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ORIGINAL PAPER

# The Optimal Velocity Criterion in the Diagnosis of Unilateral Middle Cerebral Artery Stenosis by Transcranial Doppler

**Jiafeng Chen · Lin Wang · Jing Bai · Zhijun Lun · Jinqiao Zhang · Yingqi Xing**



**Abstract** We evaluated the optimal flow velocity of transcranial doppler (TCD) in detecting unilateral middle cerebral artery (MCA) stenosis and stenosis grading by magnetic resonance angiography (MRA) as the reference standard. 302 nonconsecutive patients with unilateral MCA stenosis detected by TCD underwent MRA of the intracranial arteries. The peak systolic velocity (PSV), mean flow velocity (MFV), and end-diastolic velocity (EDV) of each MCA were recorded. 604 MCA were categorized into four groups depending on the stenosis severity: normal MCA ($n = 319$, 52.8 %), mild stenosis ($n = 94$, 15.6 %), moderate stenosis ($n = 66$, 10.9 %), and severe stenosis ($n = 125$, 20.7 %). Significant differences in PSV, MFV, and EDV between these four groups were observed ($P < 0.001$, respectively). The optimal cutoff velocities for detecting MCA stenosis were: PSV = 160 cm/s, MFV = 100 cm/s, EDV = 60 cm/s; the optimal cutoff points to distinguish mild from moderate stenosis were: PSV = 200 cm/s, MFV = 120 cm/s, EDV = 80 cm/s; the cutoffs to distinguish moderate from severe stenosis were: PSV = 280 cm/s, MFV = 180 cm/s, EDV = 110 cm/s. Using PSV as the diagnostic criteria, the correlation for diagnosing MCA stenosis using TCD and MCA was good (Kappa number $\kappa = 0.668$); using as MFV criteria, $\kappa = 0.641$. The optimal cutoff PSV values in stenosis grading on TCD were 160, 200, and 280 cm/s. The optimal cutoff MFV values were 100, 120, and 180 cm/s. PSV is more accurate than MFV in detecting and grading MCA stenosis.

**Keywords** Middle cerebral artery · Stenosis · Ultrasonography · Transcranial doppler · Magnetic resonance angiography · Flow velocity

## Introduction

The stenosis of major intracranial and extracranial carotid arteries caused by atherosclerosis or the occlusion of these arteries is a common cause of ischemic stroke. Europeans and Americans have more severe lesions in the extracranial carotid arteries, while Asians and Africans have more lesions intracranially. In the intracranial arteries, middle cerebral artery (MCA) is the most common site for the occurrence of ischemic stroke due to the extensive blood supply it provides to the brain [1–4]. Among patients with a unilateral hemodynamically significant stenosis of MCA, 60.7 % had a recurrent stroke or TIA within a year [5]. Therefore, the early diagnosis of MCA stenosis, proper treatment and regular follow-up are critical preventing the recurrence of stroke.

Transcranial doppler ultrasonography (TCD) is the first choice of examination in identifying intracranial vascular lesions because of its simplicity, portability, noninvasiveness, and affordability. At present, MCA stenosis is

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diagnosed by measuring the flow velocity by TCD. However, the measurement standards have not been well established. In this study, the optimal flow velocity of TCD for detecting and grading the stenosis of MCA was investigated by magnetic resonance angiography (MRA) as a reference, providing reliable evidence toward a diagnostic standard of MCA stenosis by TCD for the Chinese Mainland population.

## Materials and Methods

### Subjects

We examined nonconsecutive patients who presented to the Department of Neurology of the First Norman Bethune Hospital of Jilin University of China between January 2010 and October 2011 with unilateral MCA stenosis identified by TCD. MRA was performed after receiving a written informed consent from patients. Patients with insufficient acoustic windows, unilateral or bilateral moderate or severe carotid stenosis, having known sources of emboli (e.g., atrial fibrillation) and those with bilateral MCA stenosis detected by MRA were excluded. MRA was performed within 7 days following TCD.

### TCD Examination

TCD was performed with an EMS-9A (Delica, China) device, a Multi-Dop X4 (DWL, Germany) machine and a 2-MHz transducer to record the MCA flow velocities. The following arteries were explored: the M1 segment of MCA, the anterior cerebral artery (ACA) and posterior cerebral artery (PCA) were explored through temporal window insonated at the depth of 45–65, 62–68, and 64–72 mm, respectively; the carotid siphon (CS) and ophthalmic artery (OA) were explored through transorbital window insonated at the depth of 60–72 and 52–60 mm, respectively; basilar artery (BA) and vertebral arteries (VA) were explored through suboccipital window insonated at the depth of 90–110 and 40–60 mm, respectively. The carotid artery compression test was routinely performed. The peak systolic velocity (PSV) was recorded and the velocity waveform and audio signal features were also evaluated. All TCD examinations were performed by experienced technicians. The common carotid arteries, internal carotid arteries, the beginning segment of vertebral artery, and subclavian arteries were explored using an IU22 color doppler (Philips) with L3-9 linear array probe and C5-1 convex array probe. The diameters, the thickness of tunica intima and tunica media and the status of the atheroscelrotic plaque of these arteries were recorded.

### MRA Examination

MRA was performed on a 1.5 T MR scanner (Siemens, Erlangen, Germany) with the use of three-dimensional time-of-flight sequences, and images were reconstructed in maximum intensity projection (MIP). According to the standard measuring method of Samuels et al. [6], the severity of MCA stenosis on MRA was classified as following four grades based on the reduction of vascular reduction and the absence of flow signal (Fig. 1): normal (normal lumen diameter, no absence of flow signal), mild (<50 % lumen diameter reduction, slight signal absent), moderate (both the diameter reduction and flow signal absence were between 50 and 69 %), and severe (>70 % or

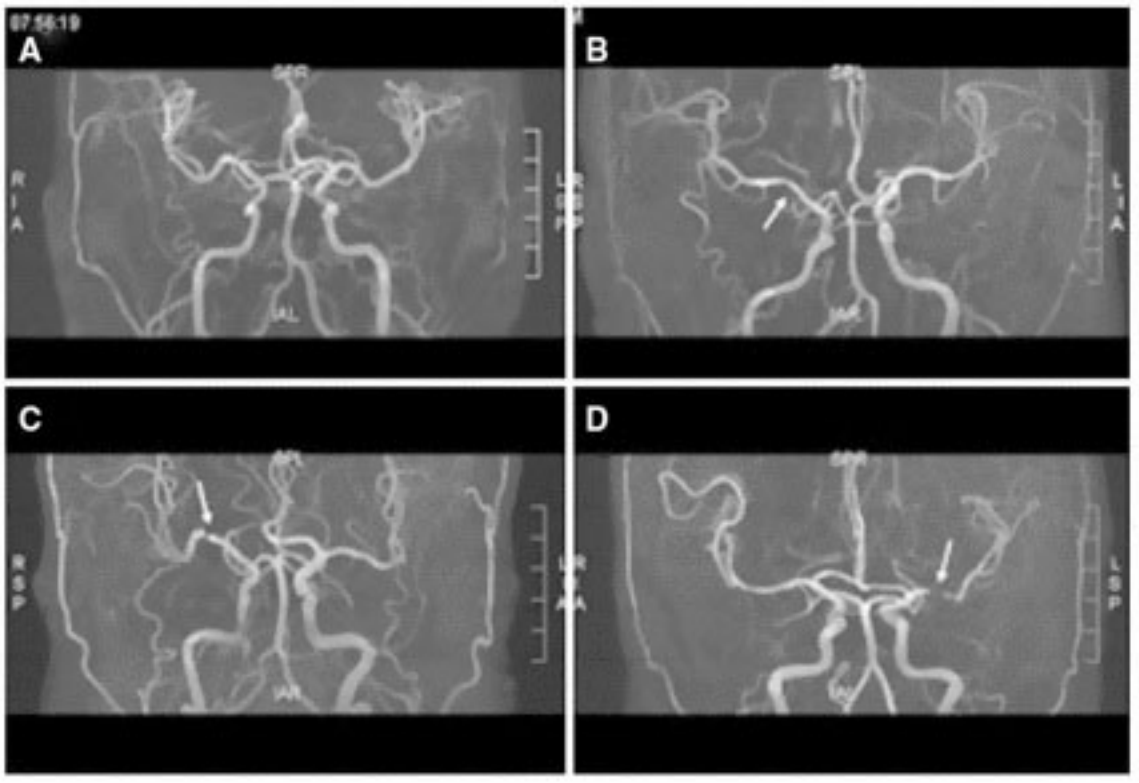


**Fig. 1** MRA images show normal MCA and MCA with various stenosis. **a** Normal MCA: normal lumen, absence of signal; **b** Mild stenosis: lumen diameter reduction <50 %, slight signal absent; **c** Moderate stenosis: both the diameter reduction and flow signal absence were between 50 and 69 %; **d** Severe stenosis lumen diameter reduction >70 %, focal void of flow signal