

A Comparison of Diffusion Weighted Imaging Abnormalities Following Balloon Remodeling for Aneurysm Coil Embolization in the Ruptured vs. Unruptured Setting

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Introduction

The pro-thrombotic milieu seen in subarachnoid hemorrhage (SAH) poses a unique challenge to neurovascular surgeons with regard to device use and microcatheter practice. Our objective is to determine how demographic factors and balloon practices impact diffusion-weighted imaging (DWI) abnormalities and outcomes in patients with subarachnoid hemorrhage (SAH) compared to those without (non-SAH).

Methods

We retrospectively analyzed 77 patients with SAH treated by balloon-assisted coiling in a single institution compared with 81 consecutive patients with unruptured aneurysms treated by balloon-assisted coiling at the same institution. Data was collected with regard to demographic factors, procedural and anatomic considerations, and DWI abnormalities on postprocedural MRI.

Table 5: Comparison of number and volume of diffusion-weighted imaging abnormality by subarachnoid hemorrhage status				
	SAH (N=27)	No SAH (N=19)**		
	Median Interquartile Range)	Median Interquartile Range)	p-value	
Number of DWI	4.0 (2.0 – 9.0)	3.0 (1.0 – 4.0)	0.0421	
Total Volume of DWI	1.3 (0.5 – 6.6)	0.3 (0.1 – 0.8)	0.0041	
*Wilcoxon rank sum test due to non-normal data reported with medians. The means and standard deviations are: for number of DWI, 7.0 (7.9) for SAH and 2.9 (2.0) for No SAH; for total volume, 7.5 (15.4) for SAH and 1.0 (1.8) for No SAH. The t-test has a p-value of 0.0168 for number of DWI and 0.039 for total volume. I suggest reporting the medians and Wilcoxon test from the table since the data is not normally distributed.				
**Total Volume of DWI only available for 17 of the 19 No SAH subjects.				

Results

SAH patients were significantly more likely to have DWI abnormality (75% vs. 21%, p<0.0001) and had higher number and volume of DWI (4.0 vs. 3.0, p=0.0421 and 1.3 vs. 0.3 cc, p=0.0041) despite similar balloon practices. SAH patients were not more likely to have DWI abnormality in vascular territory distal to the treated aneurysm, but had higher likelihood of DWI in a vascular territory unrelated to the aneurysm (81.5% vs. 47.1%, p=0.0235). Patients without DWI abnormality were significantly more likely to have a good outcome as defined by mRS 0-2 (95.6% vs. 81.6%, p=0.0328). Patients with DWI abnormality more often underwent 4-vessel angiography (70.5% vs. 48.0%, p=0.0174).

Table 1: Population comparison between subarachnoid and non-subarachnoid subjects (N=158)				
	N	SAH (N=77)	No SAH (N=81)	p-value
		N (%) or Mean (St. Dev.)	N (%) or Mean (St. Dev.)	
Gender	158			<0.0001
Female		44 (57.3%)	72 (88.9%)	
Male		33 (42.9%)	9 (11.1%)	
Age (years)	158	54.6 (13.8)	57.6 (12.4)	0.1651
Hypertension	158	33 (42.9%)	41 (50.6%)	0.3285
Diabetes	158	8 (10.4%)	10 (12.4%)	0.6089
Tobacco	158			0.0301
Current		44 (57.3%)	33 (40.7%)	
Remote		9 (11.7%)	22 (27.2%)	
None		24 (31.2%)	26 (32.1%)	
Antiplatelets	158	27 (35.3%)	51 (63.0%)	0.0005
Previous Stroke	158	1 (1.3%)	15 (18.5%)	0.0003
4-Vessel angiogram	158	74 (96.1%)	32 (39.5%)	<0.0001
Intraprocedural Heparin Anticoagulation	158	77 (100.0%)	81 (100.0%)	1.0
Pharmacological Neuroprotection	158	0 (0.0%)	1 (1.2%)	
Aneurysm Location	157			
Internal Carotid Artery		7 (9.1%)	11 (13.8%)	0.4549
Posterior Communicating Artery		11 (14.3%)	14 (17.5%)	0.5921
Anterior Communicating Artery		33 (42.9%)	5 (6.3%)	<0.0001
Middle Cerebral Artery		3 (3.9%)	7 (8.8%)	0.3285
Basilar		7 (9.1%)	11 (13.8%)	0.4549
Other*		16 (20.8%)	32 (40.0%)	0.0090
DWI in vascular territory distal to aneurysm**		18 (66.7%)	15 (88.2%)	0.1585
Procedure Times				
Total Procedural Time (min)	120	28.7 (36.5)	36.6 (26.0)	0.1961
Total Balloon Inflation (min)	120	12.3 (14.3)	19.2 (11.7)	0.0047
Balloon Inflation	123	3.3 (2.4)	4.2 (2.5)	0.0689
Average Single Inflation (min)	120	4.8 (6.6)	5.0 (2.6)	0.8459
Maximum Single Inflation (min)	120	6.5 (8.3)	7.6 (4.3)	0.3700
Total Time Down (min)**	99	21.8 (30.5)	19.7 (15.8)	0.6967
Maximum Time Down (min)**	99	14.3 (20.4)	8.8 (5.6)	0.1233
DWI Location	44			0.4897
DWI in vascular territory distal to aneurysm		5 (18.5%)	9 (52.9%)	
DWI in other territory		9 (33.3%)	2 (11.8%)	
DWI in vascular territory distal to aneurysm and in other territory		13 (48.2%)	6 (35.3%)	
Overall DWI rate	117	27 (75.0%)	17 (21.0%)	<0.0001
Table Legend: SAH: Subarachnoid hemorrhage DWI: Diffusion-weighted imaging abnormality				
*Other includes A1/A2, Ophthalmic, PICA, SCA, SHA, Vertebral, and Pericallosal.				
**16 subjects had a single balloon inflation.				

Table 2: Demographic Comparison between Cohorts with and without Diffusion-Weighted Imaging Abnormality				
		No DWI (N=73) N (%) or Mean (St. Dev.)	DWI (N=44) N (%) or Mean (St. Dev.)	p-value p-value
Demographics	Gender			0.0187
	Female	63 (86.3%)	30 (68.2%)	
	Male	10 (13.7%)	14 (31.8%)	
	Age (years)	55.9 (12.6)	58.3 (13.2)	0.3369
	Hypertension	34 (46.6%)	22 (50.0%)	0.7194
	Diabetes	6 (8.2%)	7 (15.9%)	0.2325
	Tobacco			0.2561
	Current	30 (41.1%)	25 (56.8%)	
	Remote	18 (24.7%)	8 (18.2%)	
	None	25 (34.3%)	11 (25.0%)	
	Antiplatelets	46 (63.0%)	39 (85.2%)	0.0365
	Previous Stroke	12 (16.4%)	3 (6.8%)	0.1617
Anatomic Factors	Aneurysm Location			
	Internal Carotid Artery	10 (13.9%)	3 (6.8%)	0.3568
	Posterior Communicating Artery	10 (13.9%)	8 (18.2%)	0.6011
	Anterior Communicating Artery	8 (11.1%)	17 (38.6%)	0.0008
	Middle Cerebral Artery	7 (9.7%)	0 (0.0%)	0.0483
	Basilar	9 (12.5%)	4 (9.1%)	0.7638
	Other	28 (38.3%)	12 (27.8%)	0.2015
	Circulation			
	Anterior	40 (82.2%)	36 (81.8%)	0.9593
	Posterior	13 (17.8%)	8 (18.2%)	
	Type			
	Proximal	40 (82.2%)	35 (79.6%)	0.7227
	Distal	13 (17.8%)	9 (20.5%)	
Procedural Factors	4-Vessel angiogram	35 (48.0%)	31 (70.5%)	0.0174
	Intraprocedural Heparin Anticoagulation	73 (100.0%)	44 (100.0%)	1.0
	Pharmacological Neuroprotection	1 (1.4%)	0 (0.0%)	1.0
	Total Procedural Time (min)	35.3 (28.5)	29.2 (29.3)	0.3133
	Total Balloon Inflation (min)	18.1 (14.3)	18.3 (13.2)	0.3096
	Balloon Inflation	3.8 (2.5)	3.8 (2.5)	0.8764
	Average Single Inflation (min)	5.7 (5.4)	4.2 (3.1)	0.1061
	Maximum Single Inflation (min)	8.3 (7.7)	6.2 (4.1)	0.0717
	Total Time Down (min)	19.3 (17.3)	19.1 (22.4)	0.9588
	Maximum Time Down (min)	8.5 (9.7)	7.9 (11.9)	0.7815
	Symptomatic Stroke	4 (5.5%)	8 (18.2%)	0.0578
Outcome	NHSS (median IQR)	0 (0 – 0)	0 (0 – 0)	0.6249
	Modified Rankin Scale Score (mRS)			0.1843
	0	44 (64.7%)	20 (45.5%)	
	1	14 (20.0%)	4 (13.6%)	
	2	7 (10.3%)	5 (13.2%)	
	3	0 (0.0%)	0 (0.0%)	
	4	1 (1.5%)	1 (3.7%)	
	5	0 (0.0%)	0 (0.0%)	
	6	2 (2.9%)	4 (10.5%)	
	mRS 0-2	65 (95.6%)	31 (81.6%)	0.0328

Table 3: Demographic Comparison of Subarachnoid Hemorrhage Subjects with and without Diffusion-Weighted Imaging Abnormality				
		No DWI (N=9) N (%) or Mean (St. Dev.)	DWI (N=27) N (%) or Mean (St. Dev.)	p-value p-value
Demographics	Gender			0.4427
	Female	4 (44.4%)	17 (63.0%)	
	Male	5 (55.6%)	10 (37.0%)	
	Age (years)	53.7 (14.3)	55.7 (13.5)	0.7126
	Hypertension	3 (33.3%)	17 (64.4%)	0.0560
	Diabetes	2 (22.2%)	1 (3.7%)	0.1479
	Tobacco			0.8573
	Current	5 (55.6%)	17 (69.0%)	
	Remote	1 (11.1%)	3 (11.1%)	
	None	3 (33.3%)	7 (25.9%)	
	Antiplatelets	4 (44.4%)	10 (37.0%)	0.7115
	Previous Stroke	0 (0.0%)	0 (0.0%)	
Anatomic Factors	Aneurysm Location			
	Internal Carotid Artery	0 (0.0%)	2 (7.4%)	1.0
	Posterior Communicating Artery	2 (22.2%)	0 (0.0%)	0.2552
	Anterior Communicating Artery	6 (66.7%)	14 (61.9%)	0.7003
	Middle Cerebral Artery	0 (0.0%)	0 (0.0%)	
	Basilar	0 (0.0%)	1 (4.4%)	1.0
	Other	1 (11.1%)	7 (25.9%)	0.6478
	Circulation			
	Anterior	9 (100.0%)	21 (77.8%)	0.3026
	Posterior	0 (0.0%)	6 (22.2%)	
	Type			0.3017
	Proximal	9 (100.0%)	22 (81.5%)	
	Distal	0 (0.0%)	1 (18.5%)	
Procedural Factors	4-Vessel angiogram	9 (100.0%)	25 (92.6%)	1.0
	Intraprocedural Heparin Anticoagulation	9 (100.0%)	27 (100.0%)	
	Pharmacological Neuroprotection	0 (0.0%)	0 (0.0%)	
	Total Procedural Time (min)	33.9 (45.2)	19.9 (29.7)	0.3581
	Total Balloon Inflation (min)	18.1 (29.1)	9.2 (8.3)	0.4542
	Balloon Inflation	2.3 (1.0)	3.1 (5.8)	0.2696
	Average Single Inflation (min)	8.8 (14.6)	4.2 (3.9)	0.4434
	Maximum Single Inflation (min)	12.0 (19.2)	5.6 (5.0)	0.4113
	Total Time Down (min)	20.6 (25.6)	16.3 (13.3)	0.7846
	Maximum Time Down (min)	19.4 (24.9)	10.8 (18.1)	0.4134
Outcome	Symptomatic Stroke	1 (20.0%)	6 (22.2%)	1.0
	NHSS (median IQR)	0 (0 – 1)	0 (0 – 1)	0.7489
	Modified Rankin Scale Score (mRS)			0.5704
	0	3 (42.9%)	7 (33.3%)	
	1	1 (14.3%)	3 (14.3%)	
	2	3 (42.9%)	4 (18.5%)	
	3	0 (0.0%)	0 (0.0%)	
	4	0 (0.0%)	3 (14.3%)	
	5	0 (0.0%)	0 (0.0%)	
	6	0 (0.0%)	4 (18.1%)	
	mRS 0-2	7 (100.0%)	14 (66.7%)	0.1414

Conclusions

Balloon-assisted coiling does not result in increased incidence of downstream ischemic events in SAH patients compared to non-SAH patients and is safe in this cohort of patients. Other factors, such as 4-vessel angiography of the SAH milieu itself may predispose patients to a higher rate of ischemic events.

Table 4: Demographic Comparison of Non-Subarachnoid Hemorrhage Subjects with and without Diffusion-Weighted Imaging Abnormality				
		No DWI (N=64) N (%) or Mean (St. Dev.)	DWI (N=17) N (%) or Mean (St. Dev.)	p-value p-value
Demographics	Gender			0.0868
	Female	59 (92.2%)	13 (76.5%)	
	Male	5 (7.8%)	4 (23.5%)	
	Age (years)	56.3 (12.4)	62.4 (11.3)	0.0056
	Hypertension	31 (48.4%)	10 (58.8%)	0.4464
	Diabetes	4 (6.3%)	6 (35.3%)	0.0046
	Tobacco			0.7921
	Current	25 (39.1%)	8 (47.1%)	
	Remote	17 (26.6%)	5 (29.4%)	
	None	22 (34.4%)	4 (23.5%)	
	Antiplatelets	42 (65.6%)	9 (52.9%)	0.3357
	Previous Stroke	12 (18.8%)	3 (17.7%)	1.0
Anatomic Factors	Aneurysm Location			
	Internal Carotid Artery	10 (15.9%)	1 (5.9%)	0.4414
	Posterior Communicating Artery	8 (12.7%)	6 (35.3%)	0.0649
	Anterior Communicating Artery	2 (3.2%)	3 (17.7%)	0.0617
	Middle Cerebral Artery	7 (11.1%)	0 (0.0%)	0.3355
	Basilar	9 (14.3%)	2 (11.8%)	1.0
	Other	27 (42.9%)	5 (29.4%)	0.4075
	Circulation			
	Anterior	51 (79.7%)	15 (88.2%)	0.7258
	Posterior	13 (20.3%)	2 (11.8%)	
	Type			0.7467
	Proximal	51 (79.7%)	13 (76.5%)	
	Distal	13 (20.3%)	4 (23.5%)	
Procedural Factors	4-Vessel angiogram	26 (40.6%)	6 (35.3%)	0.6894
	Intraprocedural Heparin Anticoagulation	64 (100.0%)	17 (100.0%)	
	Pharmacological Neuroprotection	1 (1.6%)	0 (0.0%)	1.0
	Total Procedural Time (min)	35.5 (26.2)	40.3 (15.7)	0.5222
	Total Balloon Inflation (min)	18.8 (11.7)	20.3 (11.5)	0.6687
	Balloon Inflation	4.0 (2.5)	4.6 (2.2)	0.4246
	Average Single Inflation (min)	5.2 (2.8)	4.3 (1.7)	0.0990
	Maximum Single Inflation (min)	7.8 (4.7)	6.9 (2.4)	0.3186
	Total Time Down (min)	19.2 (18.2)	21.1 (15.1)	0.6707
	Maximum Time Down (min)	8.6 (5.2)	9.6 (6.9)	0.5199
Outcome	Symptomatic Stroke	3 (4.7%)	2 (11.8%)	0.3608
	NHSS (median IQR)	0 (0 – 0)	0 (0 – 0)	0.3852
	Modified Rankin Scale Score			0.9502
	0	41 (67.2%)	13 (76.5%)	
	1	13 (21.3%)	3 (17.7%)	
	2	4 (6.6%)	1 (5.9%)	
	3	0 (0.0%)	0 (0.0%)	
	4	1 (1.6%)	0 (0.0%)	
	5	0 (0.0%)	0 (0.0%)	
	6	2 (3.3%)	0 (0.0%)	
	mRS 0-2	58 (95.1%)	17 (100.0%)	1.0