Original Paper

Coil Embolization of Wide-Neck Bifurcation Aneurysms Using a Single-Balloon Microcatheter

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Ascent balloon catheter · Aneurysm · Balloon-assisted coil embolization · Packing density · Wide neck

Abstract

Background: Coil embolization of wide-neck cerebral aneurysms frequently requires stent or balloon assistance. Such approaches to coil embolization increase the procedural complexity, adding risk and cost. **Objective:** To describe a series of coil embolization procedures performed using a single-balloon microcatheter to treat wide-neck aneurysms and establish the safety, feasibility and efficacy of this technique. **Methods:** A retrospective review was performed to identify cases in which the Ascent balloon (Codman Neurovascular, Raynham, Mass., USA) was used as a single-balloon microcatheter for aneurysm coil embolization at two institutions. Clinical, demographic and angiographic data were obtained, and aneurysm volumes as well as packing densities (PD) were calculated. **Results:** Eight cerebral aneurysms were treated using this technique. Six of these were unruptured. The aneurysms had an average neck diameter of 3.7 mm, and the maximum dimension ranged from 5 to 11 mm, with a mean of 7.5 mm. The mean aspect ratio was 2.07. The mean volume of the aneurysms was 180.38 mm³. The average PD achieved in these 8 aneurysms was 41.79%. Complete occlusion with coil embolization [Raymond-Roy Occlusion Classification (RROC) 1] was achieved in all cases except one, where a small residual was left deliberately and the occlusion grade was RROC 2. There were no intraprocedural complications. **Conclusion:** This initial experience demonstrates the feasibility and immediate outcomes of a single-balloon microcatheter technique in coil embolization of wide-neck cerebral aneurysms. This technique may be used to achieve a high PD, comparable to that obtained with stent-assisted coiling or coiling alone, while avoiding permanent stent placement and potentially reducing thromboembolic complications.

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Introduction

Endovascular treatment of wide-neck bifurcation aneurysms has represented a challenge for neurointerventionalists since the introduction of detachable coils in the early 1990s [1]. Balloon-assisted coil embolization (BACE) was introduced in 1994 [2] in an attempt to address this challenge. A large experience with the BACE technique has shown it to be highly effective. Another method to treat wide-neck aneurysms is stent-assisted coiling (SAC) [3], which is performed with self-expanding intracranial stents. A novel application of SAC is the ‘waffle cone technique’ [4] that involves the deployment of one end of a stent within, rather than across, the neck of bifurcation aneurysms. While effective, these techniques are more complex than traditional coiling and may be associated with an increased rate of complications [5–7].

The dual-lumen Ascent balloon microcatheter (Codman Neurovascular, Raynham, Mass., USA; fig. 1) received FDA approval in 2011. This catheter has a central lumen compatible with a 0.014-inch wire and an outer parallel noncommunicating lumen that allows the inflation of a compliant balloon at the distal tip. The inner lumen is designed to deliver compatible therapeutic agents. A unique feature of the Ascent balloon is a proximal marker band 3 cm from the tip that facilitates the use of detachable coils. The tip of the microcatheter extends 3 mm distally from the distal balloon marker. A technique for using the Ascent balloon as a stand-alone device to create a ‘temporary waffle cone’ scaffold and deliver coils to a wide-neck bifurcation aneurysm has been described in individual cases previously, which may represent an alternative to conventional BACE and SAC [8–10].

Packing density (PD) is the ratio between the volume of coils used to embolize an aneurysm and the volume of the aneurysm itself, expressed as a percentage. Several studies have shown a correlation between PD and rates of angiographic recurrence, with PD $\geq 25\%$ being associated with low rates of recurrence [11–15]. PD achieved with SAC has been found to be similar to that achieved with BACE or with coiling only [5, 16].

Our hypothesis is that this method is safe and feasible for wide-neck bifurcation aneurysms and achieves PD that are equal to or higher than generally seen with other coiling methods. In addition, this is the largest series of aneurysms treated with the Ascent catheter-facilitated technique.

Methods

An institutional review board-approved retrospective review was performed on aneurysms treated using the single-balloon microcatheter technique at two institutions. Demographic data was collected for all subjects who underwent these procedures including age, gender, vascular risk factors and comorbidities. Angiographic data was collected regarding the location, size and shape of the aneurysms and whether they were ruptured or unruptured. The type and length of coils used for embolizing these aneurysms was also collected. AngioCalc, a freely available online calculator, was applied to measure the aneurysm volumes and PD using geometric modeling. Clinical outcome data points were also studied including complications of the procedure as well as length of hospital stay. Angiographic occlusion results were evaluated and classified according to the Raymond-Roy Scale [17]. The aneurysms were then further divided into two categories: those with volumes $<100 \text{ mm}^3$ and those with volumes ranging between 100 and 600 mm^3 . The mean PD were calculated for the two groups.

Technique

All subjects who underwent elective procedures were pretreated with antiplatelet therapy as per the local protocol. For 5 cases, treatment consisted of 325 mg of aspirin and 75 mg of clopidogrel daily for a minimum of 3 days prior to the procedure, whereas for 1 case, only 325 mg of aspirin daily was used. Two ruptured aneurysms were treated without preoperative antiplatelet drugs. All procedures were performed

Fig. 1. Ascent dual-lumen balloon microcatheter. A: Marker bands for the balloon; B: vent designed for simple and quick preparation while sealing contrast and preventing blood reflux during aspiration; C: marker band 3 cm from the distal tip allows delivery of embolics; D: independent contrast lumen and inflation port; E: central lumen to deliver embolic and therapeutic agents; F: coaxial dual-lumen has a central guide-wire lumen and an outer parallel noncommunicating lumen for contrast.

Color version available online

Fig. 2. A right MCA aneurysm treated using the Ascent single-balloon microcatheter technique.

under general anesthesia. Arterial access was obtained via the femoral artery in 7 of the 8 cases. One embolization of a ruptured basilar tip aneurysm was done transradially due to an occluded abdominal aorta. Systemic heparinization was administered to achieve a target activated clotting time of ≥ 250 s, and a guiding catheter or sheath was positioned in the great vessel giving rise to the aneurysm.

In more distal anterior circulation aneurysms [i.e. middle cerebral artery (MCA) bifurcation], a triaxial system consisting of a guide sheath (Shuttle Sheath; Cook Medical), a 0.044-inch distal access catheter (Concentric Medical) and the Ascent balloon microcatheter was navigated into the desired vessel family (fig. 2). In the posterior circulation, a combination of a 6F Envoy XB guide catheter (Cordis) positioned at the V2/V3 junction and the Ascent balloon was utilized. The aneurysm was then catheterized with the Ascent balloon microcatheter over a 0.014-inch microwire and the microwire removed. A framing coiling was inserted within the Ascent catheter, and the first loop was carefully deployed into the aneurysm. The Ascent balloon was then inflated and the catheter allowed floating forward or 'Swan' into the aneurysm neck. Care was taken to avoid contact between the 3-mm radiolucent catheter tip and the aneurysm wall. Coiling was commenced with the 'temporary waffle cone' of the balloon in place, protecting the parent artery bifurcation at the neck (fig. 3b). Balloon inflation was maintained for a maximum of 5 min. These steps were repeated until it was felt that the maximum PD was achieved.

Table 1. Patients treated with the single-balloon microcatheter technique

Pa-tient	Age, years/ sex	Aneurysm location	Aneurysm status	Pretreatment antiplatelets	Aneurysm shape	Maximum diameter, mm	Neck size, mm	Aspect ratio	Volume, mm ³	PD, %	RROC	Follow-up RROC
1	66/m	MCA bifurcation	Unruptured	Aspirin + clopidogrel	Spherical	6.5	3	2.16	124.79	39.23	1	1
2	47/m	Basilar tip	Unruptured	Aspirin + clopidogrel	Ellipsoid	6	4	1.5	56.5	68.5	1	1
3	76/f	MCA bifurcation	Unruptured	Aspirin	Ellipsoid	11	3	3.67	506	18.18	1	1
4	48/m	Basilar tip	Ruptured	None	Bilobed	8.5	4	2.125	301.5	24.3	1	NA
5	77/f	MCA bifurcation	Unruptured	Aspirin + clopidogrel	Ellipsoid	7	3.5	2	91.6	62.08	1	NA
6	57/f	Basilar tip	Unruptured	Aspirin + clopidogrel	Spherical	5.2	3.5	1.48	97	33.3	1	NA
7	47/f	MCA bifurcation	Unruptured	Aspirin + clopidogrel	Spherical	5.0	3.5	1.42	65	49.3	1	NA
8	48/m	Basilar tip	Ruptured	None	Ellipsoid	11	5	2.2	200.7	39.5	2*	NA

* Residual neck left deliberately in order to protect the posterior cerebral artery.

Fig. 3. Diagrammatic illustration of the single-balloon microcatheter technique (a) and the conventional BACE technique (b) employing two microcatheters.

Results

A total of 8 aneurysms in 7 subjects were embolized using the single-balloon microcatheter technique at two institutions (table 1). Six of these aneurysms were unruptured and 2 were ruptured. Four of the 7 patients were male. Four aneurysms were located at the MCA bifurcation, whereas the remaining 4 were basilar tip aneurysms. These were all wide-neck aneurysms with an average neck diameter of 3.7 mm and the maximum dimension ranging from 5 to 11 mm, with a mean of 7.5 mm. The mean aspect ratio (maximum width of dome/width of neck) was 2.07. The mean volume of the aneurysms treated with this method was 180.38 mm³. The average PD achieved was 41.79%.

Complete occlusion [Raymond-Roy Occlusion Class (RROC) 1] was achieved in 7 cases. In the eighth case, a small residual neck was left deliberately to protect the posterior cerebral artery, and the occlusion grade achieved was RROC 2. There were no intra- or perioperative complications. In smaller aneurysms with volumes <100 mm³, the average PD in our study

Table 2. PD achieved with the single-balloon microcatheter technique

Aneurysm volume, mm ³	Mean PD [14]	Mean PD with the Ascent balloon as a temporary waffle cone
<100	26.5%	53.29%
100–600	20.6%	30.3%

was 53.3%, whereas in larger aneurysms with volumes ranging between 100 and 600 mm³, the average PD was 30.3% (table 2). Six-month follow-up angiographic data was available for 3 of the 8 cases. In all 3 cases, the aneurysms were completely occluded at follow-up, and no retreatment was required.

Discussion

Our study describes our experience with the dual-lumen coaxial Ascent balloon catheter as a stand-alone device to perform coil embolization of wide-neck bifurcation aneurysms. It is the largest case series describing this Ascent catheter-facilitated technique and the first study to demonstrate the high PD associated with its use.

The standard BACE technique requires the navigation of two or three devices [18] into the intracranial circulation (fig. 3a). The increased luminal obstruction within the guide catheter and intracranial vessels as well as the longer working times required may be associated with an increased risk of thromboembolic complications [19].

SAC requires a minimum of 6 weeks of postprocedural dual antiplatelet agent use, two separate intracranial catheterizations and the sometimes challenging navigation of a stent through tortuous intracranial circulation [20]. In addition, bifurcation aneurysms often require multiple stents deployed in complex configurations to adequately protect branch vessels. These technical complexities add risk over unassisted coiling. The elevated risks include thromboembolism, intracranial hemorrhage, in-stent stenosis, permanent neurologic deficits, vessel injury and higher mortality [5–7].

The ‘waffle cone technique’, first described by Horowitz et al. [4] in 2006, is a unique approach to treating wide-neck aneurysms. It involves the deployment of a stent within the neck of the aneurysm. A microcatheter is then navigated through the lumen of the stent into the aneurysm with the subsequent deployment of coils. The flared end of the stent serves to keep the coil mass away from the parent and branch vessels. While this technique is theoretically appealing, it retains many of the technical complexities outlined above and is potentially associated with a similar elevation of risk.

In addition to these elevated risks, there is a significant additional cost associated with the use of SAC [21]. The cost of an intracranial stent is approximately USD 5,200 for the Enterprise (Codman Neurovascular) and USD 5,315 for the Neuroform (Stryker, Kalamazoo, Mich., USA) [21]. In comparison, the list price of the Ascent balloon (Codman Neurovascular) as obtained from their regional sales office is USD 1,607, which is a fraction of the cost of an intracranial stent.

A strong inverse correlation has been found between PD and the rates of aneurysm recurrence [11–14]. Leng et al. [15] found a significantly higher risk of aneurysm recurrence with PD <20%. A PD of ≥25% [8] in aneurysms with a volume <600 mm³ has been associated with low rates of compaction at 6 months of the angiographic follow-up.

In the study by Sluzewski et al. [14], the mean PD in aneurysms ranging from 100 to 600 mm³ was found to be 20.6%. In comparison, the mean PD achieved in our series for aneurysms of a similar volume was 30.3%. For aneurysms with volumes <100 mm³, the

mean PD in their study was 26.5%, whereas in our cohort, it was 53.29% (table 2). In a large retrospective analysis [5], the PD achieved with BACE, conventional coiling and SAC was found to be similar at 28, 29 and 27%, respectively. A recent meta-analysis found the mean PD with SAC (27.4%) to be no different than in the coiling-only group (28.2%) [16]. Although our cohort is small, it shows that the single-balloon microcatheter technique can be used in wide-neck bifurcation aneurysms to achieve a PD similar or greater than that achieved with SAC.

The Scepter balloon microcatheter (MicroVention, Tustin, Calif., USA) has been used in a similar manner to that described in our series [22]. However, the Scepter catheter is not currently designed or FDA approved for coil embolization. It lacks a proximal marker band to facilitate safe coil detachment. The Ascent balloon microcatheter has a radiopaque proximal marker band 3 cm from the tip (fig. 1) that can be used to align the coil detachment zone and ensure the coil is fully deployed prior to detachment.

Single case reports of the Ascent catheter-facilitated ‘temporary waffle cone’ technique have been reported previously [8–10]. The current case series adds evidence that this technique is safe and feasible. A potential advantage of a single dual-lumen balloon microcatheter is a reduction in thromboembolic events due to less luminal obstruction and shorter working times. Indeed, no such events were noted in our series. Finally, the technique reduces the high equipment-related cost incurred with SAC and may reduce the need of retreatment given the high initial PD.

There are some limitations to this technique. It can only be used in aneurysms that are large enough to accommodate the microcatheter tip, which extends 3 mm from the distal balloon marker. The tip of the microcatheter is radiolucent and could lead to an intraprocedural rupture. In addition, the current generation of the Ascent catheter is stiffer than and not as navigable as single-lumen coiling catheters [22]. This limitation may be overcome to some extent through the use of a triaxial system as described above.

The limitations of the study itself include the low number of study subjects and the lack of long-term angiographic follow-up in all cases. Our method of volume estimation of the aneurysms is done with the AngioCalc software that uses geometric modeling, which may not be as accurate a method as angiographic mathematical modeling [23].

In conclusion, our case series adds to the growing evidence that the ‘temporary waffle cone’ technique is safe and feasible when embolizing wide-neck bifurcation aneurysms. It is the first study to demonstrate the excellent PD obtained using this technique and holds the potential to reduce cost and thromboembolic complications.

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Disclosure Statement

None of the authors have any pertinent disclosures for this paper.

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