Acta Neurochir (2015) 157:2071–2075
DOI 10.1007/s00701-015-2593-3

CASE REPORT - VASCULAR

Rescue microsurgery with bypass and stent removal following Pipeline treatment of a giant internal carotid artery terminus aneurysm

Christian A. Bowers[1] · Philip Taussky[1] · Min S. Park[1] · Jayson A. Neil[1] · William T. Couldwell[1]

Received: 20 July 2015 / Accepted: 15 September 2015 / Published online: 2 October 2015

Abstract We report the microsurgical rescue and removal of a Pipeline stent embolization of a giant internal carotid artery terminus aneurysm. After the initial placement of a Pipeline Embolization Device (PED), it migrated proximally to the cavernous carotid with the distal end free in the middle of the aneurysm, resulting in only partial aneurysm neck coverage. The patient underwent microsurgical rescue with trapping, bypass, and opening of the aneurysm with PED removal. The vessel remained patent in the proximal segment previously covered by the Pipeline stent. Microsurgical rescue for definitive aneurysm treatment with PED removal can be safe and effective for aneurysms unsuccessfully treated with PED.

Keywords Pipeline Embolization Device · Giant cerebral aneurysm · Rescue microsurgery · Open vascular surgery · Endovascular treatment

Introduction

Multiple studies have demonstrated the revolutionary success of the Pipeline Embolization Device (PED; Covidien, Plymouth, MN) for treatment of complex and challenging cerebral aneurysms, including aneurysms that have failed previous treatment [3, 4, 6, 12–17, 19, 20]. Overall PED complication rates have ranged from 5.0 to 31.7 %, but the rate of major morbidity has been reported to be only 5 %, with a mortality rate of 1 %, while often treating cases that would be extremely difficult to treat with microsurgery and that have failed other endovascular treatments [8, 20]. The U.S. Food and Drug Administration has given approval for the use of the PED in the petrous to supraclinoid internal carotid artery (ICA), but off-label PED use in other intracranial vasculature is ubiquitous and well-reported in the literature with good outcomes [5, 10, 17, 18].

Microsurgical rescue of failed endovascular treatment of cerebral aneurysms is not uncommon; a recent meta-analysis listed 29 reports with a total of 375 microsurgical clippings for previously coiled aneurysms over the past 23 years [2]. Almost all of these rescue operations (>90 %) were for either partially occluded or recurrent aneurysm formation [2]. To the best of our knowledge, successful microsurgical rescue treatment with PED removal has never been reported. We present here a case of successful microsurgical rescue treatment to demonstrate that PEDs can be removed safely with microsurgery and that the vessel can remain patent after PED removal.

Case report

Clinical presentation

A 58-year-old woman presented with a 6-month history of progressively worsening visual deficits that was treated with two recent cataract and lens surgeries that failed to provide any visual improvement. She also reported a month of intermittent severe headaches with associated vertigo, nausea, and occasional emesis. Her visual fields, color perception, and depth

Electronic supplementary material The online version of this article (doi:10.1007/s00701-015-2593-3) contains supplementary material, which is available to authorized users.

✉ William T. Couldwell
neuropub@hsc.utah.edu

[1] Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, 175 N. Medical Drive East, Salt Lake City, Utah 84132, USA

perception were all significantly affected, which severely limited her ability as a truck driver. Therefore, her primary care physician ordered an outpatient magnetic resonance imaging (MRI) exam, which revealed a giant ICA terminus aneurysm (Fig. 1a–c), prompting the patient to present to the emergency room. Her physical examination revealed significant right-sided visual impairment, but no other neurological abnormalities.

Endovascular course

The patient was admitted and underwent a diagnostic cerebral angiogram, which verified the giant right ICA terminus aneurysm of 3×2.2 cm (Fig. 1d–f). The patient desired to avoid surgery if possible and therefore we elected for endovascular treatment with PED placement. She was given 325 mg aspirin and 75 mg clopidogrel by mouth daily and underwent PED placement 3 days later (Fig. 2). Access was gained using a 6-F shuttle (Cook, Bloomington, IN) and a 058 Navien (Covidien) intermediate catheter. A Marksman microcatheter (Covidien) was placed in the M2 branch. A 4.75×35-mm PED was then placed from the M1 segment into the cavernous segment, completely covering the neck of the aneurysm; however, optimal wall apposition of the device could not be achieved during placement, and as a result, a 4×11 Scepter XC balloon (Microvention, Tustin, CA) was used to angioplasty the device for optimal wall opposition. During angioplasty the distal aspect of the PED foreshortened and continued to foreshorten even after angioplasty and wall apposition was achieved. The distal end of the PED retracted into the dome of the aneurysm. Access was gained again with the Marksman microcatheter, and the M2 segment was selectively catheterized. A second Pipeline device measuring 4.75×25 was advanced. Despite our best efforts, the second telescoping device could not be opened distally and the device could not be released from its capture coil. At this point, a dissection of a 360-degree loop in the cervical carotid needed to be stented after removal of the Navien catheter, and a decision was made to abandon the procedure. Five days later, a second attempt at placing a telescoping Pipeline device from the M1 segment into the previous device had to be abandoned because of the difficulty in passing the stented dissection in the cervical carotid artery. The patient failed a balloon occlusion test.

Operative course

The patient returned 3 days prior to her planned surgery date with an acute episode of thunderclap headache, extreme vertigo, persistent nausea, and multiple episodes of emesis. Computed tomography (CT) angiography revealed acute partial aneurysm thrombosis of the area covered by the PED (Fig. 3). The patient was started on a heparin drip to prevent further acute thrombotic complications, and she was taken to the operating room for right pterional craniotomy for trapping and bypass of this complex giant right ICA aneurysm with

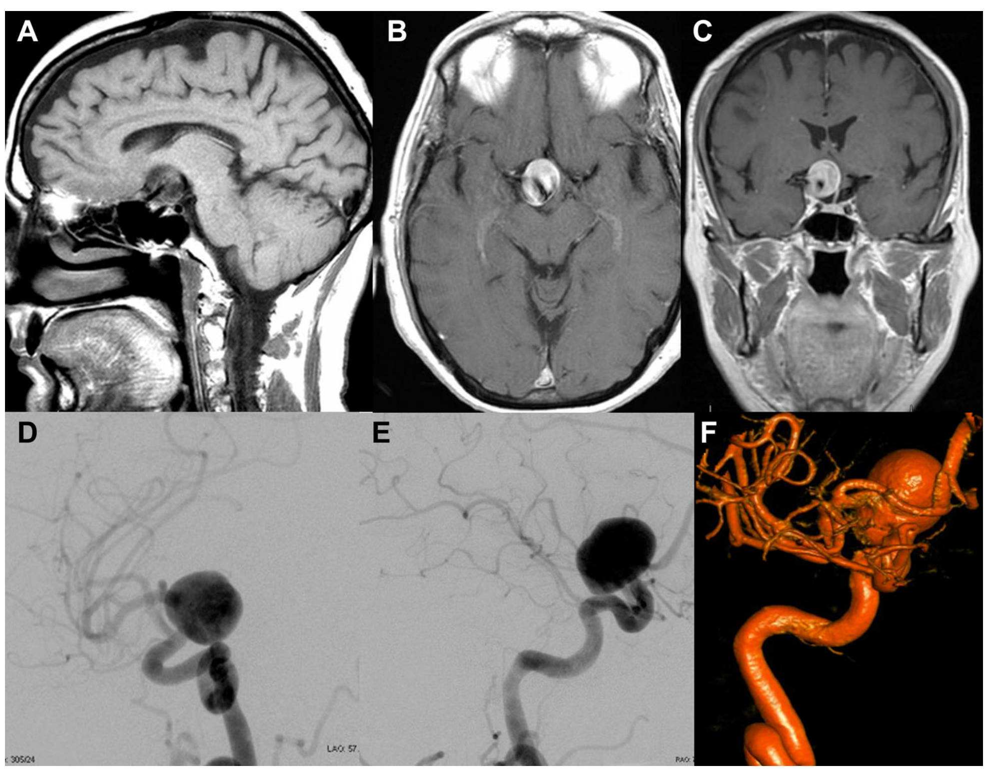

Fig. 1 **a** Sagittal midline T1-weighted MRI showing a circumscribed suprasellar mass. **b** Axial and **c** coronal contrast-enhanced MRIs demonstrating avid homogenous circumscribed suprasellar lesion consistent with a right carotid terminus aneurysm. **d** Anteroposterior and **e** lateral diagnostic cerebral angiograms showing giant right ICA terminus aneurysm. The aneurysm occupies the majority of the wall of the artery. **f** Three-dimensional reconstruction from the diagnostic cerebral angiogram showing giant right ICA terminus aneurysm

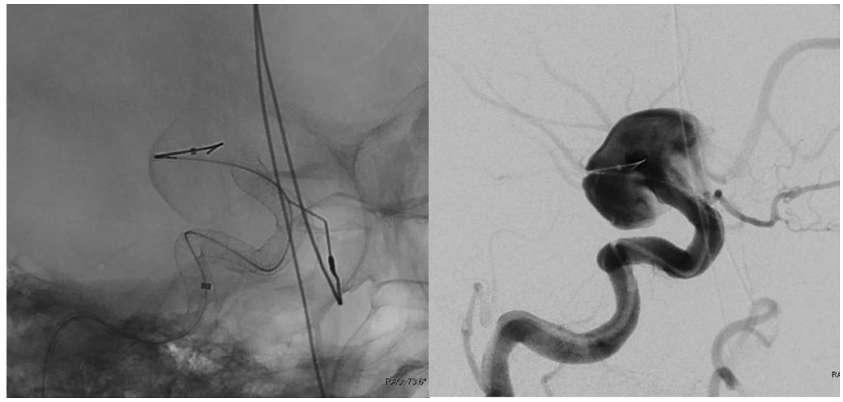

Fig. 2 **a** Diagnostic cerebral angiogram pre-injection showing the PED migration with proximal stent in the cavernous segment of the right ICA and distal end in the aneurysm. **b** Same view post-injection showing continuous aneurysm filling despite the PED

external carotid artery (ECA)–to–middle cerebral artery (MCA) bypass with a saphenous vein graft. Proximal control in the neck was planned with carotid exposure and placement of vessel loops around the right common, external carotid, and internal carotid arteries. Critical portions of the operations are presented in the accompanying video (Video 1). The ECA was dissected and prepared for bypass. A saphenous vein graft was used to anastomose the ECA (end-to-end) to M2 after the saphenous graft was passed from the neck intracranially through a small hole in the skull base created by drilling lateral to foramen ovale in the skull base [7]. The distal aneurysm clip was placed just distal to the distal aneurysm neck, and temporary proximal control was obtained with temporary ligation of the proximal right ICA in the neck. The aneurysm was incised with a no. 11 blade so that the thrombus and the PED–stent were both removed (Video 1). The aneurysm thrombus was resected to allow for optic nerve decompression. The aneurysm-involved vessel segment was completely trapped with a proximal clip placed distal to the ophthalmic artery but proximal to the aneurysm-involved vessel origin (Fig. 4). As the stent was easily removed, it was decided to trap the aneurysm in this segment to enable perfusion of the ophthalmic artery. We never visualized the anterior choroidal artery on preoperative cerebral angiograms, so we were not concerned about trapping the aneurysm at this point distal to the ophthalmic artery. The postoperative angiogram demonstrated good bypass patency and good right ophthalmic artery filling from the right ICA that had previously been covered with the PED (Fig. 5). The patient woke up at her neurological baseline with stable impaired right visual function.

Postoperative course

Postoperatively, the patient did extremely well and was discharged home after 1 week. Her vision slowly improved over the follow-up period of 6 months. The postoperative angiogram demonstrated patency of the saphenous bypass and the native ICA, terminating in a patent ophthalmic artery (Fig. 5).

Discussion

The development of flow-diverting technology and the PED has revolutionized the cerebrovascular management of some complex aneurysms, with mortality rates of approximately 1 % and major morbidity of only 5 % [8]. If PED treatment is unsuccessful, or if there is a technical error in the PED deployment that cannot be corrected, endovascular salvage options are generally limited to vessel sacrifice [9]. Of the three previous case reports of microsurgical rescues of failed

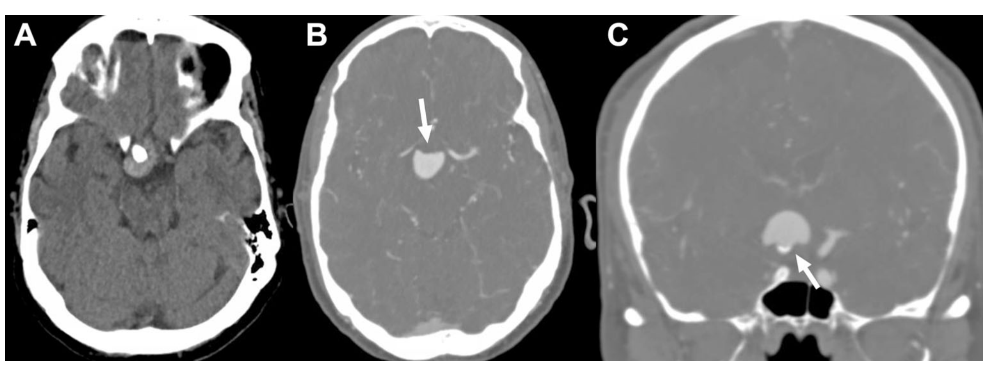

Fig. 3 **a** Head computed tomography (CT) without contrast enhancement showing hyperdense acute partial thrombus in the part of the aneurysm covered by the stent (*arrow*). **b** Axial and **c** coronal CT angiography showing partial filling defect (thrombus) (*arrow*) in the aneurysm

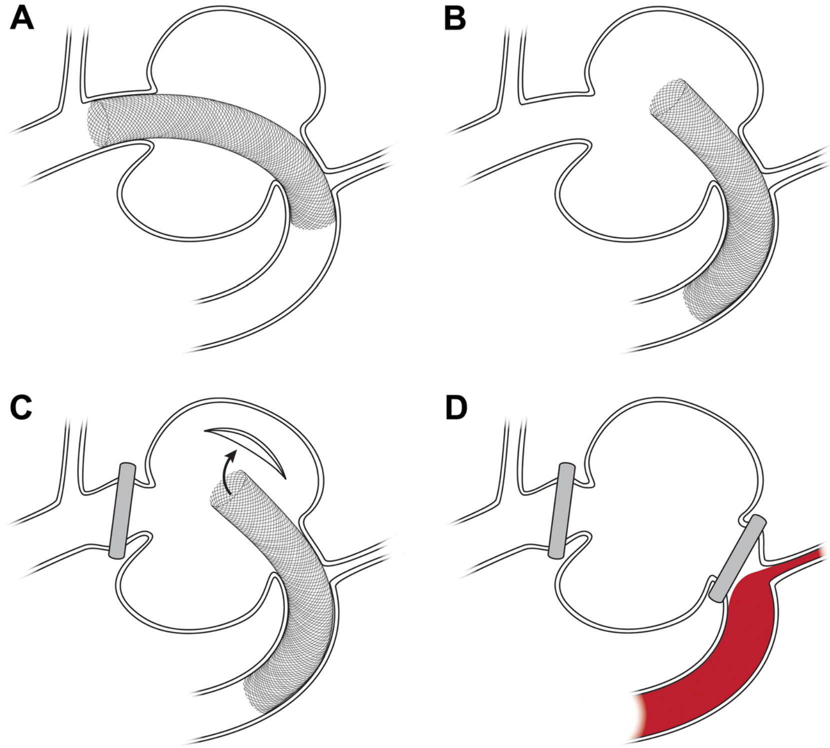

Fig. 4 Illustration of the migration of the distal end of the Pipeline stent into the lumen of the aneurysm after deployment (**a**, **b**). The microsurgical treatment employed trapping of the ICA aneurysmal segment, with removal of the stent and clipping of the ICA just distal to the takeoff of the ophthalmic artery (**c**, **d**)

PED cases, only two involved PED removal [8, 9], and both of these cases resulted in poor outcomes (death and major ischemic stroke with significant neurological deficit). The other case of microsurgical rescue demonstrated a successful bypass and ICA occlusion after failed PED, but there was no attempted PED retrieval [1].

Because of the growing use of PEDs by the neurosurgical community, successful reports of open microsurgical rescue of failed PEDs have been a goal [9, 11]. The microsurgical strategies after failed PED—aneurysm wrapping, parent vessel occlusion with bypass, aneurysm trapping with bypass or parent vessel reconstruction (requiring PED removal), and aneurysm clipping with parent vessel reconstruction with or without aneurysmorrhaphy—are technically challenging [9].

We considered the different microsurgical options in our case before deciding on aneurysm trapping with bypass and PED removal. Our patient had significantly compromised vision because of the aneurysmal mass effect on the optic nerve. The goal was to reduce mass effect on the optic apparatus and, if possible, to leave the ophthalmic artery patent, thus increasing the patient's chance for visual recovery. To this end, it was determined that trapping the aneurysmal segment of the ICA, with preservation of ICA flow to the ophthalmic artery would be best accomplished by removing the PED, which spanned

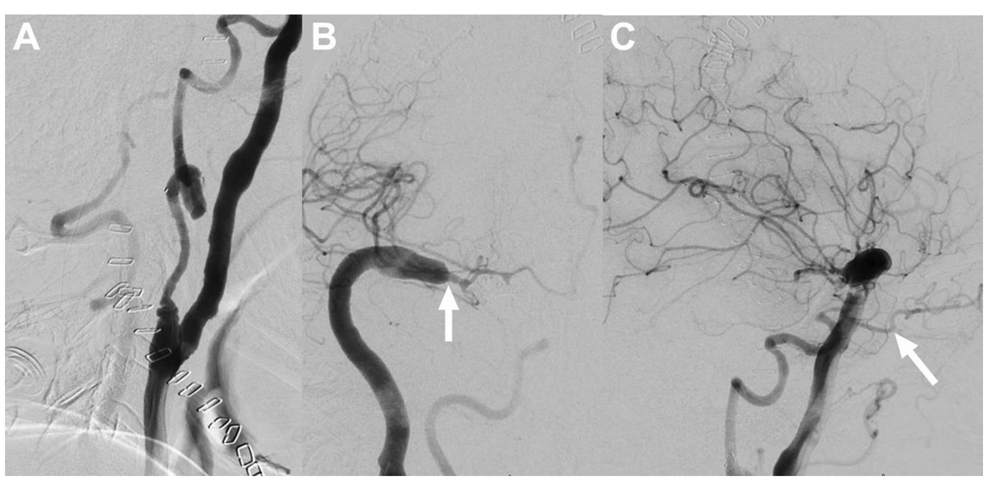

Fig. 5 Postoperative diagnostic cerebral angiogram with right common carotid injection. **a** Large patent saphenous vein bypass from the ECA (end-to-end) to right MCA M2 segment. **b** *Arrow* showing bypass anastomosis point between right ECA and MCA with good filling of MCA territory. **c** Lateral view shows right ICA filling the right ophthalmic artery (*arrow*) because the proximal aneurysm clip on the right ICA is distal to the ophthalmic artery origin

the segment of the takeoff of the ophthalmic artery. An alternative would have been more proximal sacrifice of the ICA and sacrifice of the ophthalmic artery without removal of the stent. It is also possible that the second-generation PED—the Pipeline Flex—will be less likely to fail, obviating the need for open surgery and bypass, but at the time of this procedure, the newer device had not received FDA approval.

Conclusion

PED has been an important advancement in the endovascular management of complex and large/giant aneurysms. Microsurgical rescue of failed PED is an important technique when endovascular salvage options have been exhausted. We present a case of microsurgical PED removal with subsequent functioning vessel segment that had been covered by the PED. As the use of PED becomes more widespread, microsurgical rescue strategies may be needed in selected cases.

Acknowledgments We thank Jennie Williams, MA, for illustrations, Vance Mortimer for assistance with preparation of the video, and Kristin Kraus, MSc, for editorial assistance.

Compliance with Ethical Standards The patient has consented to the submission of this case report to the journal.

Conflicts of interest None.

References

1. Abla AA, Zaidi HA, Crowley RW, Britz GW, McDougall CG, Albuquerque FC, Spetzler RF (2014) Optic chiasm compression from mass effect and thrombus formation following unsuccessful treatment of a giant supraclinoid ICA aneurysm with the Pipeline device: open surgical bailout with STA-MCA bypass and parent vessel occlusion. J Neurosurg Pediatr 14:31–37
2. Arnaout O, El Ahmadieh T, Zammar S, El Tecle N, Hamade Y, Aoun R, Aoun S, Rahme R, Eddleman C, Barrow D, Batjer H, Bendok B (2015) Microsurgical treatment of previously coiled intracranial aneurysms: systematic review of the literature. World Neurosurg 84:246-253
3. Becske T, Kallmes DF, Saatci I, McDougall CG, Szikora I, Lanzino G, Moran CJ, Woo HH, Lopes DK, Berez AL, Cher DJ, Siddiqui AH, Levy EI, Albuquerque FC, Fiorella DJ, Berentei Z, Marosfoi M, Cekirge SH, Nelson PK (2013) Pipeline for uncoilable or failed aneurysms: results from a multicenter clinical trial. Radiology 267:858–868
4. Brinjikji W, Murad MH, Lanzino G, Cloft HJ, Kallmes DF (2013) Endovascular treatment of intracranial aneurysms with flow diverters: a meta-analysis. Stroke 44:442–447
5. Chalouhi N, Starke RM, Yang S, Bovenzi CD, Tjoumakaris S, Hasan D, Gonzalez LF, Rosenwasser R, Jabbour P (2014) Extending the indications of flow diversion to small, unruptured, saccular aneurysms of the anterior circulation. Stroke 45:54–58
6. Chitale R, Gonzalez LF, Randazzo C, Dumont AS, Tjoumakaris S, Rosenwasser R, Chalouhi N, Gordon D, Jabbour P (2012) Single center experience with pipeline stent: feasibility, technique, and complications. Neurosurgery 71:679–691
7. Couldwell WT, Liu JK, Amini A, Kan P (2006) Submandibular-infratemporal interpositional carotid artery bypass for cranial base tumors and giant aneurysms. Neurosurgery 59:ONS353–ONS359
8. Ding D, Liu KC (2013) Microsurgical extraction of a malfunctioned pipeline embolization device following complete deployment. J Cerebrovasc Endovasc Neurosurg 15:241–245
9. Ding D, Starke RM, Liu KC (2014) Microsurgical strategies following failed endovascular treatment with the pipeline embolization device: case of a giant posterior cerebral artery aneurysm. J Cerebrovasc Endovasc Neurosurg 16:26–31
10. Fiorella D, Woo HH, Albuquerque FC, Nelson PK (2008) Definitive reconstruction of circumferential, fusiform intracranial aneurysms with the pipeline embolization device. Neurosurgery 62:1115–1120
11. Hampton T, Walsh D, Tolias C, Fiorella D (2011) Mural destabilization after aneurysm treatment with a flow-diverting device: a report of two cases. J Neurointerv Surg 3:167–171
12. Jabbour P, Chalouhi N, Tjoumakaris S, Gonzalez LF, Dumont AS, Randazzo C, Starke RM, Hasan D, Chitale R, Singhal S, Moukarzel LA, Rosenwasser R (2013) The Pipeline Embolization Device: learning curve and predictors of complications and aneurysm obliteration. Neurosurgery 73:113–120
13. Kan P, Siddiqui AH, Veznedaroglu E, Liebman KM, Binning MJ, Dumont TM, Ogilvy CS, Gaughen JR Jr, Mocco J, Velat GJ, Ringer AJ, Welch BG, Horowitz MB, Snyder KV, Hopkins LN, Levy EI (2012) Early postmarket results after treatment of intracranial aneurysms with the pipeline embolization device: a U.S. multicenter experience. Neurosurgery 71:1080–1087
14. Lylyk P, Miranda C, Ceratto R, Ferrario A, Scrivano E, Luna HR, Berez AL, Tran Q, Nelson PK, Fiorella D (2009) Curative endovascular reconstruction of cerebral aneurysms with the pipeline embolization device: the Buenos Aires experience. Neurosurgery 64:632–642
15. Nelson PK, Lylyk P, Szikora I, Wetzel SG, Wanke I, Fiorella D (2011) The pipeline embolization device for the intracranial treatment of aneurysms trial. AJNR Am J Neuroradiol 32:34–40
16. Park MS, Albuquerque FC, Nanaszko M, Sanborn MR, Moon K, Abla AA, McDougall CG (2015) Critical assessment of complications associated with use of the Pipeline Embolization Device. J Neurointerv Surg 7:652–659
17. Pistocchi S, Blanc R, Bartolini B, Piotin M (2012) Flow diverters at and beyond the level of the circle of willis for the treatment of intracranial aneurysms. Stroke 43:1032–1038
18. So TY, Mitchell PJ, Dowling RJ, Yan B (2014) Efficacy, complications and clinical outcome of endovascular treatment for intracranial intradural arterial dissections. Clin Neurol Neurosurg 117:6–11
19. Szikora I, Berentei Z, Kulcsar Z, Marosfoi M, Vajda ZS, Lee W, Berez A, Nelson PK (2010) Treatment of intracranial aneurysms by functional reconstruction of the parent artery: the Budapest experience with the pipeline embolization device. AJNR Am J Neuroradiol 31:1139–1147
20. Taussky P, Tawk RG, Miller DA, Freeman WD, Hanel RA (2013) New therapies for unruptured intracranial aneurysms. Neurol Clin 31:737–747