

Occurrence and Variability in Acute Formation of Leptomeningeal Collaterals in Proximal Middle Cerebral Artery Occlusion

Abstract

Background: We performed this study to semi-quantitatively characterize the formation of leptomeningeal collaterals in acute middle cerebral artery (MCA) occlusion caused by intravascular balloon inflation.

Methods: The anatomic extent of leptomeningeal collateral blood flow from the anterior cerebral artery territory to the MCA territory during occlusion of the M1 segment was graded based on angiographically visible retrograde reconstitution of the MCA segments on the delayed venous phase prior to and during inflation of the balloon.

Results: During MCA occlusion, the leptomeningeal collaterals markedly improved in 5 of 7 patients and were graded as 1 (retrograde filling of distal M1 segment) in 3 patients, 2 (retrograde filling of proximal M2 segment) in 1 patient, 4 (retrograde filling of M3 segment) in 1 patient and 5 (none or minimal) in 2 patients.

Conclusion: Leptomeningeal collaterals from the anterior cerebral artery can form rapidly during MCA occlusion with considerable individual variability.

Keywords: Leptomeningeal collaterals; middle cerebral artery occlusion; angioplasty; stent; collaterals

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Leptomeningeal collaterals provide blood to the middle cerebral artery (MCA) in retrograde fashion from either the anterior or posterior cerebral artery via anastomoses between ipsilateral cortical branches and are frequently observed in patients with acute ischemic stroke in the presence of MCA occlusion.^{1,3} It remains unclear whether these anastomotic channels are pre-existing and activated by a pressure gradient due to proximal stenosis or occlusion or are formed over time through neovascularization due to chronic ischemia. We performed this study to better understand the relationship between acute arterial occlusion and leptomeningeal collateral formation.

Methods

We retrospectively reviewed the medical records and angiographic images for patients who underwent endovascular procedures for symptomatic intracranial stenosis of the proximal segment of the MCA. The protocol for patient selection and procedures has been published previously.⁴ A combination of aspirin (325 mg daily) and clopidogrel (75 mg daily) was started 3 days prior to the procedure. Heparin was intravenously administered as a bolus dose of 70 U/kg to achieve an activated coagulation time between 300 to 350 seconds. Angiographic images were acquired using a 6-French guide catheter (Envoy; Cordis, Miami Lakes, Florida) was placed in the distal cervical internal carotid artery prior to, during, and after balloon inflation. The selected balloon catheter or stent delivery device was advanced over a 0.014-inch microguidewire and navigated to the site of stenosis. A slow inflation was performed ranging from 15 to 30 seconds at the time of angioplasty or stent deployment.

The severity of stenosis was quantitated as a ratio of the narrowest vessel visualized within the stenosis to the proximal reference vessel.⁵ The leptomeningeal collateral formation was graded based on retrograde contrast opacification of the MCA from the anterior cerebral artery on delayed angiographic images as previously described.⁶ grade 1, if collaterals reconstituted the distal most portion of the occluded vessel segment (M1 segment distal to the occlusion reconstituted); grade 2, if collaterals reconstituted vessels in the proximal portion of the segment adjacent to the occluded vessel (reconstitution to the proximal M2 vessel segments); grade 3, if collaterals reconstituted vessels in the distal portion of the segment adjacent to the occluded vessel (reconstitution to the distal portion of the M2 vessel segments); grade 4, if collaterals reconstituted vessels two segments distal to the occluded vessel (reconstitution up

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to the M3 segment branches); and, grade 5, if there was little or no significant reconstitution of the territory of the occluded vessel.

Results

The clinical and angiographic characteristics of the patients are presented in the Table 1. The initial leptomeningeal collateral blood flow was graded as 5 (none or minimal) in all 7 patients. The balloon inflation was completely occlusive in all patients (see Figures 1 and 2). During MCA occlusion, the leptomeningeal collateral blood flow was markedly improved and graded as 1 (retrograde filling of distal M1 segment) in 3 patients, 2 (retrograde filling of proximal M2 segment) in 1 patient, 4 (retrograde filling of M3 segment) in 1 patient and 5 (none or minimal) in 2 patients. No clear association could be discerned regarding the age of the patient or pre-treatment severity of stenosis. There appeared to be a suggestion that patients with limited collateral formation appeared to have a longer interval between symptom onset and treatment.

Discussion

Leptomeningeal collaterals of varying magnitude can be seen in approximately 80% of the patients with MCA occlusion^{7,8} in angiographic images acquired hours after onset of occlusion in patients with acute ischemic stroke. However, in the absence of pre-occlusion angiographic images and angiographic images concurrent with onset of occlusion, the temporal onset of these collaterals is not known. We observed rapid formation of

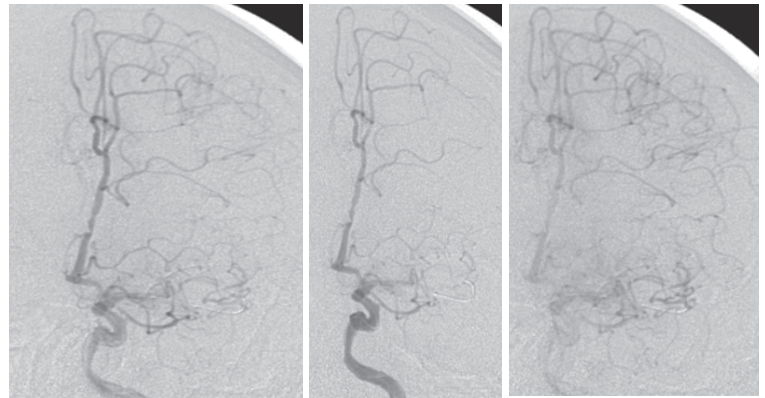


Figure 1: Angiographic images acquired during inflation of balloon in patient #1 demonstrating prominent angiographically visible retrograde reconstitution of the middle cerebral artery segments on the delayed venous phase (grade 1).

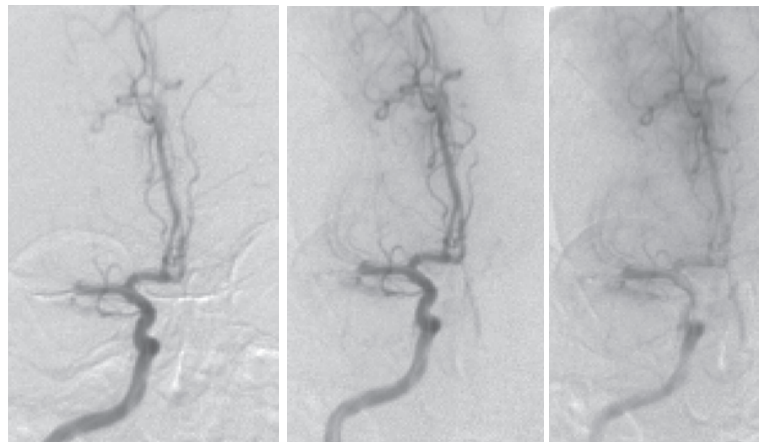


Figure 2: Angiographic images acquired during inflation of balloon in patient #3 demonstrating no angiographically visible retrograde reconstitution of the middle cerebral artery segments on the delayed venous phase (grade 5).

Table 1. Clinical and angiographic characteristics of the patients

Age/ Gender	Risk factors	Target event	Time from event to procedure	Stenosis severity and characteristics	Leptomeningeal collateral flow	
					Initial	During balloon inflation
61/ M	HTN, DM, Hyperlipidemia	Major stroke	>7 days	90%, regular	5	1
58/ M	HTN, hyperlipidemia	Major stroke	>7 days	60%, irregular	5	1
47/ M	Cigarette smoking	Major stroke	≤7 days	90%, regular	5	5
42/ F	HTN, cigarette smoking, previous stroke	TIA	≤7 days	62% irregular	5	2
54/ M	HTN, hyperlipidemia, cigarette smoking, CAD, previous stroke	TIA	>7 days	85%, irregular	5	1
67/ M	Cigarette smoking	TIA	>7 days	70%, irregular	5	4
45/ M	HTN, hyperlipidemia, cigarette smoking	Major stroke	≤7 days	80%, regular	5	5

Abbreviations used: M, male; F, female; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; TIA, transient ischemic attack, defined as reversible neurological deficits with complete resolution of symptoms within 24 hours; minor (nondisabling) stroke was defined by modified Rankin scale of 2 or less; and major (disabling) stroke was defined by modified Rankin scale of greater than 2.

leptomeningeal collaterals during acute occlusion of the MCA but the magnitude of collateral formation widely varied among individuals.

The results should be interpreted with the understanding that patients had pre-existing chronic MCA stenosis and the frequency and magnitude of leptomeningeal collaterals in response to acute occlusion may be different in patients without pre-existing MCA stenosis. The angiographic images only evaluated leptomeningeal collaterals originating from anterior cerebral artery. In the absence of simultaneous injection from the vertebral artery, we cannot comment upon leptomeningeal collateral formation from the ipsilateral posterior cerebral artery. The effect of concomitant medications on leptomeningeal collaterals formation is not known although previous studies have not suggested an acute effect of either antiplatelet agents⁹ or heparin.¹⁰

Our findings of marked variability in the augmentation of arterial collaterals as a source of retrograde perfusion to the MCA during balloon occlusion suggest hemodynamic factors not previously considered. It remains likely that a prompt drop in intravascular pressure in the distal MCA following occlusion triggers an increase in leptomeningeal collateral flow. The variability in such a response, however, may be explained by different degrees of resistance in the microcirculation and venous structures, as flow is not solely governed by pressure differentials but is also inversely related to resistance. In summary, immediate changes in arterial collaterals following occlusion may reflect mechanical factors such as pressure gradients and downstream resistance and may have implications for under-

standing the pathophysiology of acute cerebral ischemia.

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