CASE REPORT

# Simultaneous stent expansion/balloon deflation technique to salvage failed balloon remodeling

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## SUMMARY

Herniation, with possible embolization, of coils into the parent vessel following aneurysm coiling remains a frequent challenge. For this reason, balloon or stent assisted embolization remains an important technique. Despite the use of balloon remodeling, there are occasions where, on deflation of the balloon, some coils, or even the entire coil mass, may migrate. We report the successful use of a simultaneous adjacent stent deployment bailout technique in order to salvage coil prolapse during balloon remodeling in three patients. Case No 1 was a wide neck left internal carotid artery bifurcation aneurysm, measuring 9 mm×7.9 mm×6 mm with a 5 mm neck. Case No 2 was a complex left superior hypophyseal artery aneurysm, measuring 5.3 mm×4 mm×5 mm with a 2.9 mm neck. Case No 3 was a ruptured right posterior communicating artery aneurysm, measuring 4 mm×4 mm×4.5 mm with a 4 mm neck. This technique successfully returned the prolapsed coil mass into the aneurysm sac in all cases without procedural complications. The closed cell design of the Enterprise VRD (Codman and Shurtleff Inc, Raynham, Massachusetts, USA) makes it ideal for this bailout technique, by allowing the use of an 0.021 inch delivery catheter (necessary for simultaneous access) and by avoiding the possibility of an open cell strut getting caught on the deflated balloon. We hope this technique will prove useful to readers who may find themselves in a similar predicament.

## BACKGROUND

Herniation or migration of loops of coil during aneurysm embolization, raising the risk of non-target thromboembolic events, continues to be a challenge. In modern series, the incidence of such events ranges from 1.2% to 2.5%.[1 2] Several intraprocedural techniques have been described, the most common being endovascular retrieval with a variety of devices.[3] Some have used stents to trap loose coils between the stent and parent vessel endothelium.[4–7] Others have used placement of an intraluminal stent to mold herniated loops back into the aneurysm sac.[8] We report our experience with positioning and deployment of an Enterprise VRD (Codman and Shurtleff Inc, Raynham, Massachusetts, USA) while keeping the balloon inflated, and thereby maintaining the coils in position, resulting in simultaneous stent expansion concurrent to balloon deflation (figure 1). Our experience suggests that, when presented with such a challenging situation, this salvage technique offers a reasonable bailout method to prevent coil migration.

## CASE PRESENTATION

Case No 1 was a wide neck left internal carotid artery bifurcation aneurysm, measuring 9 mm×7.9 mm×6 mm with a 5 mm neck (figure 2). Case No 2 was a complex left superior hypophyseal artery aneurysm, measuring 5.3 mm×4 mm×5 mm with a 2.9 mm neck (figure 3). Case No 3 was a ruptured right posterior communicating artery aneurysm, measuring 4 mm×4 mm×4.5 mm with a 4 mm neck (figure 4). Case details and outcomes are provided in their respective figure legends.

## TREATMENT

In all cases we used the conglomerate mass technique, as initially described by Fiorella and Woo,[9] wherein a temporary balloon is positioned across the aneurysm neck and inflated followed by several rounds of embolization, with multiple coils placed during inflation to create a fixed coil mass. Typically, a stable well formed coil mass is very stable on completion of this technique; however, as the reported cases illustrate, this is not always the case. After balloon assisted coil embolization of the aneurysm and removal of the microcatheter, the balloon is slowly deflated. If coil herniation is seen, the balloon is quickly reinflated to prevent further coil migration and embolization.

In the simultaneous balloon deflation/stent expansion bailout technique, a Prowler Select Plus microcatheter (Codman and Shurtleff Inc) is advanced over an 0.014 inch microwire to cross parallel to the balloon into the distal vasculature using a gentle spinning technique. All of our cases used the Transform balloon (Stryker Neurovascular, Fremont, California, USA) for balloon remodeling. In all cases there was no difficulty advancing the Prowler Select Plus microcatheter past the Transform balloon through the Neuron 070 (Penumbra, Alameda, California, USA) guide catheter, Next, the Enterprise stent is deployed starting just distal to the still inflated balloon and aneurysm neck. As the balloon is slowly deflated, simultaneous expansion of the stent is seen. In all cases the coils were visualized to stay within the aneurysm without further movement. The Enterprise stent is noted to have good apposition to the vessel wall, and the fully deflated balloon is withdrawn (figure 1). We encountered no significant resistance in withdrawal of the balloon despite its location being between the stent and the vessel wall. We believe that the closed cell design of the Enterprise stent is critical to the easy withdrawal of the deflated balloon.

To prevent acute thrombosis with stenting, all patients were given antithrombotics. For the patient with subarachnoid hemorrhage,

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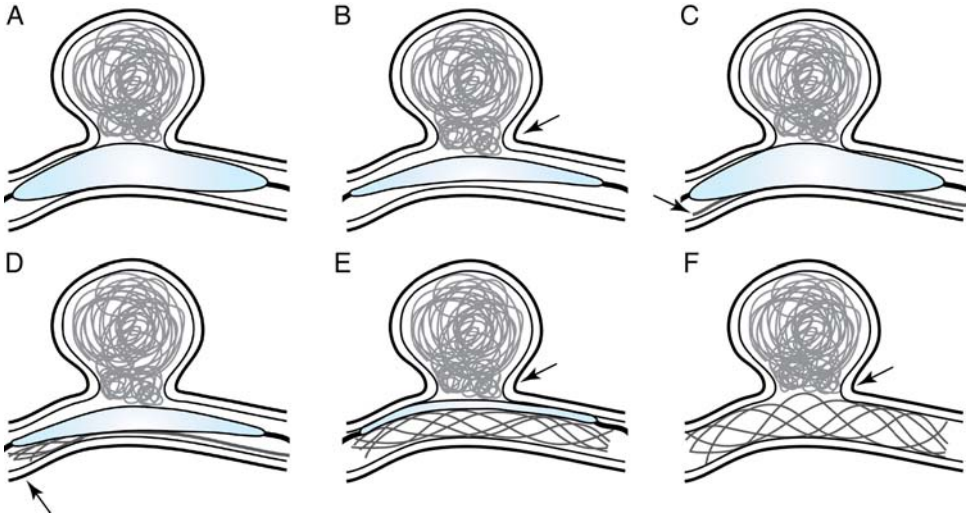


**Figure 1** Bailout stent technique. (A) Aneurysm has been successfully coiled with balloon assisted embolization. (B) As the balloon is deflated, the coil mass begins to prolapse (arrow). (C) The balloon is quickly reinflated to prevent further coil migration and allowed to sit to determine if the coil is stable within the aneurysm sac. If not, a microwire, a Prowler Select Plus, is advanced over a Synchro standard wire and crossed behind the balloon (arrow). (D) The Enterprise stent is unsheathed and deployed just distal to the still inflated balloon (arrow). The balloon is slowly deflated, visualizing stent expansion. (E) The coils are visualized to return to their previous location (arrow). The balloon is further deflated, and the stent opens up more. (F) The Enterprise stent is completely deployed, and after confirming successful placement, the balloon is withdrawn. The coils have returned completely within the aneurysm sac (arrow), supported in place by the stent scaffolding.

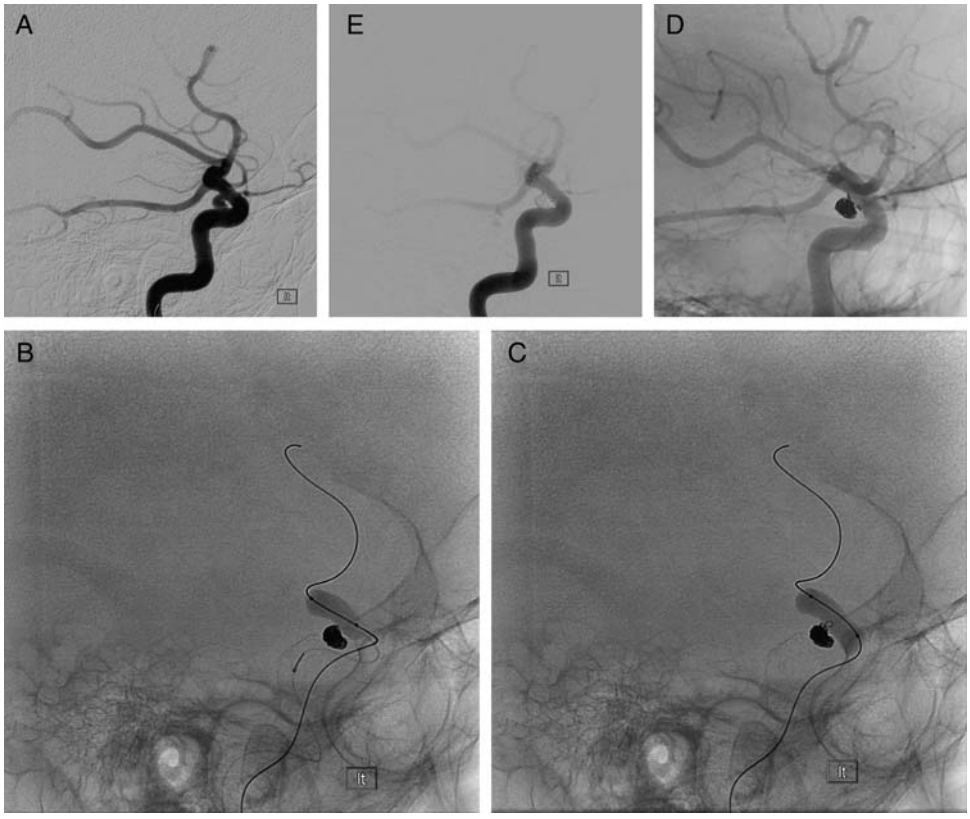


**Figure 2** Case No 1. A patient with a wide necked left superior hypophyseal artery aneurysm, measuring 5.3 mm×4 mm×5 mm with a 3 mm neck, found after workup for headaches (A). Balloon assisted embolization of the left superior hypophyseal aneurysm was done with a Transform Supercompliant balloon (Stryker) and SL-10 microcatheter (Stryker). A single round of coil packing noted a dense coil mass, with no apparent herniation (B). Multiple attempts at balloon deflation led to notable coil mass prolapse, and consequently the balloon was reinflated (C). The coil mass stabilized with balloon reinflation, and concurrent deployment of the Enterprise stent with balloon deflation led to excellent expansion of the stent without further coil mass migration (D). The final run showed Raymond grade II 98% embolization (E). At the 3 month follow-up, there was no in-stent stenosis. A stable coil mass with improved apposition of the prior coil loop against the stent wall was visualized. There was no recanalization seen.

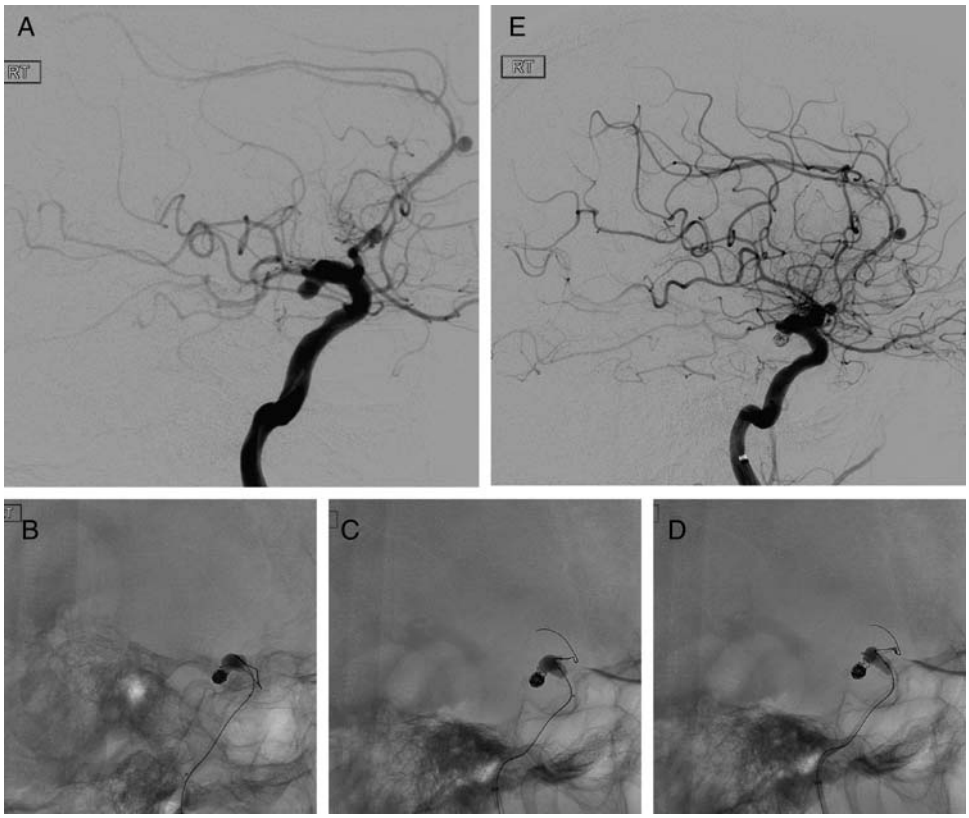


**Figure 3** Case No 2. An elderly patient with multiple medical comorbidities presented with Hunt and Hess grade 3, 5 days after rupture of a right posterior communicating artery aneurysm, measuring 4 mm×4 mm×4.5 mm with a 4 mm neck. Initial angiography already noted the development of vasospasm in the right A1 segments which was treated with intra-arterial verapamil. The patient also had three unruptured aneurysms: right pericallosal, right anterior communicating, and right middle cerebral. (A) Balloon assisted embolization was done with a Transform Supercompliant balloon (Stryker) and SL-10 Microcatheter (Stryker), resulting in a dense coil mass with excellent obliteration of the aneurysm. (B) The SL-10 was removed, and three attempts were made to deflate the balloon. Each time a single coil loop prolapse was noted, and consequently the balloon was reinflated (C). With the balloon inflated, the stent microcatheter was positioned adjacent and partly distal to the balloon (D). The Enterprise stent was deployed in the described dynamic manner with excellent apposition to the parent vessel wall. After bailout stent remodeling of the coil mass, final angiography showed Raymond grade I embolization, with some coil interstices filling with contrast but excellent dome protection. Additionally, no stenosis or embolic complication was observed (E). This patient underwent an emergent embolization with stent bailout deployment, and was given a bolus dose of eptifibatide 10 000 μg at balloon deflation/stent deployment followed by a 1 μg/kg/min infusion for 6 h. The patient was also started on aspirin 600 mg rectally, Plavix 400 mg via a nasogastric tube, and started on aspirin 325 mg and Plavix 75 mg daily. Three days after bailout–stent embolization, the patient deteriorated with worsened vasospasm on CT angiography. The patient was brought back for an angiogram and found to have moderate vasospasm of the right anterior cerebral and middle cerebral arteries. Intra-arterial verapamil was again administered with improvement on angiogram, and with a stable appearance of the coil mass and no evidence of thrombus or in-stent stenosis (not shown). Five days post-embolization the patient experienced a spontaneous large retroperitoneal hematoma resulting in severe hypotension. While this was rapidly corrected, multisystem organ failure developed (likely secondary to the episode of severe hypotension) and the family elected for comfort care. The experience of this case further supports the position of avoiding stent placement if at all possible in patients with subarachnoid hemorrhage. Bailout stent remodeling was felt to be a reasonable option given the delayed presentation and lack of hydrocephalus. However, it is likely that aspirin and Plavix contributed to the retroperitoneal hematoma and, as a result, likely contributed to eventual death.

immediately prior to balloon deflation the patient was given an intravenous loading dose of eptifibatide followed by a 6 h infusion, and aspirin 300 mg rectally; Plavix 400 mg via a nasogastric tube was administered prior to extubation. Rectal aspirin was used for its more rapid absorption profile.[10] In the two elective patients, pretreatment as outpatients with aspirin and Plavix occurred, given the wide neck nature of their aneurysms and potential need for stent placement. However, once the intraprocedural decision was made for balloon remodeling, deployment of stent occurred as a bailout given the coil mass migration. All patients were given intraprocedural boluses of heparin with a target activated clotting time of 200–250 s. There were no incidents of acute thromboembolic complications.

## DISCUSSION

In large modern series using detachable coils, the incidence of coil prolapse or migration has ranged from 1.2% to 2.5%.[1 2] Retrieval using devices such as stent retrievers and snare devices has been the most commonly used technique when embolization occurs.[3] Stent assisted remodeling has been reported, particularly when retrieval fails. Fessler *et al*[4] first described one case of trapping the migrated/fractured coil between the stent and endothelium of the parent vessel. This has been described in five other cases with favorable results.[5–7]

Yoo *et al*[8] first described using the Neuroform stent to rescue herniated loops in 16 aneurysm cases. Satisfactory stabilization of the coils was achieved in 12/16 (75%) cases. The described technique is one of serial stent placement only, after coiling or

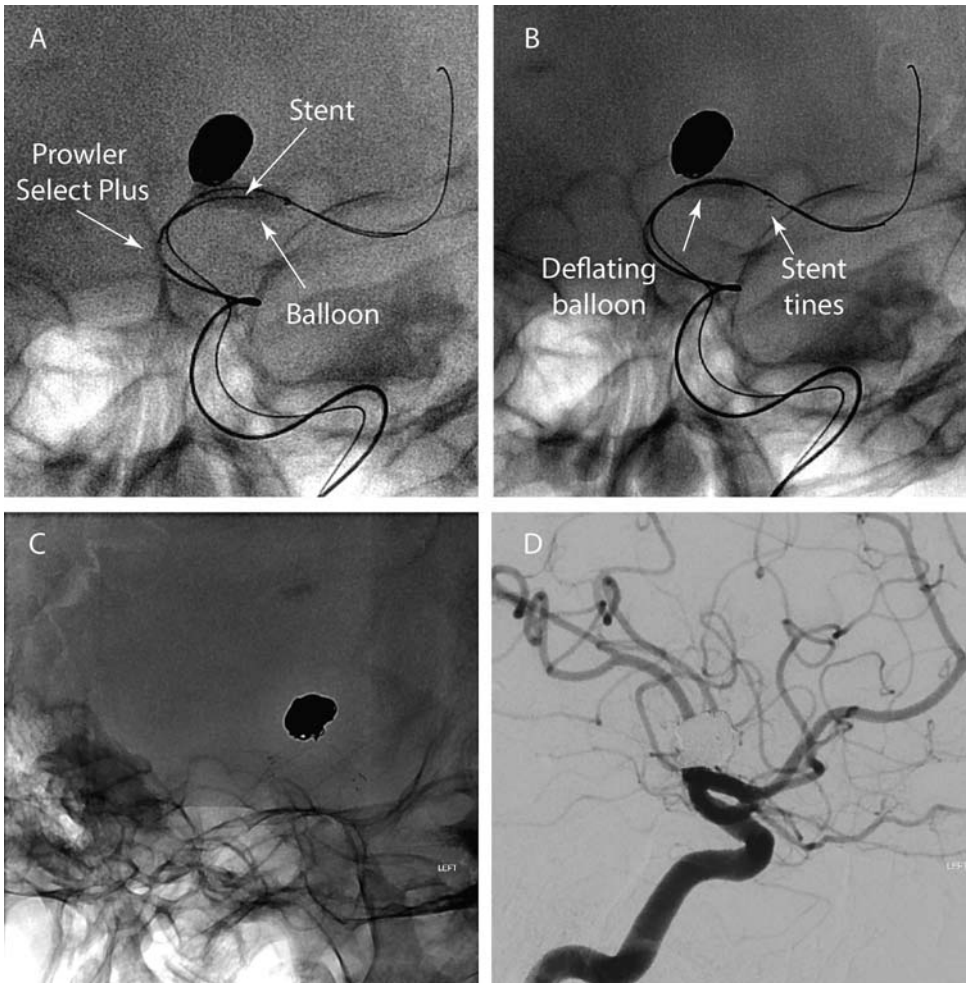


**Figure 4** Case No 3. A patient with a wide neck left internal carotid artery bifurcation aneurysm, measuring 9 mm×7.9 mm×6 mm with a 5 mm neck, presented with transient ischemic attack symptoms of unclear origin. Balloon assisted embolization was undertaken. Balloon assisted embolization of the left internal carotid artery bifurcation aneurysm was undertaken with a Transform Supercompliant 7 mm×10 mm balloon (Stryker) and SL-10 microcatheter (Stryker). During balloon deflation after two rounds of balloon assisted embolization, the coil mass had herniated into the parent vessel. The balloon was immediately reinflated and a Prowler Select Plus microcatheter (Codman) was exchanged over a Synchro Standard microwire (Stryker) and brought behind the inflated balloon (A). Next, the Enterprise stent system was deployed with concurrent deflation of the Transform balloon; note the distal stent tines are seen (B). After bailout stent remodeling of the coil mass, final angiography showed Raymond grade II 98% embolization, excellent remodeling of the parent vessel, and no coil mass herniation (not shown). The 3 month follow-up angiography demonstrated Raymond grade I 100% embolization with no in-stent stenosis (C, D).

balloon remodeling. Only four cases in total used balloon inflation, three cases involved balloon use during the initial aneurysm embolization, and one case attempted balloon remodeling, prior to stent placement. While this series is the best described series of stent assisted molding of coil mass back into the aneurysm, Yoo's technique is one of serial stent placement after coiling or balloon remodeling, rather than ours of simultaneous stent deployment during balloon deflation after coiling.

While stent placement to stabilize a coil mass is not new, the important technical note highlighted in our series is that when there is fear of immediate mobilization of coils during balloon deflation, it is technically feasible to access the parent vasculature through the existing access system and simultaneously deploy a stent and deflate the balloon. We demonstrated that through the same 0.070 guide catheter, with the Transform balloon in place, an 0.021 catheter can be simultaneously brought up into the vasculature to cross the aneurysm neck and then deploy a closed cell stent prior to balloon deflation, thereby effecting simultaneous stent inflation during balloon deflation. No additional groin puncture or guide catheter is necessary in our technique, saving valuable time and further reducing thromboembolic risk.

It is critical to note that a closed cell stent with robust opening force is crucial to the successful employment of this technique. The Enterprise stent (Codman and Shurtleff Inc) is especially suited to the simultaneous bailout stent technique due to its closed cell design and greater radial force than the Neuroform stent. This allows one to effectively 'jail' the balloon outside of the stent, without concern for the balloon getting caught on the tynes of an open cell design. We experienced no resistance in withdrawing the balloon during any of our cases, and observed no evidence of stent migration with balloon withdrawal. We would emphasize that the distal edge of the stent must be deployed distal to the end of the balloon to avoid the risk of the balloon catching on the distal end of the stent. Furthermore, having the stent deployed distal to the balloon provides a benefit by creating distal protection from embolization should any coils herniate despite the use of this technique.

Other techniques that exist for practitioners to consider when faced with coil herniation include deflation of the balloon after

the coil is brought into position, but prior to final detachment. This can allow for direct visualization, and if the coil cannot be stabilized, then the coil can still be resheathed and a stent assisted coiling technique similar to Yoo *et al* can be utilized. Another technique is to use a double microcatheter technique to place simultaneous coils or alternating from one microcatheter to the other, which can allow for increased stability for wide neck aneurysms.[11] Should these preventative measures fail to secure the coil mass, or if they are not employed initially, then our described simultaneous stent bailout technique can be readily utilized through the existing vasculature access.

Balloon remodeling has become a popular option in aneurysm coil embolization, but coils can prolapse during balloon deflation, particularly in wide neck aneurysms. In these cases, the simultaneous stent bailout technique allows for simultaneous deployment across the neck with concurrent balloon deflation to stabilize the coil mass and prevent unnecessary coil prolapse or migration. However, this technique is not without risks. Any time a stent is placed there is a risk of acute thrombosis or in-stent stenosis. Each center has its own protocol for providing appropriate antiplatelet therapy prior to urgent stent placement, and our case number is too small to advocate any particular management paradigm. With regards to delayed in-stent stenosis, the documented incidence in a large registry of Enterprise stent coiling was 3.4%.[12]

On follow-up angiography, none of our patients demonstrated any significant in-stent stenosis. Additionally, in no cases were any instances of thromboembolic complications identified. Finally, this experience further highlights the risks associated with stent assisted coiling in ruptured aneurysm patients. While the technical components of the simultaneous stent bailout technique proceeded without difficulty, the patient with subarachnoid hemorrhage died from a delayed retroperitoneal hematoma a week later that likely was at least worsened as a result of the patient's double antiplatelet therapy.

## Learning points

- The incidence of coil prolapse or migration during coil embolization of aneurysms has ranged from 1.2% to 2.5%.
- During balloon assisted coil embolization, coils can prolapse during balloon deflation, particularly in wide neck aneurysms.
- Simultaneous Enterprise VRD stent expansion concurrent to balloon deflation offers a reasonable bailout method to prevent coil migration.

**Contributors** All authors have contributed substantially and have reviewed and approved the final version.

**Competing interests** JM is a consultant for Lazarus Effect, Medina Medical, Pulsar Vascular, Reverse Medical, and Edge Therapeutics; an investor in Blockade Medical and Medina Medical; and is on the advisory board for Codman Neurovascular.

**Patient consent** Not obtained.

**Ethics approval** The study was approved by Vanderbilt institutional review board (# 121403).

**Provenance and peer review** Not commissioned; externally peer reviewed.

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