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● *Original Contribution*

THE ASSESSMENT OF DIAGNOSTIC ACCURACY FOR BASILAR ARTERY STENOSIS BY TRANSCRANIAL COLOR-CODED SONOGRAPHY

JIE YANG,* YANG HUA,* XIANG LI,* MINGJIE GAO,* QIUPING LI,* BEIBEI LIU,* and LIQUN JIAO†

* Department of Vascular Ultrasonography, Xuanwu Hospital, Capital Medical University, Beijing, China; and † Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, China

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Abstract—This study aimed to determine the optimal criteria for evaluating basilar artery stenosis (BAS) by transcranial color-coded sonography (TCCS). A total of 403 cases with both TCCS and digital subtraction angiography (DSA) were enrolled. Peak systolic velocity (PSV), end diastolic velocity (EDV) and mean flow velocity (MFV) of the basilar artery (BA), intracranial vertebral artery (IVA) and posterior cerebral artery (PCA) were measured. The ratios PSV_{BA}/PSV_{IVA} and PSV_{BA}/PSV_{PCA} were calculated. With DSA as the reference, the optimal criteria for grading BAS were determined by receiver operating characteristic analysis. They were as follows: PSV ≥110 cm/s, MFV ≥70 cm/s and PSV_{BA}/PSV_{IVA} ≥1.5 for <50% BAS; PSV ≥150 cm/s, MFV ≥90 cm/s and PSV_{BA}/PSV_{IVA} ≥2.0 for 50%–69% BAS; PSV ≥210 cm/s, MFV ≥120 cm/s and PSV_{BA}/PSV_{IVA} ≥3.0 for 70%–99% BAS. The combination of PSV, MFV and PSV_{BA}/PSV_{IVA} may increase the accuracy for diagnosing 70%–99% BAS. (E-mail: dryanghua99@163.com) © 2018 World Federation for Ultrasound in Medicine & Biology. All rights reserved.

Key Words: **Transcranial color-coded sonography, Basilar artery, Stenosis, Diagnostic, Hemodynamic.**

INTRODUCTION

Basilar artery stenosis (BAS) is one of the most important causes of posterior circulation ischemic stroke, especially symptomatic stenosis greater than 50%, which is associated with multiple transient ischemic attacks (TIAs) and a high risk of recurrent stroke (Marquardt et al. 2009). The Warfarin-Aspirin Symptomatic Intracranial Disease (WASID) Study Group (1998) indicated that even on antithrombotic therapy, the rate of stroke in the same area of BAS was 10.7% per y in followed-up patients. Thus, the accurate diagnosis and early treatment of BAS are necessary for preventing recurrent ischemic events.

Although digital subtraction angiography (DSA) is the gold standard for the assessment of BAS, because of the radiation risk, inconvenience and cost of the test, alternative diagnostic methods such as transcranial color-coded sonography (TCCS) would be preferable as the first choice for screening and follow-up, with the advantage of being non-invasive, economic and repeatable. TCCS is considered better than conventional transcranial Doppler (TCD) because TCCS enables visualization of the cerebral artery in color, especially for narrowing flow beam in the stenosis segment. TCCS can acquire more accurate velocity by angle correction, especially in bent vessels (Arkuszewski et al. 2012). There is a high agreement between TCCS and DSA in the evaluation of intracranial artery stenosis (Roubec et al. 2011), and several articles have confirmed the value of TCCS for screening BAS (Baumgartner et al. 1999; Kermer et al. 2006; Tateishi et al. 2008). However, the diagnostic criteria for the various degrees of BAS by TCCS were not identical.

The present study retrospectively analyzed 403 samples from a single center and aimed to define the criteria of hemodynamic parameters for diagnosing various degrees of BAS such as mild (<50%), moderate (50%–69%) and severe (70%–99%), with DSA as the standard of reference.

METHODS

Patients

From December 2014 to December 2016, 514 consecutive and in-hospital patients with posterior cerebral ischemic events were retrospectively enrolled. This retrospective study protocol was approved by the Ethics Committee of Xuanwu Hospital, Capital Medical

Address correspondence to: Yang Hua, Department of Vascular Ultrasonography, Xuanwu Hospital, Capital Medical University, 45 Changchun Street, Xicheng District, Beijing, 100053, China. E-mail: dryanghua99@163.com

University, Beijing, China. All patients have signed a consent form before the angiography procedure. According to the AHA/ASA guidelines for the prevention of stroke (Kernan et al. 2014), the presenting ischemic events were classified as TIA in 298 patients (73.9%) and stroke in 105 cases (26.1%) in posterior circulation. Inclusion criteria were as follows: (i) Basilar arteries (BA) were examined by TCCS and confirmed by DSA, and the time interval between TCCS and DSA was shorter than 2 wk; (ii) the temporal and occipital windows were sufficient for obtaining blood flow signals from the posterior cerebral artery (PCA), intracranial vertebral artery (IVA) and BA; and (iii) a straight vessel segment was long enough for Doppler sample volume location and measuring the flow velocities.

The exclusion criteria were as follows: Patients (i) had absent temporal or occipital windows (14 cases); (ii) had ≥70% stenosis or occlusion of the anterior circulation artery, vertebral artery (VA) and subclavian artery, which may influence the flow velocity of the BA attributable to the impact of collateral circulation compensation or decreasing blood flow of the BA (48 cases); (iii) had a bilateral posterior communicating artery opening or type of embryonal PCA (25 cases); (iv) had tortuous, long or multiple stenosis of the BA that may have had low flow velocity (16 cases); and (v) were allergic to the contrast agents (8 cases). Finally, 403 patients (327 men and 76 women) with a mean age of 62.7 ± 8.8 y (range 37–84 y) were enrolled in this study.

TCCS examination

Philips IU22 (Koninklijke Philips N.V., Amsterdam, The Netherlands) and Hitachi Ascendus (Hitachi, Tokyo, Japan) ultrasound systems with 1.0–5.0 MHz phased array probes were used for the TCCS examinations. All of the TCCS examinations were performed by sufficiently trained and experienced sonographers (with more than 5 y of experience) who were blinded to the results of the DSA.

Color doppler flow imaging

A Y-shaped color flow image of the bilateral IVA and BA was visualized through the occipital window (Fig. 1a). The BA was detected from the junction of the bilateral VA to the end of the BA, and the detection range was 2–4 cm because the average length of the BA was 2.5–3.8 cm (Mamatha et al. 2012). The BA was considered normal when color filled the arterial lumen and considered stenotic when color flow lumen narrowed at a local site. Through the temporal window, using color flow imaging modalities in the midbrain section, the complete circle of Willis was identified, including the middle cerebral artery (MCA), the anterior cerebral artery (ACA) and the PCA (Fig. 1c). The posterior communicating artery could be visualized from this section when it was embryonic existence or opening (Fig. 1c).

Spectrum doppler

The flow velocities of the BA, IVA and PCA were acquired. Angle correction was performed as less than 30° when the sample volume (with 5-mm gate) was located in a sufficiently long and straight vessel (Nedelmann et al. 2009). For each artery, the peak systolic velocity (PSV), end diastolic velocity (EDV) and mean flow velocity (MFV) were measured. The highest PSV of the bilateral PCA and the IVA were adopted as PSV_{PCA} and PSV_{IVA}. The PSV of the unilateral PCA was recorded as PSV_{PCA} when TCCS detected a contralateral posterior communicating opening. The ratios of PSV in the BA to that in the IVA and PCA (PSV_{BA}/PSV_{IVA} and PSV_{BA}/PSV_{PCA}) were also calculated.

Digital subtraction angiography procedure

The DSA examinations were performed using the double C arms of an Artis Zee biplane angiography machine (Siemens, Munich, Germany). The degree of BAS was evaluated by DSA as the gold standard independent of ultrasound by two skilled interventional neurology specialists.

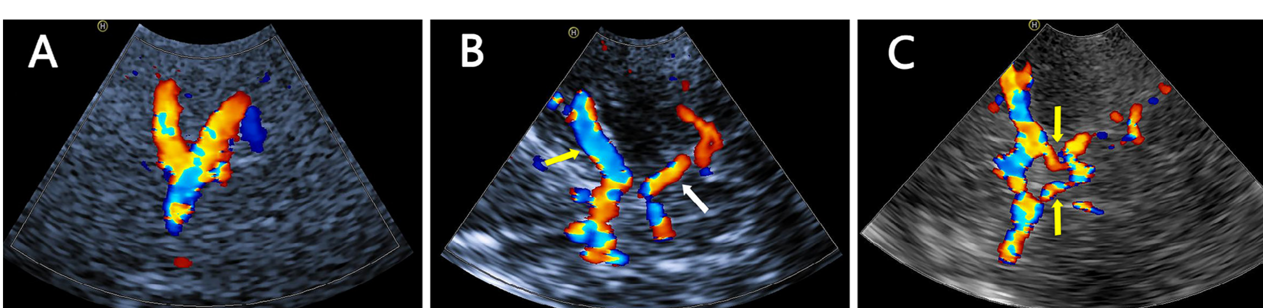

Fig. 1. TCCS image of normal BA, IVA, PCA and opening posterior communicating artery. (a) TCCS reveals the Y shape of normal BA and the bilateral side of the IVAs. (b) TCCS reveals the MCA (*yellow arrow*) and PCA (*white arrow*) through temporal windows. (c) TCCS reveals the bilateral side of the opening posterior communicating artery (*yellow arrow*). TCCS = transcranial color-coded sonography; BA = basilar artery; IVA = intracranial vertebral artery; PCA = posterior cerebral artery; MCA = middle cerebral artery.

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