Effect of Carotid Siphon Anatomy on Aneurysm Occlusion after Flow Diversion for Treatment of Internal Carotid Artery Aneurysms

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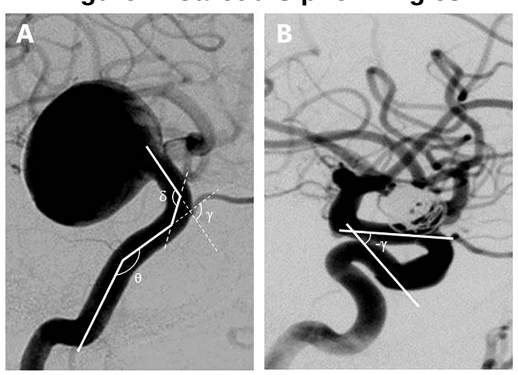
Introduction

Flow diversion (FD) is effective for treatment of intracranial internal carotid artery (ICA) aneurysms. We aimed to determine whether carotid siphon (CS) geometry influences the efficacy of FD when employed for ICA aneurysms.

Methods

Outcomes of a consecutive series of patients with ICA aneurysms treated with FD were retrospectively reviewed. CS anatomy was quantified through measurement of the posterior, anterior, and anterosuperior bend angles in accordance with previously described methodology. The relationship of CS geometry to likelihood of incomplete aneurysm occlusion at one year after treatment was assessed with multivariate logistic regression analysis.

Figure 1. Carotid Siphon Angles



Results

There were 167 ICA aneurysms in 164 patients treated with FD during the study period. The mean age of our cohort was 55.7 years [Standard Deviation (SD): 12.3] and a majority of patients were female (145/164, 86.8%). Anterior (47.4 degrees vs 8.5, $p < 0.001$) and anterosuperior bend angles (100.9 vs 76.5, $p = 0.002$) were significantly greater in aneurysms that required repeat FD after initial treatment. On multivariate logistic regression analysis, increasing patient age (Unit OR: 1.05, 95% CI 1.01-1.08; $p = 0.003$) and anterior bend angle =-3.5 (OR: 2.47, 95% CI 1.04-5.86; $p = 0.046$) were associated with increased odds of incomplete aneurysm occlusion at one year after treatment.

Table 1. Patient Characteristics

TABLE 1. Patient characteristics and treatment outcomes

Variable	Value
No. Patients	164
No. Aneurysms	167
Age, Mean (SD)	55.6 (12.4)
Range	(23-81)
Female, n (%)	142 (86.6)
Aneurysm Location	
Cavernous	40 (23.9)
Paraclinoid	107 (64.1)
Posterior Communicating	17 (10.2)
ICA Terminus	3 (1.8)
Previously Ruptured Aneurysm	20 (12.0)
Aneurysm Size	12.6 (8.3)
Range	(1.8-50.0)
Aneurysm Morphology	
Saccular	158 (94.6)
Blister	5 (3.0)
Fusiform	4 (2.4)
Previously Coiled	34 (21.1)
Posterior Bend Angle	70.6 (33.8)
Range	(2.8-154.6)
Anterior Bend Angle	10.1 (29.4)
Range	(-60.5-94.3)
Anterosuperior Bend Angle	77.8 (20.8)
Range	(35.7-146.3)
Unable to Deploy	7 (4.5)
Intraprocedural Angioplasty	12 (7.8)
>1 Device Required	41 (27.7)
Repeat Flow Diversion	7 (5.0)
ICA Occlusion	7 (4.7)
Complete Occlusion at 1 year	92 (66.2)

Table 2. Predictors of Procedural Complications

TABLE 2. Relationship of carotid siphon geometry to incidence of complications*

	Anterior Bend (mean, SD)	Posterior Bend	Anterosuperior Bend
Unable to Deploy			
Yes	1.9 (24.8)	78.2 (29.5)	74.9 (21.9)
No	10.5 (29.6)	70.3 (34.0)	77.9 (20.8)
P-value	0.487	0.582	0.734
Intraprocedural Angioplasty			
Yes	14.1 (23.5)	64.8 (28.1)	87.1 (13.7)
No	9.8 (30.3)	70.6 (34.5)	76.9 (21.3)
P-value	0.652	0.586	0.119
>1 Device Required			
Yes	0.5 (29.4)	59.6 (31.6)	76.0 (21.0)
No	14.3 (28.9)	74.5 (34.2)	78.6 (20.8)
P-value	0.010	0.016	0.494
Repeat Flow Diversion			
Yes	47.4 (31.4)	79.5 (46.1)	100.9 (30.4)
No	8.5 (28.8)	69.8 (33.8)	76.5 (19.7)
P-value	<0.001	0.470	0.002
ICA Occlusion			
Yes	10.5 (41.7)	56.7 (32.2)	90.6 (32.2)
No	10.5 (29.2)	70.9 (34.1)	77.4 (20.2)
P-value	0.998	0.318	0.128

Table 3. Univariate Analysis

TABLE 3. Univariate logistic regression analysis indicating predictors of incomplete occlusion at one year

Variable	OR (95% CI)	P-Value
Age	1.06 (1.02-1.09)*	0.001
Female	0.74 (0.25-2.22)	0.593
Aneurysm Location		
Cavernous	Reference	
Paraclinoid	0.65 (0.28-1.53)	0.324
Posterior Communicating	2.50 (0.71-8.78)	0.153
ICA Terminus	0.83 (0.07-10.20)	0.887
Aneurysm Size	1.04 (0.99-1.09)	0.092
Previously Ruptured Aneurysm	0.50 (0.13-1.90)	0.310
Previously Coiled	0.85 (0.35-2.05)	0.722
Intraprocedural Angioplasty	3.22 (0.86-12.03)	0.082
Posterior Bend ≥43.1	2.94 (1.04-8.30)	0.042
Anterior Bend ≥-3.5	2.69 (1.16-6.24)	0.021
Repeat Flow Diversion	4.19 (0.74-23.75)	0.106

Table 4. Multivariate Analysis

TABLE 4. Multivariate stepwise logistic regression analyses indicating predictors incomplete occlusion at one year

Variable	OR (95% CI)	P-Value	C-Statistic
Age	1.05 (1.01-1.08)	0.007	
Aneurysm Size	1.02 (0.96-1.07)	0.602	
Intraprocedural Angioplasty	3.23 (0.68-15.44)	0.142	
Anterior Bend ≥-3.5	2.43 (1.02-5.81)	0.046	0.718
Age	1.05 (1.01-1.08)	0.006	
Aneurysm Size	1.01 (0.96-1.07)	0.590	
Intraprocedural Angioplasty	3.18 (0.69-14.71)	0.138	
Posterior Bend ≥43.1	2.36 (0.80-6.94)	0.119	0.710

Conclusions

These findings suggest that variations in CS anatomy may influence the efficacy of FD treatment and should be analyzed prior to offering FD for treatment of ICA aneurysms. Further investigation into the hemodynamic effects of CS geometry is warranted.

Learning Objectives

By the conclusion of this session, participants should be able to: 1) quantify carotid siphon anatomy through the use of specific angle measurements, and 2) understand how variations in carotid siphon anatomy affects the efficacy of flow diversion for internal carotid artery aneurysms.