Quantitative Assessment of Flow Reduction After Feeder Embolization in Meningioma by Using Pseudocontinuous Arterial Spin Labeling

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■ BACKGROUND: **Meningioma is a hypervascular tumor of the central nervous system. Angiographic disappearance of tumor blush after preoperative feeder embolization allows qualitative, but not quantitative, assessment of flow reduction. Pseudocontinuous arterial spin labeling (PCASL), which has evolved from magnetic resonance imaging techniques, allows noninvasive measurement of cerebral blood flow (CBF) using water protons in the arterial blood flow.**

■ OBJECTIVE: **We applied PCASL for assessment of blood flow in meningioma and its reduction on preoperative embolization.**

■ METHODS: **Forty-one consecutive patients (11 males, 30 females) with histologically proven meningioma were evaluated by PCASL. Quantitative assessment by an absolute value of tumor blood flow (TBF) and a relative value of tumor vascular index (tVI; calculated as TBF divided by CBF) were calculated. In 8 cases, in which preoperative embolization was achieved, flow reduction rate was evaluated.**

■ RESULTS: **TBF of meningiomas, 155.8 mL/100 g·min^{-1} on average, was 2.6 times higher than CBF, 59.9 mL/100 g·min^{-1} ($P < 0.001$). Patients who underwent feeder embolization showed statistically greater flow reduction rate, which was calculated as 42.7% ($P < 0.05$). Mean tVI before embolization was 4.1, which was reduced to 2.1 after embolization.**

■ CONCLUSION: **PCASL could yield quantitative assessment of blood flow in meningioma including flow reduction rate in cases of feeder embolization.**

INTRODUCTION

Meningioma is one of the most frequently occurring hypervascular tumors of the central nervous system. "4D" such as devascularization, detachment, debulking, and dissection are 4 key procedures to remove meningioma. Among these, devascularization is an initial step, even though it is performed by an intravascular embolization or direct coagulation during surgery. The vanguard reports establishing the efficacy of preoperative embolization in reducing intraoperative blood loss and facilitating surgery for meningiomas had been published in the 1970s, and to date, there have been a number of reports on the efficacy, which leads to tumor softening and intratumoral necrosis, relatively easy tumor resection with diminished operative time, and intraoperative blood loss.[1,2]

Key words
- Feeder embolization
- Magnetic resonance imaging
- Meningioma
- Pseudocontinuous arterial spin labeling
- Tumor blood flow

Abbreviations and Acronyms
ASL: Arterial spin labeling
CASL: Continuous ASL
CBF: Cerebral blood flow
DSA: Digital subtraction angiography
DSC: Dynamic susceptibility contrast
ECA: External carotid artery
ICA: Internal carotid artery
MCA: Middle cerebral artery
MMA: Middle meningeal artery
MRI: Magnetic resonance imaging
NBCA: N-butyl-2-cyanoacrylate
PASL: Pulsed or pseudo ASL
PCASL: Pseudocontinuous ASL
ROI: Region of interest
SNR: Signal-to-noise ratio
STA: Superficial temporal artery
TBF: Tumor blood flow
tVI: Tumor vascular index
WHO: World Health Organization

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Citation: World Neurosurg. (2016) 93:237-245.
http://dx.doi.org/10.1016/j.wneu.2016.06.004

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

Recent development of microcatheters, embolic materials and technical advances, in addition to the knowledge of the dangerous anastomosis between the external and internal carotid arteries, have provided the means for safe and specific preoperative embolization.[3,4] Although disappearance of tumor blush is qualitatively evaluated using angiographic findings, it has been difficult to obtain quantitative assessments about the efficacy of the preoperative embolization.

Table 1. Demographic Data of Patients

Number of cases	41	
With embolization	8	
Without embolization	33	
Age		
21–40	5	
41–60	19	
>61	17	
Gender		
Male	11	
Female	30	
Pathology		
WHO grade I	25	
Meningothelial	19	
Fibrous	3	
Transitional	1	
Microcystic	2	
WHO grade II	13	
Atypical	10	
Chordoid	3	
WHO grade III	3	
Anaplastic	3	
Blood flow		
CBF (ave. ± SD, mL/100 g·min^{-1})		
	59.9 ± 20.5	
TBF (ave. ± SD, mL/100 g·min^{-1})		
Total	155.8 ± 118.0	$P < 0.001$
WHO grade I	156.0 ± 121.5	
WHO grade II	174.8 ± 121.3	
WHO grade III	72.8 ± 26.8	
tVI (ave. ± SD)		
Total	2.6 ± 1.9	
WHO grade I	2.5 ± 1.9	
WHO grade II	3.0 ± 2.0	
WHO grade III	1.8 ± 1.3	

WHO, World Health Organization; ave., average; CBF, cerebral blood flow of the contralateral middle cerebral artery region; SD, standard deviation; TBF, tumor blood flow as an absolute value; tVI, tumor vascular index.

Arterial spin labeling (ASL) permits noninvasive measurement of cerebral perfusion with magnetic resonance imaging (MRI) using the magnetization of water protons in the arterial blood flow as an intrinsic, freely diffusible tracer.[5,6] ASL sequences are commonly classified as continuous ASL (CASL) and pulsed or pseudo ASL (PASL).[5-7] CASL, with long-lasting continuous-mode radiofrequency transmission, has a larger ASL signal change and the greatest signal-to-noise ratio (SNR) as advantages and low sensitivity of adiabatic inversion to flow velocity as a disadvantage.[8,9] PASL has high and stable tagging efficiency with respect to flow velocity as its advantage; however, low SNR becomes a disadvantage under the influence of transit effect. Pseudocontinuous ASL (PCASL) appears to combine the advantages of CASL and PASL while excluding the disadvantages of both.[10] With the increasing availability of 3.0T units, PCASL is clinically a useful technique to quantitatively measure cerebral blood flow (CBF) with ease.[11,12]

We have applied PCASL to evaluate tumor blood flow (TBF) for a meningioma. A quantitative assessment was obtained by both an absolute value of TBF and a relative evaluation as tumor vascular index (tVI), which was calculated as TBF divided by CBF. In addition, flow reduction effects after preoperative feeder embolization were also objectively evaluated by PCASL.

MATERIAL AND METHODS

PCASL Perfusion Image Acquisition

Forty-one consecutive patients (11 males, 30 females) ranging in age from 28 to 83 years old (mean, 57 years) with histologically

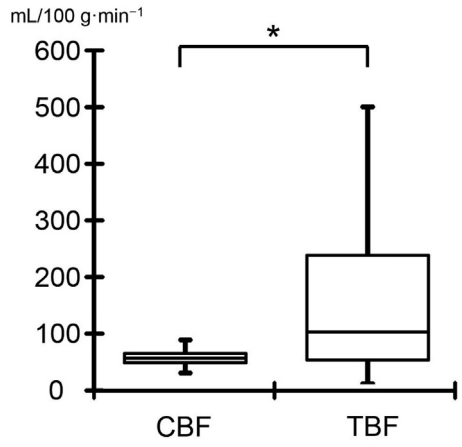

Figure 1. Comparison between cerebral blood flow (CBF) and tumor blood flow (TBF). The CBF calculated as the normal-appearing middle cerebral artery region in the contralateral hemisphere revealed 59.9 ± 20.5 mL/100 g·min^{-1}. On the contrary, the TBF of the meningioma demonstrated a much higher value. Values are the means ± standard deviation. *$P < 0.001$ (Mann-Whitney U test).