been no recanalization at the site of aneurysmal embolism.

## Discussion

According to previous studies, the incidence of technical failure associated with stent deployment during stent-assisted coil embolization is approximately 3%–5%. Using the Neuroform Atlas, it ranges from 0% to 11.1%.[1–5] Of our patients (n = 36), the proximal end of the Neuroform Atlas migrated during its deployment with simple pull operations in two patients. In these patients, the stent fell or became intussuscepted into the aneurysm. As one factor for a similar phenomenon, the intra-microcatheter course of a stent immediately before deployment involves a route corresponding to the shortest distance of the vascular lumen, whereas that after deployment involves the vascular course; the stent course may change after deployment in comparison with that before deployment. The post-deployment stent course involves a longer route; therefore, under distal-end fixation related to stent deployment, the proximal end of the stent may migrate to the distal side in comparison with the pre-deployment position. This phenomenon is more marked when the vascular diameter is larger, but less marked when the vascular lumen is thinner. Therefore, it is marked in the internal carotid artery, but not in peripheral arteries such as the MCA. In Case 1, a difference in the stent course after deployment may have led to the migration of the proximal end of the stent during deployment at the internal carotid artery aneurysm site. Therefore, the advantage of an open cell stent is the absence of shortening before and after stent deployment, but it is dangerous to evaluate whether neck bridging is possible by referencing the position of a proximal marker before stent deployment. Open cell stents, including the Neuroform Atlas, facilitate intended neck bridging regardless of the position of a proximal marker immediately before deployment only if the distal end of a stent is accurately established before surgery. In the present case, there was a difference in the stent course after deployment, and whether neck bridging was possible was evaluated by referencing the position of a proximal marker before deployment despite the start of deployment at an area more distal than expected, resulting in stent falling. Furthermore, in Case 1, a working angle was established such that the aneurysm did not overlap with the internal carotid artery, and the distance of the C2 internal carotid artery was recognized as shorter on fluoroscopy. This may have played a role in the above result. It is necessary to establish a working angle that facilitates the accurate assessment of the vascular course at the site of stent insertion at an appropriate time, but a large aneurysm, as observed in the present case, may overlap with the course of a parent blood vessel on fluoroscopy; it is often difficult to establish a working angle ideal for stent insertion. The preoperative/intraoperative three-dimensional assessment of the vascular course may be necessary.

On the other hand, in Case 2, a stent migrated/became intussuscepted into the MCA aneurysm during deployment at a distal area where the vascular lumen was relatively thin. Therefore, the influence of a difference in the stent course after deployment was slight, suggesting another factor. Quintana et al.[6] reported the poor position of deployment related to similar stent migration in 1 of 29 patients. In this patient, stent migration occurred while deploying a Neuroform Atlas at the A1 to A2 areas for the management of an anterior communicating artery (Acom) aneurysm; it occurred during deployment at a relatively distal area, as demonstrated in Case 2. In simple pull operations, an unsheathed stent is deployed by fixing a delivery wire passing through the lumen of a microcatheter and pulling out the microcatheter alone. For the Neuroform Atlas, this procedure is recommended by the manufacturer. This is because excessively pushing the deliver wire of a stent leads to stent collapse. If the course of a microcatheter is linear, stent migration may not occur on simple pull operations. However, if it is tortuous, the force for a stent to advance may be generated on simple pull operations. This may be because a delivery wire relatively harder than a microcatheter is advanced through the lumen of a microcatheter when it is pulled/linearized. Indeed, in an *in vitro* experiment, a Neuroform Atlas was deployed by simple pull operations alone using a hollow, silicon-based tortuous blood vessel model, and stent migration was noted; the stent became intussuscepted into the aneurysm (Movie 4). This suggests that stent deployment using simple pull operations leads to the generation of a force for a delivery wire/stent to advance when the torsion of a microcatheter for delivery is marked. In particular, if a bifurcation angle involving the M2 to M1 regions, where a Neuroform Atlas is to be inserted, is sharp, as demonstrated in Case 2, the stent may become intussuscepted into the aneurysm during migration related to simple pull operations; therefore, caution is needed. When adopting a Neuroform Atlas in such patients, a distal access catheter (DAC) should be used coaxially to a microcatheter for deployment. The use of a DAC prevents stent migration during simple pull operations. In patients with MCA or Acom artery aneurysms, the insertion of a DAC into the M1 or A1 arteries, of which the diameters are small, hinders blood flow, increasing the risk

of thromboembolism; therefore, caution is needed. In this case, the insertion of a DAC into the terminal of the internal carotid artery may have sufficiently reduced microcatheter torsion during stent deployment, improving operability. If proximal-marker migration suggestive of stent migration is observed during deployment with simple pull operations in the presence of difficulties in the use of a DAC, the tension of the entire system should be adjusted using system pull operations at an appropriate time without adhering to simple pull operations alone. When conducting system pull operations, it should be confirmed that the distal end of the stent is sufficiently open, and the tension of a delivery wire must be carefully reduced because excessive system pulling may lead to proximal falling of the stent. If there is resistance on system pull operations after Neuroform-Atlas intussusception into the aneurysm, as demonstrated in Case 2, the Neuroform Atlas cell may be intertwined and aggressive pulling may be dangerous. In the present case, intra-aneurysmal embolization was possible even when the stent became intussuscepted. Therefore, switching to coil embolization after the completion of stent deployment is safer than stent reduction in some cases.

Intra-stent microcatheter passage using the trans-cell technique after deployment of a Neuroform Atlas may induce stent migration; therefore, caution is needed. The Neuroform Atlas is characterized by easiness in delivery to a distal area and a low metal-to-artery ratio. In contrast, the stability of this stent after deployment is lower than that of the original Neuroform stent. At a distal area, a 3-mm Neuroform Atlas is frequently used. On the trans-cell technique, a microguidewire or catheter may interfere with the stent. For this reason, the trans-cell technique using a 3-mm Neuroform Atlas after deployment should be avoided if possible. The jailing technique may be safer. When adopting the trans-cell technique, a Neuroform Atlas measuring 30 mm in length should be selected to improve the stability of the stent inserted. When applying a Neuroform Atlas at a distal area, we select a Neuroform Atlas measuring 3 mm in diameter and 21 mm in length to reduce the metal volume to reduce the risk of thromboembolism. However, the selection of a Neuroform Atlas measuring 30 mm in length, which is highly stable after insertion, should be considered in cases in which microcatheter guidance using the trans-cell technique is scheduled such as the present case. Furthermore, caution is needed to reduce stent interference. When guiding a microcatheter using the trans-cell technique, the U-shaped end of a microguidewire should be prepared such that its end is not caught in the stent strut. However, if the U-shape of the microguidewire end is not sufficiently smaller than the vascular diameter, as demonstrated in Case 3, it may push the stent; therefore, caution is needed. If stenosis is present at the site of Neuroform Atlas insertion, a microcatheter must be passed through a narrow stent, and the risk of stent migration is higher. Of our patients (n = 32) in whom a Neuroform Atlas was used, stent migration into the aneurysm during deployment was observed in two patients, and stent migration related to the trans-cell technique after deployment was observed in one patient. In the three patients, the intended stent position was not achieved, but there were no complications. Coil embolization was possible. The metal-to-artery ratio of a Neuroform Atlas is 6%–12% (6% when inserted into a 4.5-mm blood vessel and 12% when inserted into a 2.0-mm blood vessel), being lower than that of other stents; therefore, thromboembolism may not occur and this stent may be highly safe.[3] Furthermore, previous studies in which patients in the acute phase of rupture were not included suggested that the risk of thromboembolism was approximately 2.7%–5.2%.[3,5–7] As the stent cell is large, it is not difficult to guide a microcatheter into the aneurysm using the trans-cell technique.[8] Based on these characteristics, the Neuroform Atlas may not induce thrombotic complications even if there are difficulties and post-trouble recovery may be relatively easy. Thus, this stent may be highly safe. However, this stent is impossible to recapture, and its post-deployment stability is lower than that of conventional Neuroform stents; therefore, trouble may occur, as presented in this study. Unsatisfactory stent deployment may increase the risk of thromboembolism. A previous study reported that thromboembolism was observed in 14.8% of cases involving the acute phase of rupture.[9] Therefore, the risk of thromboembolism cannot be deprecated in the presence of hypercoagulability or in non-responders to antiplatelet drugs, although the metal-to-artery ratio of the Neuroform Atlas is low. To prevent thromboembolism, the preoperative administration of antiplatelet drugs and sufficient intraoperative anticoagulant therapy may be necessary.

## Conclusion

The Neuroform Atlas facilitates delivery and deployment, but it is impossible to recapture. It must be considered that the proximal end of the stent may migrate during deployment. After deployment, the Neuroform Atlas may migrate through microcatheter- or guidewire-related interference.

## Disclosure Statement

We declare no conflict of interest.

## References


1) Caragliano AA, Papa R, Pitrone A, et al: The low-profile Neuroform Atlas stent in the treatment of wide-necked intracranial aneurysms - immediate and midterm results: an Italian multicenter registry. *J Neuroradiol* 2019; pii: S0150-9861(18)30391-2.
2) Goertz L, Dorn F, Siebert E, et al: Safety and efficacy of the Neuroform Atlas for stent-assisted coiling of intracranial aneurysms: a multicenter experience. *J Clin Neurosci* 2019; 68: 86–91.
3) Jankowitz BT, Hanel R, Jadhav AP, et al: Neuroform Atlas stent system for the treatment of intracranial aneurysm: primary results of the Atlas Humanitarian Device Exemption cohort. *J Neurointerv Surg* 2019; 11: 801–806.
4) Semeraro V, Ganimede MP, Lucarelli NM, et al: Rescue stenting using Neuroform Atlas stent during coiling protrusion for ruptured intracranial aneurysms. *World Neurosurg* 2019; 128: e454–e460.
5) Ulfert C, Pham M, Sonnberger M, et al: The Neuroform Atlas stent to assist coil embolization of intracranial aneurysms: a multicentre experience. *J Neurointerv Surg* 2018; 10: 1192–1196.
6) Quintana EM, Valdes PV, Deza EM, et al: Initial experience and one-year follow-up with Neuroform Atlas Stent System for the treatment of brain aneurysms. *Interv Neuroradiol* 2019; 25: 521–529.
7) Tsai JP, Hardman J, Moore NZ, et al: Early post-Humanitarian Device Exemption experience with the Neuroform Atlas stent. *J Neurointerv Surg* 2019; 11: 1141–1141.
8) Ciccio G, Robert T, Smajda S, et al: Double stent assisted coiling of intracranial bifurcation aneurysms in Y and X configurations with the Neuroform ATLAS stent: immediate and mid term angiographic and clinical follow-up. *J Neurointerv Surg* 2019; 11: 1239–1242.
9) Ten Brinck MFM, de Vries J, Bartels RHMA, et al: NeuroForm Atlas stent-assisted coiling: preliminary results. *Neurosurgery* 2019; 84: 179–189.