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MULTISLICE CT ANGIOGRAPHY AND PERFUSION ASSESSMENT AFTER EXTRA-INTRACRANIAL MICROANASTOMOSIS IN MOYAMOYA DISEASE

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Abstract
The article describes the application of CT angiography of the brachiocephalic and intracranial arteries in combination with cerebral CT perfusion for the evaluation of patients with moyamoya disease before and after extra-intracranial microanastomosis. These imaging methods are used to assess vascular changes, determine the condition of cerebral blood flow, and monitor postoperative results.
Keywords: CT angiography, CT perfusion, brachiocephalic arteries, intracranial arteries, extra-intracranial microanastomosis, moyamoya disease.

Introduction
Moyamoya disease is an idiopathic, progressive occlusive cerebrovascular disorder of non-inflammatory and non-atherosclerotic origin. It mainly involves the vessels of the circle of Willis, particularly the supraclinoid segments of the internal carotid arteries.

Moyamoya disease (MMD) is a rare cerebrovascular arteriopathy characterized by gradual stenosis of the terminal internal carotid arteries and/or the proximal arteries of the circle of Willis, most often the middle and anterior cerebral arteries. As the disease progresses, a compensatory abnormal vascular network develops at the base of the brain. The condition was first reported in 1957 by the Japanese physicians Takeuchi and Shimizu. In 1967 it was named “moyamoya,” a Japanese expression meaning “a puff of cigarette smoke in the air,” because the collateral vessels have this appearance on angiographic images.

The highest frequency of MMD is observed in East Asian populations, especially in Japan and Korea, where the reported prevalence is approximately 3.16 cases per 100,000 people, which is 7-10 times higher than in many other regions. The mechanisms of disease development remain incompletely understood. Histological examination typically reveals fibrocellular

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thickening of the intima, corrugation and contraction of the internal elastic lamina, proliferation of smooth-muscle cells, and thinning of the media, without signs of inflammation or atherosclerosis.

There is currently no medication capable of stopping or reliably slowing the progression of moyamoya disease. Conservative therapy is therefore mainly supportive, whereas surgical cerebral revascularization is considered the principal treatment method. The goal of surgery is to increase cerebral perfusion by creating additional pathways for extra-intracranial blood flow. Published clinical experience shows that revascularization can reduce the risk of ischemic and hemorrhagic brain injury and improve functional recovery and quality of life.

Surgical revascularization is performed using two main approaches: direct extra-intracranial microanastomosis (EIICMA) and indirect synangiosis between the cerebral cortex and well-vascularized extracranial tissues. In modern practice, combined revascularization that includes both direct and indirect techniques is increasingly preferred.

In patients with internal carotid artery occlusion, cerebral hypoperfusion is a frequent hemodynamic consequence. Formation of an extra-intracranial microanastomosis enhances collateral circulation and increases regional cerebral blood flow.

Cerebral perfusion can be evaluated by perfusion CT, perfusion MRI, positron emission tomography, and single-photon emission computed tomography. Among these modalities, CT perfusion is widely available and provides sufficiently informative quantitative data.

Research objective: to evaluate the diagnostic role of multislice CT angiography and CT perfusion in the assessment of cerebral revascularization before and after extra-intracranial microanastomosis in patients with moyamoya disease.

Materials and Methods

Multislice CT angiography of the intra- and extracranial arteries supplying the brain was performed using a Revolution CT scanner (GE, 128-slice). The study included 10 patients with zones of occlusion and/or stenosis of the internal carotid artery. Six patients were men and four were women. The mean age was 35 years in men and 40 years in women.

Results

All patients underwent non-contrast CT, CT angiography, and CT perfusion before and after surgical treatment.

On non-contrast CT, ischemic changes in the subcortical regions of the parietal and temporal lobes were detected in five patients (50%) (Fig. 1).

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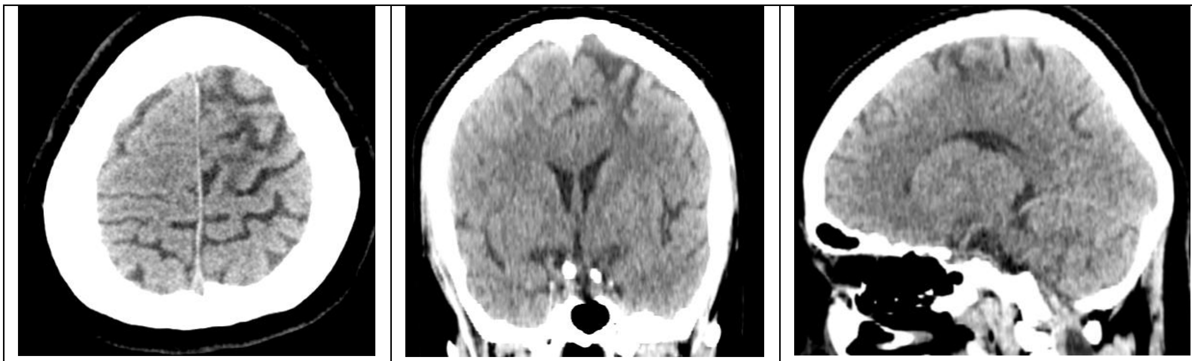
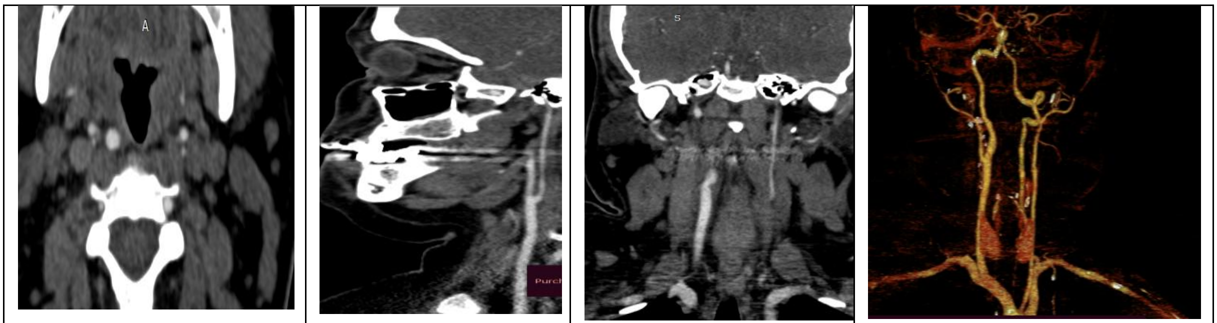


a) axial projection	b) coronal projection	c) sagittal projection

Fig. 1. Female patient, 27 years old. Moyamoya disease. Subcortical hypodense areas in the left frontoparietal region, density +26 to +27 HU.

Before surgery, CT angiography showed hypoplasia of the left internal carotid artery along its entire course (segments C1-C7) in all patients (Fig. 2).



a) axial projection	b) coronal projection	c) sagittal projection	d) 3D reconstruction - angular pathological tortuosity (kinking) and pathological tortuosity in the form of a loop (coiling) of the left BCA

Fig. 2. Female patient, 27 years old. Moyamoya disease. Preoperative CT angiography of the extracranial cerebral vessels. Hypoplasia of the left internal carotid artery.

All patients underwent brain CT perfusion. In every case, cerebral blood volume (CBV) was decreased, but the reduction was not critical. On CT perfusion, decreased CBV reflects reduced total blood volume within the examined brain tissue and, when analyzed together with cerebral blood flow (CBF), serves as an important marker of impaired perfusion and possible infarct core. In all patients, CBF was reduced to 20±0.03 mL/100 g/min on the right and to 15±0.04 mL/100 g/min on the left. Tmax and mean transit time (MTT) remained within normal limits (Table 1).

Table 1. CT perfusion parameters in patients with moyamoya disease before EIICMA surgery

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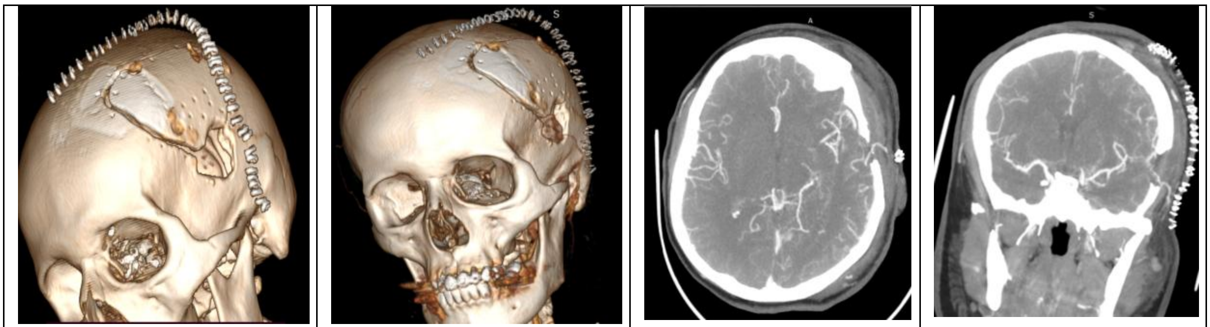
Region	**Hemisphere**	**CBV (mL/100 g)**	**Tmax (s)**	**CBF (mL/100 g/min)**	**MTT (s)**
MCA territory, temporoparietal region, lateral sections	Right	1.8±0.012	3.4	20±0.03	4.2
MCA territory, temporoparietal region, lateral sections	Left	1.7±0.015	4.0	15±0.04	5.1

Reference ranges used for interpretation: CBV 2-4 mL/100 g (typical normal tissue values 4-5 mL/100 g); infarct threshold <1.0-1.5 mL/100 g when interpreted together with CBF. Tmax 12-15 s. CBF 25-55 mL/100 g/min (typical normal values 50-80 mL/100 g/min); ischemia threshold <20 mL/100 g/min, infarct threshold <12 mL/100 g/min. MTT approximately 4-5 s.

All patients with MMD underwent combined extra-intracranial microanastomosis surgery. On the second postoperative day, CT angiography of the brachiocephalic arteries was performed to assess the created extra-intracranial anastomosis.



a) 3D reconstruction	b) coronal projection	c) axial projection	d) coronal projection

Fig. 4. CT angiography of the cerebral vessels on postoperative day 2 after extra-intracranial microanastomosis.

Three months after surgery, follow-up brain CT perfusion demonstrated a clear increase in CBF in both hemispheres. Left-sided CBV remained reduced at 1.8±0.011 mL/100 g, whereas right-sided CBV reached the lower limit of the reference range. During follow-up, Tmax decreased on the left, while MTT showed a slight increase on the right (Table 2).

Table 2. CT perfusion parameters in patients with moyamoya disease three months after EIICMA surgery

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Region	Hemisphere	CBV (mL/100 g)	Tmax (s)	CBF (mL/100 g/min)	MTT (s)
MCA territory, temporoparietal region, lateral sections	Right	2.1±0.012	3.4	32±0.01	5.3
MCA territory, temporoparietal region, lateral sections	Left	1.8±0.011	3.4	27±0.03	5.1

Reference ranges used for interpretation: CBV 2-4 mL/100 g (typical normal tissue values 4-5 mL/100 g); infarct threshold <1.0-1.5 mL/100 g when interpreted together with CBF. Tmax 12-15 s. CBF 25-55 mL/100 g/min (typical normal values 50-80 mL/100 g/min); ischemia threshold <20 mL/100 g/min, infarct threshold <12 mL/100 g/min. MTT approximately 4-5 s.

Conclusions

1. Multislice CT angiography is an informative imaging method for determining the level, extent, and anatomical characteristics of occlusive lesions of the brachiocephalic arteries, thereby contributing to the selection of an appropriate surgical or conservative treatment strategy.
2. After extra-intracranial bypass surgery, multislice CT angiography allows reliable visualization of the microanastomosis and provides an objective assessment of its patency.
3. CT perfusion enables quantitative assessment of cerebral perfusion status by analyzing CBV, CBF, MTT, and Tmax parameters, which reflect tissue blood volume, cerebral blood flow, mean transit time, and contrast bolus delay.
4. The combined use of CT angiography and CT perfusion makes it possible to evaluate both vascular anatomy and functional cerebral hemodynamics, identify areas of hypoperfusion and ischemic risk, and objectively monitor changes before and after surgical revascularization.

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