Exploring the Influence of Dual Revascularization Techniques on Preoperative Middle Meningeal Artery Collateral Networks in Moyamoya Angiopathy

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Introduction

Moyamoya disease is characterized by spontaneous and progressive occlusion of the intracranial carotid arteries and their proximal branches. One treatment involves a combined surgical revascularization technique: direct revascularization with a superficial temporal artery to middle cerebral artery (STA-MCA) bypass, along with indirect revascularization using encephaloduroarteriosynangiosis (EDAS).

Despite some direct STA-MCA bypasses occluding over time, cerebral perfusion and clinical status remain unaffected. Given that the middle meningeal artery (MMA) is a major branch of the external carotid artery (ECA), we hypothesize that MMA collaterals compete with the direct bypass for flow, while overall cerebral perfusion remains largely unchanged.



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Fig. 1.: 27-year-old female patient presented with fainting and left-sided hand tremor. Cerebral angiography conformed Moyamoya disease. A Right internal carotid artery RICA coronar preop. **B** RICA sagittal preop. **C** Right external carotid artery RECA sagittal preop with no relevant preoperative MMA collaterals. The patient underwent combined bypass surgery on the right hemisphere. **D** RECA 10 month postoperative shows occluded direct bypass

Fig. 2.: 31-year-old woman who presented with sensory loss in the left hand and was found to have multiple small acute, subacute, and chronic infarcts in the right cerebral hemisphere. Diagnostic angiography demonstrated unilateral right-sided moyamoya disease with occlusion of the right distal internal carotid artery ICA. A Right common carotid artery RCCA preop coronal. B RCCA sagittal. The patient underwent direct and indirect bypass surgery on the right hemisphere. C 6 month postop cerebral angio shows patent direct bypass and strong collaterals from left MMA frontal branch.



Fig.3.: 59-year-old woman presents after 4 recurrent strokes in 3 years. Cerebral angio shows severe distal ICA stenosis. A Left internal carotid artery LICA preop coronar. B LICA preop sagittal. C Left external carotid artery LECA preop. Direct and indirect bypass surgery on the left hemisphere were performed. 11 month postop cerebral angio shows patent direct bypass and strong collaterals from left MMA frontal branch. **D** LECA postop sagittal. **E** LECA postop coronar.

but strong collaterals from MMA and STA indirect bypass.

Methods

- **Study Design:** Retrospective, single-center, single-surgeon case series.
- Participants: 30 eligible patients with ischemic Moyamoya disease who underwent exclusively combined surgical revascularization.
- Data Collection: •
 - Preoperative and postoperative cerebral angiograms analyzed for MMA collateral networks.
 - Postoperative angiograms at long term assessed for direct bypass patency.
 - Pre- and postoperative NOVA-MRA data from 29 patients examined.
 - Total hemispheric blood flow calculated as the sum of ICA, ACA, MCA, and PCA flow in the respective hemisphere, with direct bypass flow added postoperatively.

Results

•Bypass Patency:

- All 36 patients who underwent combined revascularization had patent bypasses postoperatively.
- 24 (66.6%) direct bypasses remained robustly patent, while 12 regressed (median follow-up: 13 months).

•MMA Collateral Networks:

- Preoperative MMA collaterals: 12 patients (33.3%).
- Post-revascularization MMA collaterals: 23 patients (64%).
- Patent bypass group: 54% had MMA collaterals.
- Diminished bypass group: 83% had MMA collaterals.

Stroke Incidence:

Conclusion

•Direct Bypass Regression & MMA Collaterals:

- Long-term regression of direct bypasses correlates with increased MMA collateral networks.
- Direct bypasses enhance immediate cerebral perfusion, while MMA collaterals restore perfusion long-term.
- One-third of cases showed regression of the direct bypass without an increased stroke rate.

•NOVA-MRA & Chronic Disease Progression:

- Three patients suffered minor strokes during follow-up:
 - Two with patent bypasses and MMA collaterals (6- and 13-weeks postsurgery).
 - One with an occluded bypass (19 months post-surgery).

•NOVA-MRA Findings:

- 9 patients showed improved total hemispheric blood flow, while 20 worsened.
- Average postoperative total hemispheric blood flow decreased by 36 ml/min.
- Three patients with new strokes:
 - One had a reduced total hemispheric flow (-101 ml/min).
 - Two showed increased flow (+33 ml/min and +65 ml/min).

- NOVA data reveal chronic disease progression with reduced postoperative hemispheric blood flow.
- Despite decreased total hemispheric flow, MMA collaterals may play a crucial role in preventing symptoms.
- Future NOVA protocols for Moyamoya patients should include ECA flow to account for increased MMA collateral contributions.