Comparison of flow diversion with clipping and coiling for the treatment of paraclinoid aneurysms in 115 patients

Michael A. Silva, BA,¹ Alfred P. See, MD,¹ Priyank Khandelwal, MD,² Ashutosh Mahapatra, MD,² Kai U. Frerichs, MD,¹ Rose Du, MD, PhD,¹ Nirav J. Patel, MD,¹ and Mohammad A. Aziz-Sultan, MD¹

¹Department of Neurosurgery, Brigham and Women's Hospital, Boston, Massachusetts; and ²Department of Neurology, University of Miami/Jackson Health System, Miami, Florida

OBJECTIVE Paraclinoid aneurysms represent approximately 5% of intracranial aneurysms (Drake et al. [1968]). Visual impairment, which occurs in 16%–40% of patients, is among the most common presentations of these aneurysms (Day [1990], Lai and Morgan [2013], Sahlein et al. [2015], and Silva et al. [2017]). Flow-diverting stents, such as the Pipeline Embolization Device (PED), are increasingly used to treat these aneurysms, in part because of their theoretical reduction of mass effect (Fiorella et al. [2009]). Limited data on paraclinoid aneurysms treated with a PED exist, and few studies have compared outcomes of patients after PED placement with those of patients after clipping or coiling.

METHODS The authors performed a retrospective analysis of 115 patients with an aneurysm of the cavernous to ophthalmic segments of the internal carotid artery treated with clipping, coiling, or PED deployment between January 2011 and March 2017. Postoperative complications were defined as new neurological deficit, aneurysm rupture, recanalization, or other any operative complication that required reintervention.

RESULTS A total of 125 paraclinoid aneurysms in 115 patients were treated, including 70 with PED placement, 23 with coiling, and 32 with clipping. Eighteen (14%) aneurysms were ruptured. The mean aneurysm size was 8.2 mm, and the mean follow-up duration was 18.4 months. Most aneurysms were discovered incidentally, but visual impairment, which occurred in 21 (18%) patients, was the most common presenting symptom. Among these patients, 15 (71%) experienced improvement in their visual symptoms after treatment, including 14 (93%) of these 15 patients who were treated with PED deployment. Complete angiographic occlusion was achieved in 89% of the patients. Complications were seen in 17 (15%) patients, including 10 (16%) after PED placement, 2 (9%) after coiling, and 5 (17%) after clipping. Patients with incomplete aneurysm occlusion had a higher rate of procedural complications than those with complete occlusion ($p = 0.02$). The rate of postoperative visual improvement was significantly higher among patients treated with PED deployment than in those treated with coiling ($p = 0.01$). The significant predictors of procedural complications were incomplete occlusion ($p = 0.03$), hypertension, ($p = 0.04$), and diabetes ($p = 0.03$).

CONCLUSIONS In a large series in which patient outcomes after treatment of paraclinoid aneurysms were compared, the authors found a high rate of aneurysm occlusion and a comparable rate of procedural complications among patients treated with PED placement compared with the rates among those who underwent clipping or coiling. For patients who presented with visual symptoms, those treated with PED placement had the highest rate of visual improvement. The results of this study suggest that the PED is an effective and safe modality for treating paraclinoid aneurysms, especially for patients who present with visual symptoms.

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KEYWORDS paraclinoid aneurysms; flow diversion; Pipeline Embolization Device; vision; endovascular; vascular disorders

PARACLINOID aneurysms are a significant cause of morbidity and death and represent 5% of intracranial aneurysms.¹⁴ These aneurysms can be defined as those that affect the region between the cavernous segment of the internal carotid artery (ICA) and the origin of the posterior communicating artery. Although most paracli-

noid aneurysms are detected incidentally, they often cause visual symptoms or other cranial nerve palsies because of their proximity to the ophthalmic artery and optic, oculomotor, trochlear, and abducens nerves.

Paraclinoid aneurysms have been treated traditionally with clipping, but endovascular treatment has supplanted

ABBREVIATIONS FET = Fisher exact test; ICA = internal carotid artery; PED = Pipeline Embolization Device.

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surgical treatment in recent years.²³ In addition to coiling, flow diversion, such as that with the Pipeline Embolization Device (PED), is a newer alternative. The PED is an endoluminal intracranial stent that relies on the principle of flow diversion to stagnate intrasaccular blood flow and promote thrombus formation and thus to exclude the aneurysm sac.¹⁶ The PED is currently approved for the treatment of large (> 10-mm) and giant (> 25-mm) wide-necked aneurysms (neck > 4 mm) from the petrous to hypophyseal segments of the ICA (see https://www.accessdata.fda.gov/cdrh_docs/pdf10/P100018B.pdf), and high rates of occlusion and low rates of complications with its use in patients with such aneurysms have been found.^{4,6,24,37,40,46}

Although these early data on the PED are promising, most PED studies have focused on large and wide-necked aneurysms despite increasing off-label use. The existing literature on paraclinoid aneurysms treated with a PED has been limited and consists mostly of small studies or heterogeneous multicenter data. Few studies have reported specifically on vision outcomes, and very few studies have compared PED placement directly to clipping and coiling.^{26,30} Given the increasing use of PEDs to treat paraclinoid aneurysms, we performed a retrospective analysis of 115 patients (with a total of 125 paraclinoid aneurysms) treated with PED placement, clipping, or coiling. This 2-site study is one of the largest to have directly compared flow diversion to clipping and coiling in a population of patients with such an aneurysm.

Methods

A retrospective analysis of 115 patients with a paraclinoid aneurysm treated with clipping, coiling, or PED placement between January 2011 and March 2017 was performed. Aneurysms that affected the cavernous to ophthalmic segments of the ICA were included. The patients were treated by 1 of 3 interventionists; all patients who underwent PED deployment were treated by the same interventionist. All the patients were treated at the same institution except for 28 patients who underwent PED placement at a second institution. Institutional review board approval for the study was obtained through the Partners Human Research Committee.

Procedural Details

Patients who underwent PED deployment were given preoperative medication with aspirin (325 mg daily) and clopidogrel (75 mg daily), placed on at least 6 months of postoperative dual-antiplatelet therapy, and then prescribed aspirin (325 mg) daily indefinitely after interval angiographic confirmation of stent patency. Neither the responsiveness nor the resistance of aspirin and clopidogrel was tested in the absence of thromboembolic symptoms. Endovascular procedures (PED placement or coiling) were performed after the induction of general anesthesia.

Outcomes and Follow-Up

Complete aneurysm occlusion was determined based on postoperative angiography. Follow-up angiography was performed in most patients 6 months after the procedure and annually thereafter until follow-up imaging was dis-

continued. We categorized treatment response as incomplete (Raymond-Roy class II/III)³⁴ or complete (Raymond-Roy class I) instead of using a more typical Raymond-Roy/Montreal classification due to our evolving understanding of the treatment mechanism in flow diverters, which is not described as well using the coiling treatment response scale. Postoperative complications were defined as aneurysm rupture, death, ischemic stroke in the immediate postoperative period, or new neurological deficit (transient or permanent), including visual impairment. Visual symptoms were defined as field cuts, blindness, scotoma, amaurosis fugax, decreased acuity, or other deficits thought to have resulted from optic nerve impairment. Diplopia and ophthalmoplegia were classified separately as nonvisual neurological deficits. Patients who presented with or developed new visual symptoms underwent neuroophthalmological assessment when possible.

Statistical Analysis

All statistical analyses were performed in R 3.0 (R Project for Statistical Computing). Comparison between intervention groups was performed using the Fisher exact test (FET) for categorical variables and ANOVA for continuous variables. Bonferroni correction was used for pairwise comparison between treatment groups using the FET, and adjusted p values were calculated accordingly. Multivariate logistic regression was performed to assess for predictors of aneurysm occlusion or postoperative complications using a p value of 0.05. Subgroup analyses using multivariate logistic regression were also performed.

Results

Patient Characteristics

Between January 2011 and March 2017, 125 aneurysms were treated with clipping, coiling, or PED placement at 1 of 2 institutions by 1 of 3 surgeons. A total of 115 patients (104 female, 11 male) with a paraclinoid aneurysm were treated. Patient characteristics are summarized in Table 1. The patients were predominantly female (90%) with a mean age of 54.5 years (SD 12.1 years). Sixty-two patients with a total of 70 aneurysms underwent treatment with a PED, 23 patients with a total of 23 aneurysms were treated with coiling, and 30 patients with a total of 32 aneurysms were treated with microsurgical clipping. Two patients underwent 2 separate PED deployments for distinct paraclinoid aneurysms. Eight patients with more than 1 paraclinoid aneurysm were treated with a single procedure. We found no statistically significant differences between the patient cohorts treated with any of these interventions.

Aneurysm Characteristics

One hundred twenty-five aneurysms were treated in total, 70 with PED placement, 23 with coiling, and 32 with clipping. Four patients treated with a PED were treated concurrently with coils. Six coiling procedures were stent assisted. Eighteen (14%) were ruptured at the time of presentation. Aneurysms in most patients (55 [48%]) were detected incidentally. Twenty-three (20%) patients presented with subarachnoid hemorrhage, including from another aneurysm(s), 13 (11%) presented with isolated vi-

TABLE 1. Patient and aneurysm characteristics

Characteristic	Total	PED	Coil	Clip	PED vs Coil (adjusted p value)	PED vs Clip (adjusted p value)	Coil vs Clip (adjusted p value)	p Value	
								FET	ANOVA
Patients	115	62	23	30					
Procedures	117	64	23	30					
Sex									
Male	11 (10)	6 (10)	2 (9)	3 (10)	>0.99	>0.99	>0.99	>0.99	
Female	104 (90)	56 (90)	21 (91)	27 (90)					
Age in yrs (mean [SD])	54.5 (12.1)	55.3 (12)	55.6 (10.8)	52 (13.3)					0.4
Comorbidities									
Diabetes	10 (9)	4 (6)	4 (17)	2 (7)	0.2 (0.6)	>0.99	0.4 (0.6)	0.4	
Smoking	59 (51)	26 (42)	13 (57)	20 (67)	0.3 (0.5)		0.6 (0.6)	0.08	
Hypertension	47 (41)	29 (47)	8 (35)	10 (33)	0.5 (0.7)	0.3 (0.7)	>0.99	0.3	
Anticoagulation	4 (3)	1 (2)	1 (4)	2 (7)	0.5 (0.7)	0.2 (0.7)	>0.99	0.9	
Family history*	23 (26)	12 (35)	4 (17)	7 (23)	0.2 (0.6)	0.4 (0.6)	0.7 (0.7)	0.1	
Aneurysms	125	70	23	32					
Presentation					0.2 (0.3)	0.09 (0.3)	0.3 (0.3)	0.06	
Incidental	55 (48)	25 (39)	10 (43)	20 (67)					
SAH	23 (20)	9 (14)	8 (35)	6 (20)					
Visual changes	13 (11)	11 (17)	1 (4)	1 (3)				0.2	
Diplopia	12 (10)	8 (13)	1 (4)	3 (10)					
Other cranial nerve palsy	4 (3)	3 (5)	1 (4)	0 (0)					
Ischemic stroke	2 (2)	1 (2)	1 (4)	0 (0)					
Other	6 (5)	5 (8)	1 (4)	0 (0)					
Location					0.4 (0.4)	0.0001† (0.0004†)	0.002† (0.003†)	0.0003†	
Ophthalmic	42 (34)	18 (26)	6 (26)	18 (56)					
Superior hypophyseal	42 (34)	24 (34)	12 (52)	6 (18.8)					
Cavernous	19 (15)	17 (24)	2 (9)	0 (0)					
Dorsal variant	14 (11)	5 (7)	2 (9)	7 (22)					
Other paraclinoid	8 (6)	6 (9)	1 (4)	1 (3)					
Side					0.8 (0.8)	0.4 (0.8)	0.8 (0.8)	0.8	
Right	54 (43)	32 (46)	10 (43)	12 (38)					
Left	71 (57)	38 (54)	13 (57)	20 (63)					
Size in mm (mean [SD])	8.2 (5.7)	8.4 (5.8)	9.7 (5.5)	6.5 (5.2)					
Small (<15)	110 (88)	61 (87)	19 (83)	30 (94)					
Large (15 to <25)	11 (9)	7 (10)	3 (13)	1 (3)	0.6 (0.6)	0.6 (0.6)	0.4 (0.6)	0.7	
Giant (≥25)	4 (3)	2 (3)	1 (4)	1 (3)					
Aneurysms ≤10 mm	99 (79)	54 (77)	16 (70)	29 (91)	0.6 (0.6)	0.2 (0.3)	0.08 (0.2)	0.1	
Aneurysms >10 mm	26 (21)	16 (23)	7 (30)	3 (9)					

SAH = subarachnoid hemorrhage.

Values are presented as the number (%) unless stated otherwise. Not all percentage totals reach 100% because of rounding.

* The family history status was unknown for 28 patients treated with PED placement.

† Significant result.

sual symptoms, 12 (10%) with diplopia, 4 (3%) with other cranial nerve palsies, 2 (2%) with stroke, and 6 (5%) presented with other symptoms. We observed no statistically significant differences in presentation between treatment groups (Table 1).

Fifty-four (43%) aneurysms were right sided, and 69 (55%) were left sided; we found no significant difference

between the groups ($p = 0.8$). Forty-two (34%) aneurysms were of the ophthalmic segment, 42 (34%) were of the hypophyseal segment, 19 (15%) were cavernous, 14 (11%) were dorsal variants, and 8 (6%) were other paraclinoid variants (Fig. 1). Ophthalmic segment aneurysms were treated most often with clipping, superior hypophyseal aneurysms with coiling, and cavernous aneurysms with PED

FIG. 1. Number of aneurysms according to location treated with clipping, coiling, or PED. Figure is available in color online only.

placement (combined $p = 0.0003$) (Table 1). The mean aneurysm size was 8.2 mm (SD 5.7 mm) (8.4 mm in the PED group, 9.7 mm in the coiling group, and 6.5 mm in the clipping group; $p = 0.1$) (Fig. 2). One hundred ten aneurysms were small (< 15 mm), 11 were large (15 to < 25 mm), and 4 were giant (≥ 25 mm). Twenty-six (21%) aneurysms were > 10 mm, including 16 (22.9%) that were treated with a PED. Aneurysm characteristics are summarized in Table 1.

Angiographic Occlusion

Complete angiographic occlusion at the last follow-up visit was observed in 89% of the aneurysms, including 89% of those after PED treatment, 78% after coiling, and 97% after clipping (Table 2). PED deployment resulted in a higher rate of occlusion than did coiling ($p = 0.4$), and clipping yielded a higher rate of occlusion than did coiling ($p = 0.2$), but neither result was statistically significant.

Complications

Seventeen (15%) complications occurred, including 10 (16%) in patients after PED placement, 2 (9%) in those after coiling, and 5 (17%) in those after clipping (Table 2). We found no significant differences between treatment groups. Serious complications, including rupture, immediate postoperative stroke, and permanent neurological defi-

cit, were seen in 12 (10%) patients, including 6 (9%) after PED deployment, 1 (4%) after coiling, and 5 (17%) after clipping, with no significant difference between groups ($p = 0.4$) (Table 2). Delayed postoperative rupture occurred in 1 patient after treatment with a PED. New neurological deficits were observed in 13 patients (8 permanent and 5 transient deficits). New visual symptoms were found in 8 patients (4 permanent and 4 transient symptoms). No deaths from procedural complications occurred. Univariate analysis of complications identified only complete occlusion as an associated independent variable. Patients with complete aneurysm occlusion had a significantly lower rate of complications (11.5%) than those with incomplete occlusion (38.5%) ($p = 0.02$) (Supplementary Table 1). We found no association between aneurysm size (> 10 or ≤ 10 mm) and the rate of complete occlusion or procedural complications (Supplementary Table 2).

Vision Outcomes

Twenty-one patients presented with visual symptoms; their outcomes are listed in Table 3. Fifteen patients were treated with PED placement (3 of which included the addition of coils), 3 with coiling (1 stent assisted), and 3 with clipping. Postoperative vision was improved in 15 (71%) patients, including 14 (93%) of 15 patients treated with a PED. The rate of postoperative visual improvement was significantly higher among patients treated with PED placement than among those treated with coiling ($p = 0.01$) (Table 3). New visual symptoms were seen in 7 (6%) patients (3 after PED deployment, 1 after coiling, and 3 after clipping), and we found no significant difference between the groups ($p = 0.6$). In 4 of these patients, symptoms were transient; in the other 3, symptoms were persistent at the last follow-up visit (Table 3).

Multivariate Regression Analysis

Multivariate regression analysis including all patient and aneurysm characteristics listed in Table 1 as independent variables revealed hypertension ($p = 0.04$) and incomplete occlusion ($p = 0.03$) as predictors of procedural complications; diabetes was shown to be protective ($p = 0.03$). Ophthalmic location was a predictor of permanent complications ($p = 0.05$). An analysis of subgroups based on size or location of the aneurysms did not reveal any significant associations.

Discussion

To the best of our knowledge, this study is the largest to date to have directly compared PED deployment to coiling and clipping for the treatment of paraclinoid aneurysms. Our cohort included 70 aneurysms treated with a PED by 1 interventionist, which makes it one of the largest and most homogeneous series of patients who have undergone PED placement to date. Complications associated with treating paraclinoid aneurysms, including recanalization, intraoperative or delayed rupture, neurological decline, and incomplete occlusion, that occur after PED placement, clipping, and coiling have been well described.^{3,5,7,9,27,31,35} For the patients who underwent PED placement, we found a high rate of complete angiographic occlusion (89%), a rate

FIG. 2. Boxplot of aneurysm sizes in the PED, coiling, and clipping groups. Most aneurysms were small and were distributed similarly among treatment modalities. Figure is available in color online only.

of permanent procedural complications (9%) comparable to those after coiling and clipping, no procedure-related deaths, and a significantly higher rate of visual improvement (93%) after treatment, which suggests that PED deployment is an effective alternative to traditional treatment modalities.

Previous studies focused on the treatment of large and

giant wide-necked aneurysms between the petrous and cavernous segments of the ICA, for which the PED was approved originally.^{4,6,24,37,40,46} These promising results led to increasing off-label use of the PED for aneurysms that are not large and not wide necked, and several groups have found similarly strong results after treating small aneurysms^{11,17,26} and other off-label applications.^{2,10,13,28,32,36}

TABLE 2. Comparative outcomes

Outcome	Total	PED	Coil	Clip	PED vs Coil (adjusted p value)	PED vs Clip (adjusted p value)	Coil vs Clip (adjusted p value)	p Value	
								FET	ANOVA
Procedures	117	64	23	30					
FU duration in mos (mean)	18.4	9.6	23.7	22.5	0.01*	0.02*	0.8		0.01*
Complete occlusion	104 (89)	57 (89)	18 (78)	29 (97)	0.3 (0.4)	0.4 (0.4)	0.07 (0.2)	0.1	
Complications	17 (15)	10 (16)	2 (9)	5 (17)	0.5 (1.0)	1.0 (1.0)	0.7 (1.0)	0.8	
Rupture	1 (1)	1 (2)	0 (0)	0 (0)					
Stroke	3 (3)	2 (3)	0 (0)	1 (3)					
New neurologic deficit									
Permanent, nonvisual	4 (3)	2 (3)	1 (4)	1 (3)					
Permanent, visual Sxs	4 (3)	1 (2)	0 (0)	3 (10)					
Transient, nonvisual	1 (1)	1 (2)	0 (0)	0 (0)					
Transient, visual Sxs	4 (3)	3 (5)	1 (4)	0 (0)					
Permanent complications	12 (10)	6 (9)	1 (4)	5 (17)	0.7 (0.7)	0.3 (0.5)	0.2 (0.5)	0.400	
Visual complications	8 (7)	4 (6)	1 (4)	3 (10)	1.0 (1.0)	0.7 (1.0)	0.6 (1.0)	0.8	

FU = follow-up; Sxs = symptoms.

Values are presented as the number (%) unless stated otherwise.

* Significant result.

TABLE 3. Vision outcomes

Outcome	Total	PED	Coil	Clip	PED vs Coil (adjusted p value)	PED vs Clip (adjusted p value)	Coil vs Clip (adjusted p value)	p Value (FET)
Preop visual Sxs (patients)	21	15	3	3	0.4 (0.6)	0.2 (0.5)	>0.99	0.8
Postop vision					0.02* (0.07)	0.2 (0.3)	>0.99	0.02*
Improved	15 (71)	14 (93)	0 (0)	1 (33)	0.005* (0.01*)	0.06 (0.09)	>0.99	0.002*
Unchanged	2 (10)	1 (7)	1 (33)	0	0.3 (0.9)	>0.99	>0.99	0.500
Declined	2 (10)	0 (0)	1 (33)	1 (33)	0.2 (0.3)	0.2 (0.3)	>0.99	0.07
Deceased/lost to FU	2 (10)	0 (0)	1 (33)	1 (33)				
New postop visual Sxs					>0.99	0.4 (0.9)	0.6 (0.9)	0.6
Permanent	3 (3)	0 (0)	0 (0)	3 (10)				
Transient	4 (3)	3 (5)	1 (4)	0 (0)				

Values are number (%) unless stated otherwise.

* Significant result.

Still, the number of studies on use of the PED to treat small aneurysms has been limited, and very few have directly compared patient outcomes with those of patients after coiling or clipping.³⁰

The mean aneurysm size in this study was 8.2 mm, which is smaller than the minimum size (10 mm) for which the PED is approved. In fact, only 17 of the 70 aneurysms treated with a PED (24%) were larger than 10 mm. Our promising findings suggest that off-label use of the PED for small aneurysms might be as effective as has been demonstrated for large and giant wide-necked aneurysms. Important to note is that outcomes were similarly promising when compared to those of coiling and clipping. In our series, only 1 aneurysm smaller than 5 mm was coiled. This decision was guided by the interventionist's experience, who had found that small aneurysms are particularly difficult to coil adequately.^{22,33,38,39,43,45}

Even fewer groups have studied off-label use of the PED for paraclinoid aneurysms. Burrows et al.⁸ and Griesenauer et al.^{18,19} recently reported that PED deployment might be as efficacious for smaller paraclinoid aneurysms as it is for the large wide-necked aneurysms for which the device is approved. Our results corroborate the findings of these studies and also provide data from a direct comparison of PED placement to coiling and clipping among patients treated over a 6-year period. In 1 of the few other comparative studies, Kim et al.²⁶ reported the treatment of 24 paraclinoid aneurysms with PED placement, 24 with clipping, and 41 with stent-assisted coiling. Treatment with a PED resulted in complete aneurysm occlusion in 81% of the patients, and they found a 13% rate of posttreatment cranial nerve palsy, compared to a 0% rate after coiling and a 29% rate after clipping.²⁶ We found similar rates of occlusion and complications in our study.

Paraclinoid aneurysms are in close proximity to the ophthalmic artery, optic nerve, and other cranial nerves; thus, visual deficits are among the most common complications after treatment of these aneurysms.^{15,21,23} It has been hypothesized that physical compression of the optic nerve by the aneurysm sac and thrombosis can play a role in the high rate of visual symptoms observed in patients with such an aneurysm, and this mass effect also might explain other cranial nerve palsies.^{1,15,16,20,25,41,44} The PED is thought

to provide the added benefit of diminishing mass effect of the aneurysm sac,¹⁶ which might prove beneficial for aneurysms in patients who present with symptoms secondary to mass effect. Thus, paraclinoid aneurysms are particularly well suited to capitalize on the proposed mechanistic benefits of the PED over those of other treatment modalities.

As many as 40% of patients with a paraclinoid aneurysm present with visual symptoms, which can include field defects, decreased acuity, and blindness.^{12,29,41} Our recently published meta-analysis revealed a 38% rate of visual symptoms among these patients.⁴² PED placement might specifically improve visual outcomes when used to treat paraclinoid aneurysms, according to the results of our meta-analysis, in which we found a high rate of visual improvement (71%) among patients treated with a PED and similarly low rates of visual complications compared to those after clipping and coiling.⁴² Among the 14% of patients in this series who presented with visual symptoms, we found a significantly higher rate of vision improvement among those treated with PED deployment than among those treated with coiling or clipping. Although symptomatic visual improvement is just 1 factor to be considered when choosing a treatment modality, the findings of our study suggest that PED use might be particularly beneficial for patients with a paraclinoid aneurysm who present with visual symptoms.

There are several limitations of this study. Use of the PED has increased in frequency and has largely supplanted coiling or clipping for paraclinoid aneurysms, and others, since its introduction. As a result, we often had specific reasons for which coiling or clipping was used instead of PED placement to treat paraclinoid aneurysms, especially in the later years of this study, which is a potential source of selection bias and is especially true for patients who presented with symptoms. The predominance in recent years of PED use for patients with a paraclinoid aneurysm resulted in fewer patients with visual symptoms being treated with coiling or clipping.

Similarly, the increased use of PED deployment in recent years could have introduced selection bias to the population of paraclinoid aneurysms treated with clipping or coiling. For example, the higher frequency of ophthalmic aneurysms in the clipping cohort represents a possible

source of selection bias. Given the location of these aneurysms, they might be expected to have a greater effect on vision than other paraclinoid aneurysms, which might explain the differences in visual outcomes observed between the groups. The higher proportion of ophthalmic aneurysms among the patients who underwent clipping could also explain the higher rate of complications seen in the clipping cohort. Important to note is that the rates of complications seen after PED placement (16%), coiling (9%), and clipping (17%) are comparable to those reported from previous studies.^{17,21,26} Other studies have found similar selection bias as a result of the evolving usage of PEDs.²⁶

Other trends in our cohort could be sources of confounding. Aneurysms treated with clipping were generally smaller than those treated with coiling or PED placement, although this result was not statistically significant. Moreover, we found a statistically significant difference in aneurysm locations among the treatment modalities ($p = 0.0003$). Cavernous aneurysms were treated most often with PED deployment, superior hypophyseal aneurysms with coiling, and ophthalmic aneurysms with clipping. This unequal distribution might play a confounding role in explaining the outcomes we observed in the patients after treatment with a PED, coiling, or clipping.

The limited availability of clipping and coiling data from 1 institution contributed to the greater number of PED deployments than of clipping and coiling in the combined cohort. The fact that fewer patients were treated with clipping and coiling than with a PED, especially when many patients at lower risk were treated with PED placement in recent years, might have biased the conclusions that can be drawn from comparison of the 3 treatment modalities. The distribution of PED placements, clipping, and coiling procedures in this study does not necessarily reflect the treatment practices or patterns of modality usage at our institution at any specific time point; the decision-making algorithm for treating paraclinoid aneurysms has evolved with the increasing usage of PEDs and will continue to evolve as new technology and data become available.

Conclusions

Flow diversion is a safe and effective option for the treatment of paraclinoid aneurysms. In this study, we found a high rate of aneurysm occlusion and a low rate of complications for patients with paraclinoid aneurysms who were treated with PED placement, coiling, or clipping, regardless of aneurysm size. Flow diversion was associated with improved vision outcomes in patients compared to the outcomes in those who underwent coiling or clipping, and it might be beneficial for patients who present with visual symptoms. This study of a large series of patients with a paraclinoid aneurysm is one of the few to have compared PED deployment to traditional treatment modalities, and our results provide further evidence to support the increasing application of flow diversion.

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Disclosures

Dr. Aziz-Sultan is a proctor for Medtronic and Covidien and participates in the training of other physicians in the use of the PED.

Author Contributions

Conception and design: See, Silva, Khandelwal, Frerichs, Du, Patel, Aziz-Sultan. Acquisition of data: all authors. Analysis and interpretation of data: See, Silva, Khandelwal, Aziz-Sultan. Drafting the article: Silva. Critically revising the article: See, Silva, Mahapatra, Aziz-Sultan. Reviewed submitted version of manuscript: See, Silva, Aziz-Sultan. Approved the final version of the manuscript on behalf of all authors: See. Statistical analysis: See, Silva. Study supervision: Frerichs, Du, Patel, Aziz-Sultan.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

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Correspondence

Alfred P. See: Brigham and Women's Hospital, Harvard Medical School, Boston, MA. psee@partners.org.