Use of the PulseRider Device in the Treatment of Ruptured Intracranial Aneurysms: A Case Series

Zach Folzenlogen[1], Joshua Seinfeld[2], Sheila Kubes[2], David Kumpe[2], David Case[2], Christopher Roark[2]

■ BACKGROUND: **Wide-necked intracranial aneurysms present unique treatment challenges in the setting of subarachnoid hemorrhage. New generations of endoluminal devices (stents) have expanded our ability to treat complex aneurysms. The PulseRider Aneurysm Neck Reconstruction Device (PulseRider [Cerenovus, Irvine, California, USA]) is new to the U.S. market after receiving Food and Drug Administration approval in June 2017. Official recommendation for use of the PulseRider is with dual antiplatelet therapy (DAPT). Its design has been hypothesized to carry a lower risk of thromboembolic complications in the circumstance that DAPT needs to be discontinued.**

■ METHODS: **Between March and June 2018, we treated 4 cases of ruptured wide-necked basilar tip aneurysms at the University of Colorado Hospital, Aurora, Colorado, with PulseRider-assisted coil embolization. Imaging and chart reviews were performed retrospectively on each of these patients.**

■ RESULTS: **All 4 aneurysms were successfully treated with PulseRider-assisted coil embolization. There were no periprocedural hemorrhages and no postprocedural reruptures. Two patients developed nonocclusive thrombi in the posterior cerebral arteries at the time of coiling, which was resolved with intra-arterial glycoprotein IIb/IIIa receptor antagonists. Two patients developed external ventricular drain–associated hemorrhages, only one of which developed after the administration of DAPT. All patients were eventually discharged to home.**

■ CONCLUSIONS: **The PulseRider device represents a novel design for stent-assisted coil embolization. We report a small but promising series of its successful use in the acute treatment of wide-necked, ruptured basilar artery aneurysms. Additional experience is needed to determine if this device has a place in our armamentarium for treatment of ruptured aneurysms.**

INTRODUCTION

Wide-necked intracranial aneurysms present unique treatment challenges in the setting of subarachnoid hemorrhage (SAH). New generations of endoluminal devices (stents) have expanded our ability to treat complex aneurysms with endovascular therapy. These advances include a newer generation of flow diversion (Pipeline Flex [Medtronic, Minneapolis, Minnesota, USA), small closed-cell stents (LVIS Jr [MicroVention, Inc., Aliso Viejo, California, USA), and now open-cell stents that fit inside smaller microcatheters (Neuroform Atlas [Stryker, Kalamazoo, Michigan, USA]). The need for antiplatelet therapy with the use of adjunctive endoluminal devices is still required to reduce the risk of embolic events. Dual antiplatelet therapy (DAPT) has allowed for the rapid expansion of stent technology in the last decade by significantly decreasing the risk of embolic stroke associated with the use of foreign bodies in the cerebrovascular circulation.

Stent remodeling and DAPT use in endovascular therapy for ruptured aneurysms are not without consequence. Procedure-related complications of stent coiling can be 10 times higher than patients with nonruptured aneurysms.[1] Many of these

Key words
- Aneurysm
- Coiling
- Devices
- PulseRider
- Stent
- Subarachnoid hemorrhage

Abbreviations and Acronyms
ASA: acetylsalicylic acid
DAPT: Dual antiplatelet therapy
DSA: Digital subtraction angiography
EVD: External ventricular drain
PRU: Platelet reactivity unit
SAH: Subarachnoid hemorrhage

From the Departments of [1]Neurosurgery and [2]Neurosurgery & Radiology, University of Colorado, Aurora, Colorado, USA

To whom correspondence should be addressed: Zach Folzenlogen, M.D. [E-mail: Zach.folzenlogen@ucdenver.edu]

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Table 1. Patient Demographics, Aneurysm Characteristics, and Patient Outcomes

Patient Number	Age (years)	Sex	Aneurysm	HH/Fisher Grade	Dome/Neck Ratio (mm)	Discharge MRS Score	Discharge Disposition
1*	40	F	Basilar tip	5/4	3.9/3.6	3	Home
2	33	M	Basilar tip	3/4	5.9/5.3	1	Home
3	69	M	Basilar tip	5/4	5.2/4.6	1	Acute rehabilitation to home
4	58	F	Basilar tip	1/2	8.4/6.1	1	Home

MRS, modified Rankin Scale; F, female; M, male; HH, Hunt and Hess score.
*Presented with eclampsia.

patients will require invasive procedures such as ventriculostomy, tracheostomy, and gastrostomy tube placement. Although data are suggestive that single agent antiplatelet therapy is safe for tracheostomy and gastrostomy,[2,3] there are little data for patients on DAPT at the time of these procedures. Patients requiring ventriculostomy are at higher risk of hemorrhagic complications on DAPT.[4,5] The use of endoluminal aneurysm bridging devices for the treatment of complex ruptured aneurysms therefore has to be weighed against the morbidity of other treatment options such as microsurgery.[6,7]

The PulseRider Aneurysm Neck Reconstruction Device (PulseRider [Cerenovus, Irvine, California, USA]) is new to the U.S. market after receiving Food and Drug Administration approval in June 2017. This device is a nitinol (nickel titanium), self-expanding implant for the treatment of wide-necked aneurysms located at or near branching areas of arteries in the brain. Unlike other endoluminal reconstruction devices for the treatment of intracranial aneurysms that use a traditional tubular stent configuration, the PulseRider has a unique design whereby the 2 petals formed by numerous struts span the aneurysm neck, whereas support within the proximal parent vessel lumen is provided by struts oriented perpendicular to the neck bridging portion of the device. Although the official recommendation for use of the PulseRider is with DAPT, its design, which intends to minimize the intraluminal footprint within the parent vessel, has been hypothesized to carry a lower risk of thromboembolic complications in the circumstance that DAPT needs to be discontinued. Initial results with this device in the treatment of unruptured aneurysms have been promising.[8] Here we present our early experience with ruptured, wide-necked, basilar bifurcation aneurysms treated with PulseRider-assisted coil embolization.

METHODS

Between March and June 2018, we treated 4 consecutive cases of ruptured wide-necked basilar bifurcation aneurysms at the University of Colorado Hospital, Aurora, Colorado, with PulseRider-assisted coil embolization. Imaging and chart reviews were performed retrospectively on each of these patients. All aneurysms were initially diagnosed on head computed tomography angiogram and underwent formal digital subtraction angiography (DSA) showing morphology unsuitable for primary coil embolization. We discussed the specific use of this device with patients or their representatives. This discussion included its recent approval for the U.S. market and the off-label use in the setting of SAH. We obtained informed consent for the use of this device in addition to procedural consent for treatment. Table 1 outlines primary demographic and clinical data from these 4 cases.

Time to Treatment

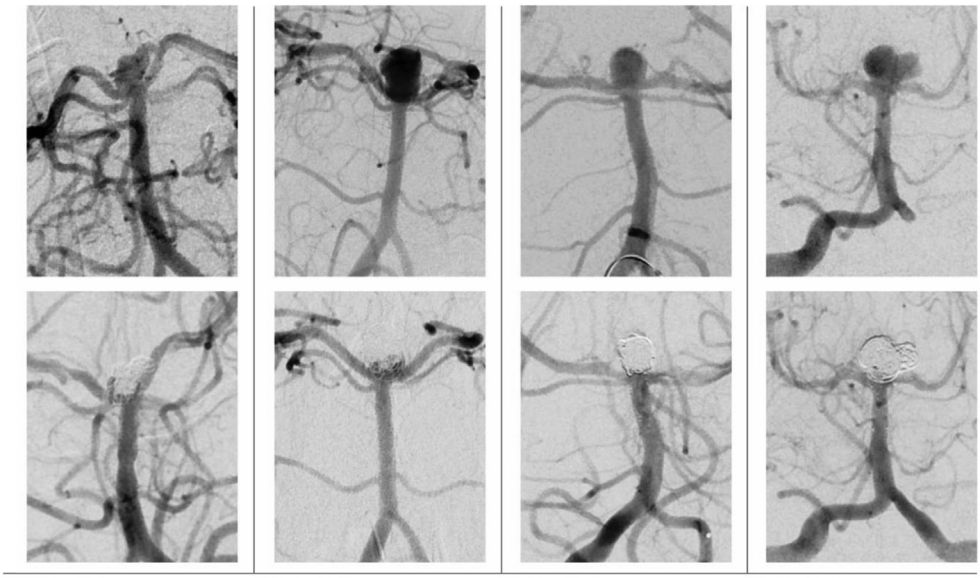
As a referral center for a large geographic area, our time to treatment varies significantly. Patient 1 underwent embolization within approximately 14 hours, patient 2 underwent embolization within 22 hours, and patient 3 underwent embolization within 12 hours. Patient 4 experienced symptoms for 6 days prior to seeking medical attention and was treated within 20 hours of presentation to the emergency department.

Standard Treatment Technique

We used general endotracheal anesthesia for each case. Standard techniques were used to access the common femoral artery, and diagnostic cerebral angiography was performed to evaluate the angioarchitecture of the ruptured aneurysm and screen for the presence of other aneurysms. An exchange technique was used to place a 6-French shuttle sheath (Flexor Shuttle Guiding Sheath [Cook Medical, Bloomington, Indiana, USA]) into the dominant vertebral artery. Two rotating hemostatic valves were attached to this, and continuous heparinized saline flush was used for the duration of the case. The operator then placed his preferred coiling microcatheter in the proximal basilar artery. The Prowler Select Plus microcatheter (Codman Neurovascular, Raynham, Massachusetts, USA) was used to open the appropriately sized PulseRider at the aneurysm neck. In this series, we deployed 3 devices intra-aneurysmal and 1 device extra-aneurysmal (patient 4).

The deployment of this device is described fully elsewhere.[9] We accessed the aneurysm with the coiling catheter after opening the device in a satisfactory position at the neck of the aneurysm. The PulseRider was not detached from the deployment system until aneurysm coiling was complete. Aneurysms were coiled with the operator's choice of coils until angiography demonstrated cessation of aneurysm filling and protection of the dome. Figure 1 shows pre- and posttreatment angiography.

We loaded all patients with DAPT approximately 30 minutes before deployment of the PulseRider, when exchanging the diagnostic system for the 6-French shuttle. For 1 patient, this included 325 mg aspirin and 412.5 mg clopidogrel, whereas the other 3 received 325 mg aspirin and 180 mg ticagrelor. Clopidogrel resistance is found in a significant portion of the population.[10,11]



Patient 1	Patient 2	Patient 3	Patient 4
HH 5, Fischer 4	HH 3, Fischer 4	HH 5, Fischer 4	HH 1, Fischer 2
RROC: Class II	RROC: Class II	RROC: Class I	RROC: Class I
Device: 6mm Y-Shape	Device: 10mm T-Shape	Device: 8mm T-Shape	Device: 10mm T-Shape

HH, Hunt and Hess Score; RROC, Raymond-Roy occlusion classification;

Figure 1. Angiography of the 4 ruptured basilar tip aneurysms pre- and posttreatment with PulseRider-assisted coil embolization. HH, Hunt and Hess Score; RROC, Raymond-Roy occlusion classification.

Our institution has now transitioned to using ticagrelor for acute intraprocedural loading given the less predictable therapeutic profile of clopidogrel. In the setting of SAH, we prefer to load the patients with DAPT immediately after the decision is made for endovascular repair. This allows for safe microsurgical clip ligation if that is the most appropriate treatment based on DSA imaging. Ticagrelor has the advantage of a much faster time of onset (30 minutes) and time to peak (2 hours) when compared with clopidogrel.[12]

At our institution, heparin is used in the drip bags for all cases (unless heparin-induced thrombocytopenia and thrombosis is known or suspected in which case bivalirudin is used). In cases of SAH, additional intravenous heparin is generally not administered until there is occlusion of most of the aneurysm dome. If this corresponds to the completion of coiling—as can be seen in a small aneurysm that requires just a few coils—then no additional heparin is administered.

RESULTS

All 4 of the aneurysms were successfully treated with PulseRider-assisted coil embolization. There were no patients where PulseRider deployment was attempted and then aborted. We achieved Raymond-Roy class 1 occlusion rates on 2 cases and class II on the other 2 patients.

Thrombotic Events

Patients 3 and 4 developed nonocclusive thrombi in the posterior cerebral arteries at the time of coiling. Patient 3 was given 4 mg of abciximab through the microcatheter at the base of the aneurysm. Patient 4 received 3 mg of eptifibatide through the microcatheter and an additional 4 mg through the arterial sheath with complete resolution. There were no hemorrhagic complications associated with these medications. Repeat angiography in both patients revealed complete resolution of the thrombi and preserved posterior cerebral artery patency. Patient 4 received 3500 U of heparin after the PulseRider and first coil were placed. Patient 3 received no heparin other than that contained in the continuous guide and microcatheter infusions during the procedure. No radiographic or clinical signs of cerebral ischemia occurred as a result of these thrombotic events. Both patients underwent diagnostic cerebral angiography the day after treatment, demonstrating complete resolution of the thrombi.

Hemorrhagic Complications

Patients 2 and 3 had small hemorrhages along the tracts of their external ventricular drains (EVDs). Patient 2 developed this 6 days after initiation of DAPT, and his EVD was placed 22 hours prior to initiation of DAPT. Patient 3 had a small EVD tract hemorrhage before we initiated DAPT. The preexisting EVD hemorrhage in patient 3 remained stable, and neither hemorrhage caused an apparent clinical deficit. We discovered these hemorrhages on routine computed tomography imaging.

Vasospasm

Three of the 4 patients developed radiographic evidence of vasospasm. Two of these patients required intra-arterial verapamil

Table 2. Antiplatelet Dosing, CSF Diversion, and Associated Complications

Patient Number	Antiplatelet Load	Antiplatelet Regimen Postprocedure	PRU Range	PRU Mean	Discharge Regimen	CSF Diversion	Hemorrhage or Thrombotic Events
1	325 mg ASA, 412.5 mg clopidogrel	81 mg ASA daily, 75 mg clopidogrel daily	69–333	172	81 mg ASA daily, 37.5 mg clopidogrel every other day	EVD	Small EVD-associated hemorrhage 6 days post-DAPT initiation
2	325 mg ASA, 180 mg ticagrelor	81 mg ASA daily, 60 mg ticagrelor twice daily	12–182	80	325 mg ASA	EVD	Small EVD-associated hemorrhage prior to antiplatelet administration
3	325 mg ASA, 180 mg ticagrelor	81 mg ASA daily, 60 mg ticagrelor twice daily	87–295	169	81 mg ASA daily, 60 mg ticagrelor twice daily	EVD	Intraprocedural thrombus resolved with abciximab infusion
4	325 mg ASA, 180 mg ticagrelor	81 mg ASA daily, 30 mg ticagrelor twice daily	110–255	184	81 mg ASA daily, 60 mg ticagrelor twice daily	Lumbar drain, shunt	Intraprocedural thrombus resolved with eptifibatide infusion

PRU, platelet reactivity unit; CSF, cerebrospinal fluid; EVD, external ventricular drain; DAPT, dual antiplatelet therapy; ASA, acetylsalicylic acid.

infusion. Patient 1 had vasospasm present on postbleed day 5 and underwent DSA with intra-arterial verapamil administration a total of 7 times during her course. The bilateral posterior cerebral artery P1 segments had mild spasm, and the basilar artery appeared widely patent. Her spasm was significantly worse in the anterior circulation. Patient 2 showed no clinical or radiographic evidence of vasospasm. On postbleed day 4, patient 3 exhibited mild anterior circulation vasospasm on computed tomography angiography, which was resolved by day 8. Patient 4 had mild anterior circulation vasospasm seen on DSA, which we treated with intra-arterial verapamil on postbleed day 3. This patient's spasm resolved by day 15 without further endovascular treatment. There was no significant device-associated spasm during the embolization procedure in any of the 4 patients.

Posttreatment Antiplatelet Therapy

All patients were continued on 81 mg aspirin (some patients temporarily received 300 mg per the rectum when enteral access was not available) after aneurysm repair. The dosing of the thienopyridines was monitored and adjusted using platelet reactivity units (PRUs). In the setting of SAH, our aim was for values between 100 and 200. As can be seen in Table 2, there was significant variability in PRU values between patients, and this led to dose adjustments throughout their hospital course. Patient 1 was started on clopidogrel 75 mg daily postprocedurally but was ultimately discharged on 37.5 mg every other day because clopidogrel caused her PRU value to drop precipitously. We timed the intermittent use of clopidogrel to allow for other invasive procedures (tracheostomy and percutaneous endoscopic gastrostomy tube placement). Patient 2 was started on 60 mg twice daily of ticagrelor. We held ticagrelor for several days because of supratherapeutic PRU values. Subsequently, we used 45 mg twice daily and eventually discontinued this medication entirely. He was discharged on single agent 325 acetylsalicylic acid (ASA) daily. Patient 3 was started on 60 mg ticagrelor twice daily in addition to 81 mg ASA and was discharged on this regiment. He received 90 mg ticagrelor twice daily for 6 days because of elevated PRU values >250 during the middle of his hospitalization. Patient 4 was started on 30 mg ticagrelor twice daily, and we increased this to 60 mg twice daily during her hospital course to achieve our goal PRU values. PRU values are checked twice daily in intensive care unit patients on thienopyridines. In patients found to be outside what we consider to be the target PRU range of 100–200, doses were held for hypertherapeutic values and reinstituted at lower maintenance doses until stable values in the desired range were obtained.

Cerebrospinal Fluid Diversion

All patients required cerebrospinal fluid diversion. Patient 1 had an EVD placed before her antiplatelet load because of her high-grade presentation. A small EVD-associated hemorrhage was noted 6 days after antiplatelet treatment began. Patient 2 had an EVD placed before transfer to our institution. A small EVD-associated hemorrhage was seen on computed tomography scan prior to embolization. This hemorrhage remained stable throughout the hospital course while on DAPT. Patient 3 had an EVD placed before transfer to our institution. There were no hemorrhagic complications noted, and the EVD was eventually removed. Patient 4 had a lumbar drain placed, which we discontinued without hemorrhagic complication. Eventually, this patient underwent ventriculoperitoneal shunt placement without complication.

No patients died during their hospital course. Three of the patients were discharged with a modified Rankin Scale score of 1, and 1 patient had a score of 3. Three patients were discharged to home, and 1 patient was discharged to acute rehabilitation and then home.

Patient Follow-Up and Treatment Durability

Two of the 4 patients would eventually require additional elective treatment for residual aneurysm. Patient 2 had an initial Raymond-Roy occlusion classification II treatment and as a result was scheduled for early DSA follow-up. Ongoing coil compaction was seen on follow-up DSA 2.5 months after initial treatment and with interval worsening at 6 months. He underwent stent-assisted coil embolization at 6 months using an LVIS Jr (MicroVention) and

3 additional coils. Patient 3 also demonstrated filling within the coil mass at 6.5 months follow-up DSA and underwent placement of an additional 4 coils. Patients 1 and 4 transferred their care to another physician because of insurance and geographic reasons.

DISCUSSION

The publication of trials such as International Subarachnoid Aneurysm Trial[7] and Barrow Ruptured Aneurysm Trial[13] in the 21st century established endovascular embolization as first-line therapy for most ruptured intracranial aneurysms. Preservation of parent vasculature during repair of wide-necked ruptured aneurysms poses a challenge for both microsurgical clip ligation and endovascular embolization. Aneurysm bridging stents have been revolutionary in the management of unruptured aneurysms but are used sparingly and with caution in the setting of SAH given the inherent risks of DAPT in this patient population. Complex basilar bifurcation aneurysms can be among the most challenging to treat because of the numerous small but crucial thalamoperforating arteries arising at the neck of these lesions, and endovascular therapy has largely replaced open treatment.[7,13] Surgical ligation is made more difficult by the narrow and deep working channels afforded by the various described skull base approaches to this region.[14] For this reason, there is incentive to define endovascular strategies that can safely and effectively treat these aneurysms. To our knowledge, these 4 patients represent the first reported experience describing the use of the PulseRider device in the setting of intracranial aneurysm rupture.

The PulseRider represents a novel endoluminal device designed to address wide-necked aneurysms. This design results in a stent with a significantly smaller footprint in the parent vasculature when positioned correctly. The manufacturer claims that the PulseRider has 90% less metal on the artery wall than using a double-Y stent[15]; however, we are unaware of independent verification of this claim. In theory, this should lead to a lower risk of thromboembolic complications and allow for the more judicious use of DAPT in the setting of SAH. Complication rates associated with stent-assisted coiling have been shown to be significantly higher when treating ruptured versus unruptured aneurysms.[1,16,17] In our series, we were able to give patients extended "holidays" from thienopyridines to allow for other invasive procedures to be safely performed. Although no patient experienced a delayed thromboembolic event as a result of this, we cannot substantiate the claim that the PulseRider device yields a lower risk of thromboembolic complications in the setting of single antiplatelet therapy or DAPT.

One potential advantage of the PulseRider device is the option for 3 different configurations of deployment: intra-aneurysmal, where both leaflets are placed inside the aneurysm neck; extra-aneurysmal, where both leaflets are outside an aneurysm along the wall of the parent vessels; and hybrid, with one leaflet in the aneurysm and the other leaflet along the wall of a parent vessel. In smaller aneurysms, intra-aneurysmal deployment theoretically could pose more risk of rupture. Deployment of the device in our series was based on the anatomy of the aneurysm and how we felt we could best reconstruct the base. We positioned the device intra-aneurysmal in 3 of the 4 patients in this series. Although this minimizes endoluminal material in normal vasculature, it can predispose to greater neck residual. This is consistent with our experience. Two of the 3 patients with intra-aneurysmal deployment had Raymond-Roy occlusion classification of 2. The only patient with an extra-aneurysmal position of the leaflets was a patient with Raymond-Roy occlusion classification 1, as was the third patient with intra-aneurysmal PulseRider deployment.

Each of the 4 patients treated in this series did receive DAPT prior to treatment (aspirin with clopidogrel or ticagrelor). Two of the 4 patients developed nonocclusive thrombus in the left posterior cerebral artery at the base of the aneurysm during embolization. These were successfully dissolved with intra-arterial administration combined with intravenous infusion of glycoprotein IIb/IIIa receptor antagonists (abciximab and eptifibatide). Neither the thrombus formation nor acute lysis resulted in hemorrhagic or ischemic complications. Only 2 of the patients received heparin after placement of the first coil during the procedure, one of whom developed intraprocedural device-associated thrombus. Formation of thrombus during the embolization may be related to the timing of our DAPT load, all of which were within 30 minutes of stent deployment. Aspirin has a relatively quick onset of 5–30 minutes. Ticagrelor has therapeutic onset at 30 minutes but does not peak until 2 hours. In the setting of SAH, we prefer to load the patient with DAPT only after initial DSA imaging is obtained and a definitive plan has been formulated. This close interval may increase the risk of intraprocedural thrombus formation.

The literature confirms that a hypercoagulable state can exist in the setting of SAH,[18] and stent-associated thrombotic events occur with significant frequency.[1] In addition to potential ischemic complications associated with SAH, DAPT-related hemorrhagic events are a concern. EVD-associated hemorrhage is a well-known complication in the setting of DAPT use. This risk increases when EVD insertion follows the initiation of DAPT.[4,5] Two patients in this series had EVD-associated hemorrhages despite placement before starting DAPT. One hemorrhage preceded DAPT, and the other developed a spontaneous track hemorrhage on postprocedural day 6. As with most reported cases, neither hemorrhage was of clinical consequence.[5]

It is unclear what PRU values are ideal in the setting of patients with SAH who have undergone stent-assisted coiling and, more specifically, PulseRider-assisted coiling. We monitored PRU levels daily after embolization with a goal of 100–200. We based these values on those reported to be associated with hemorrhagic complications (<60–70) and those reported to be associated with thromboembolic complications (>208–240) in neurovascular procedures.[19] These data are limited and not specific to the PulseRider device and are based on clopidogrel therapy. Further studies will be needed to optimize this regimen. The role of platelet function testing after stent deployment is controversial.[20] What is well known is the variability of responsiveness to clopidogrel among patients.[21-23]

The PulseRider device showed promise in the acute stabilization of 4 ruptured aneurysms at our institution. The durability of treatment with the PulseRider device is unclear, and in our series 2 of the 4 patients required additional embolization at 6 months. The other 2 patients may also require ongoing treatment but have transitioned their care to other institutions. Currently, several endovascular treatment choices exist for basilar bifurcation aneurysms, including isolated coiling, balloon-assisted coiling,

and other stent-coiling combinations. Surgical clipping remains an option and has shown to be a more durable treatment when compared with endovascular occlusions.[7,24,25] The Woven EndoBridge (MicroVention) intraluminal device shows promise for basilar bifurcation aneurysm treatment, but device-related complications remain significant.[26] Whether the PulseRider device will be superior, inferior, or equal to other treatment modalities in the setting of SAH remains unclear.

There are several limitations to this series. Only 4 patients were evaluated, and our follow-up time was short. As the body of experience with the PulseRider device grows, knowledge gained regarding its role in the acute treatment of aneurysmal SAH will be clearer. Based on this limited experience with the PulseRider, we think there may be promise with the continued use of this device in the setting of SAH; however, there is not enough information available to make concrete statements regarding its effectiveness or postprocedural use of DAPT.

CONCLUSIONS

The PulseRider device represents a novel design for stent-assisted coil embolization. We report a small series of its successful use in the acute stabilization of wide-necked, ruptured basilar artery aneurysms. The durability of PulseRider treatment was limited in our small series. Additional experience will be necessary to determine if this device has a place in our armamentarium for treatment of ruptured aneurysms.

REFERENCES

1. Bechan RS, Sprengers ME, Majoie CB, Peluso JP, Sluzewski M, Van Rooij WJ. Stent-assisted coil embolization of intracranial aneurysms: complications in acutely ruptured versus unruptured aneurysms. *Am J Neuroradiol*. 2016;37:502-507.
2. Barton CA, McMillian WD, Osler T, et al. Anticoagulation management around percutaneous bedside procedures: is adjustment required? *J Trauma Acute Care Surg*. 2012;72:815-820.
3. Sohail U, Harleen C, Mahdi AO, Arif M, Nguyen DL, Bechtold ML. Bleeding risk with clopidogrel and percutaneous endoscopic gastrostomy. *World J Gastrointest Endosc*. 2016;8:553.
4. Kung DK, Policeni BA, Capuano AW, et al. Risk of ventriculostomy-related hemorrhage in patients with acutely ruptured aneurysms treated using stent-assisted coiling. *J Neurosurg*. 2011;114:1021-1027.
5. Bruder M, Schuss P, Konczalla J, et al. Ventriculostomy-related hemorrhage after treatment of acutely ruptured aneurysms: the influence of anticoagulation and antiplatelet treatment. *World Neurosurg*. 2015;84:1653-1659.
6. Molyneux AJ, Kerr RS, Birks J, et al. Risk of recurrent subarachnoid haemorrhage, death, or dependence and standardised mortality ratios after clipping or coiling of an intracranial aneurysm in the International Subarachnoid Aneurysm Trial (ISAT): long-term follow-up. *Lancet Neurol*. 2009;8:427-433.
7. Molyneux AJ, Kerr RS, Yu LM, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet*. 2005;366:809-817.
8. Gory B, Spiotta AM, Mangiafico S, et al. PulseRider stent-assisted coiling of wide-neck bifurcation aneurysms: periprocedural results in an international series. *Am J Neuroradiol*. 2016;37:130-135.
9. *English Instructions for Use: PulseRider Aneurysm Neck Reconstruction Device*. Los Gatos, CA: Pulsar Vascular; 2017.
10. Uchiyama S. Clopidogrel resistance: identifying and overcoming a barrier to effective antiplatelet treatment. *Cardiovasc Ther*. 2011;29:e100-e111.
11. Tantry US, Bliden KP, Meeran T, Gurbel PA. Clopidogrel resistance. In: Waksman R, Gurbel PA, Gaglia MA, eds. *Antiplatelet Therapy in Cardiovascular Disease*. Hoboken, NJ: John Wiley & Sons Ltd.; 2014:285-292.
12. Gurbel PA, Bliden KP, Butler K, et al. Randomized double-blind assessment of the ONSET and OFFSET of the antiplatelet effects of ticagrelor versus clopidogrel in patients with stable coronary artery disease: The ONSET/OFFSET study. *Circulation*. 2009;120:2577-2585.
13. Spetzler RF, McDougall CG, Zabramski JM, et al. The Barrow Ruptured Aneurysm Trial: 6-year results. *J Neurosurg*. 2015;123:609-617.
14. Spiessberger A, Strange F, Fandino J, Marbacher S. Microsurgical clipping of basilar apex aneurysms: a systematic historical review of approaches and their results. *World Neurosurg*. 2018;114:305-316.
15. Cardiva. PULSE RIDER. Available at: https://www.cardiva.com/productos/pulse-rider-2/?lang=en. Accessed July 23, 2018.
16. Muto M, Giurazza F, Ambrosanio G, et al. Stent-assisted coiling in ruptured cerebral aneurysms: multi-center experience in acute phase. *Radiol Med*. 2017;122:43-52.
17. Chung J, Lim YC, Suh SH, et al. Stent-assisted coil embolization of ruptured wide-necked aneurysms in the acute period: incidence of and risk factors for periprocedural complications. *J Neurosurg*. 2014;121:4-11.
18. Ramchand P, Quattrone F, Frangos SG, et al. Thromboelastography determines a transient late hypercoagulable state after aneurysmal subarachnoid hemorrhage. *Neurocrit Care*. 2013;19. S265-S265.
19. Kim KS, Fraser JF, Grupke S, Cook AM. Management of antiplatelet therapy in patients undergoing neuroendovascular procedures. *J Neurosurg*. 2018;129:890-905.
20. Skukalek SL, Winkler AM, Kang J, et al. Effect of antiplatelet therapy and platelet function testing on hemorrhagic and thrombotic complications in patients with cerebral aneurysms treated with the pipeline embolization device: a review and meta-analysis. *J Neurointerv Surg*. 2016;8:58-65.
21. Ferguson AD, Dokainish H, Lakkis N. Aspirin and clopidogrel response variability: review of the published literature. *Tex Heart Inst J*. 2008;35:313-320.
22. Kang HS, Kwon BJ, Kim JE, Han MH. Preinterventional clopidogrel response variability for coil embolization of intracranial aneurysms: clinical implications. *Am J Neuroradiol*. 2010;31:1206-1210.
23. Ben-Dor I, Kleiman NS, Lev E. Assessment, mechanisms, and clinical implication of variability in platelet response to aspirin and clopidogrel therapy. *Am J Cardiol*. 2009;104:227-233.
24. Van Eijck M, Bechan RS, Sluzewski M, Peluso JP, Roks G, Van Rooij WJ. Clinical and imaging follow-up of patients with coiled basilar tip aneurysms up to 20 years. *Am J Neuroradiol*. 2015;36:2108-2113.
25. Sekhar LN, Tariq F, Morton RP, et al. Basilar tip aneurysms: a microsurgical and endovascular contemporary series of 100 patients. *Neurosurgery*. 2013;72:284-298.
26. Lawson A, Eng M, Molyneux A, et al. Safety results from the treatment of 109 cerebral aneurysms using the Woven EndoBridge technique: preliminary results in the United Kingdom. *J Neurosurg*. 2018;128:144-153.

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