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Transcranial Doppler Ultrasonography of the Basilar Artery in Cerebral Small Vessel Disease

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Abstract

This study evaluates the diagnostic value of transcranial Doppler ultrasonography (TCD) of the basilar artery in patients with cerebral small vessel disease (CSVD). TCD, specifically via the transforaminal (suboccipital) approach, is a non-invasive method to assess cerebral hemodynamics, particularly in the posterior circulation. Although it cannot directly visualize small vessels due to limited spatial resolution, it can detect indirect indicators of microvascular dysfunction—most notably elevated pulsatility index (PI) and reduced end-diastolic velocity (EDV), both of which suggest increased distal resistance and impaired perfusion.

A clinical study involving 84 patients with CSVD (verified by STRIVE criteria) found that the mean PI was significantly elevated (1.6±0.1), while EDV and mean flow velocity (MFV) were decreased, reflecting posterior hypoperfusion. No macroangiopathy (e.g., stenosis, turbulent flow) was observed. In patients with accessible temporal windows, additional TCD via the transtemporal approach revealed similar findings, reinforcing the transforaminal method's utility when the temporal bone window is closed—common in elderly patients.

The method demonstrated 76.9% sensitivity and 81.3% specificity for detecting indirect signs of CSVD. Though operator-dependent and non-specific in differentiating from other pathologies, transforaminal TCD offers practical advantages: it is non-invasive, suitable for repeated use, and valuable when MRI is unavailable. It is most effective when integrated into a multimodal diagnostic approach, including clinical evaluation and neuroimaging.

Conclusion: Transforaminal TCD is a clinically promising and sufficiently accurate tool for assessing cerebral hemodynamics in CSVD, especially for identifying increased cerebrovascular resistance and impaired posterior perfusion.

Key words: transcranial doppler; transforaminal access; posterior circulation; cerebral small vessel disease; blood perfusion

Transcranial Doppler ultrasonography (TCD) of the basilar artery is a non-invasive method for assessing cerebrovascular hemodynamics, especially in the posterior circulation of the brain [1, 2]. In the context of cerebral small vessel disease (CSVD) [3]—a condition primarily affecting penetrating arterioles—Doppler sonography can provide supportive information, even though the small vessels themselves are not directly visualized due to the limited spatial resolution of the method [1, 4].

Although small vessel pathology mainly involves penetrating arterioles (e.g., lenticulostriate arteries), examination of large basal arteries, such as the basilar artery, may yield indirect indicators of cerebral microcirculation. Typical changes include elevated pulsatility index (PI), which reflects increased distal resistance, and reduced linear blood flow velocity. It is important to note that normal flow in the basilar artery does not rule out CSVD, but rather indicates the absence of large-vessel involvement [4-6].

TCD enables dynamic monitoring of cerebral hemodynamics and the effectiveness of treatment (e.g., antihypertensive therapy) [7]. In addition, abnormal parameters may be useful for risk stratification in patients with lacunar strokes or white matter hyperintensities. Limitations of the method include its inability to directly visualize small cerebral vessels (thus functioning as an indirect marker) and operator dependence. It may also be less informative in the presence of complex basilar artery anatomy [1, 2, 8].

A significant advantage of the method is its applicability when the temporal window is inaccessible (which is often the case in elderly patients or those with dense cranial bones) [1, 4, 8]. In such scenarios, transcranial Doppler via the temporal window (e.g., for the middle cerebral artery) may not be feasible, whereas the basilar artery can be assessed via the transforaminal (suboccipital) approach, making this method clinically promising [1, 2]. Unfortunately, the number of studies on basilar artery TCD remains limited.

The aim of this study was to assess the diagnostic value of basilar artery Doppler sonography in cerebral small vessel disease.

Materials and Methods

The study was conducted at the clinical departments of the Medical Institute of Petro Mohyla Black Sea National University (Mykolaiv) from 2021 to 2024. A total of 84 patients with CSVD verified according to STRIVE criteria [9] were examined. All patients underwent TCD via the transforaminal approach; in 33 patients with an accessible temporal window, additional examination via the transtemporal approach was performed.

The study was conducted in accordance with modern bioethical standards [10]. All patients signed informed consent forms. Statistical analysis was performed using frequency methods in Statistica 14.1.25 software (TIBCO, USA) [11].

Results

The mean age of patients with CSVD was 63.5±0.4 years. Men predominated—49 patients (58.3%). All patients reported memory and attention deficits and difficulties with planning activities (100%). Seventy-one patients (84.5%) experienced rapid mental fatigue. Frequent headaches were reported by 78 (92.9%) patients, dizziness by 40 (47.6%), and unsteady gait by 33 (39.3%). Tremor was observed in 43 (51.2%) patients, and urinary disturbances in 28 (33.3%).

The most common comorbidities were hypertension (79 cases, 94.1%), coronary heart disease (54 cases, 64.3%), type 2 diabetes mellitus (35 cases, 41.7%), and COPD (19 cases, 22.6%). A history of transient ischemic attacks was present in 37 (44.0%) patients.

White matter changes were graded as Fazekas I in 9 patients (10.7%), Fazekas II in 43 (51.2%), and Fazekas III in 32 (38.1%).

In patients with accessible temporal windows, cerebral hemodynamic changes were detected by ultrasonography in the form of elevated reactivity index (up to 1.4±0.3) and pulsatility index (up to 0.7±0.1), indicating impaired perfusion and reduced cerebrovascular reserve.

The following hemodynamic parameters were recorded by TCD (Table 1). The average peak systolic velocity was 40.5±0.9 cm/s, end-diastolic velocity—11.4±0.8 cm/s, and mean flow velocity—21.2±0.9 cm/s. The mean Gosling's pulsatility index was 1.6±0.1, and Pourcelot's resistive index was 0.7±0.1.

Table 1. TCD Parameters in Patients with CSVD

Parameter	**Value**	**Reference Range**
Peak Systolic Velocity	44.5±0.9 cm/s	40–60 cm/s
End-Diastolic Velocity	11.4±0.8 cm/s	18–25 cm/s
Mean Flow Velocity	21.2±0.9 cm/s	30–45 cm/s
Pulsatility Index (PI)	1.6±0.1	0.6–1.2
Resistive Index (RI)	0.7±0.1	0.50–0.65

The blood flow spectrum was laminar, without signs of turbulence (Fig. 1).

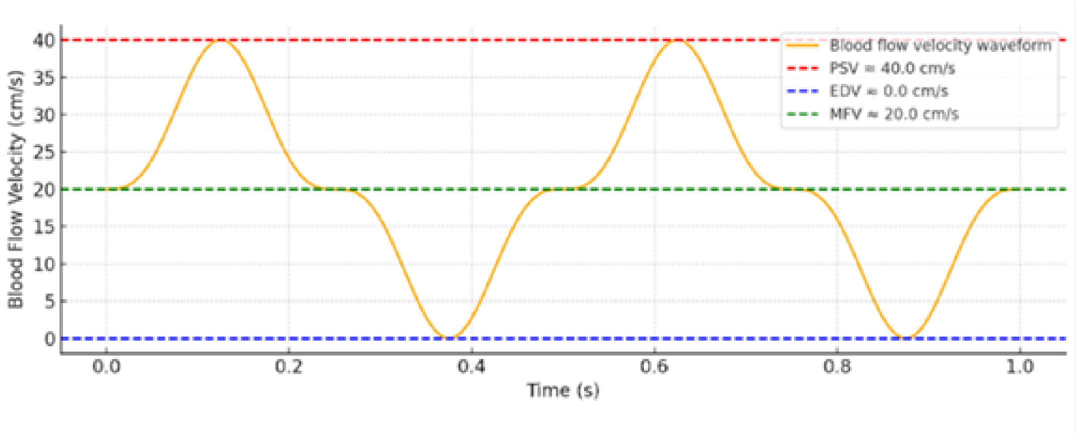

Fig. 1. Blood flow spectrum in the basilar artery in CSVD

Thus, blood flow in the basilar artery in patients with CSVD is characterized by increased PI, indicating elevated resistance in distal (small) vessels. Additionally, decreased EDV and MFV values reflect reduced perfusion in the posterior circulation, correlating with white matter hypoperfusion. The absence of stenosis or turbulent flow suggests no signs of macroangiopathy.

Although the described changes are not pathognomonic for CSVD, when considered alongside clinical data and MRI findings, they support the diagnosis of hypoperfusion in the posterior circulation and increased cerebrovascular resistance.

While Doppler sonography of the basilar artery does not allow direct visualization of small vessel lesions, elevated PI and altered flow patterns may serve as indirect indicators of microvascular dysfunction. The method is most effective as part of a multimodal assessment, including MRI (white matter hyperintensities, lacunes, etc.) and clinical evaluation.

Transcranial Doppler ultrasonography via the transforaminal approach holds significant promise for the diagnosis of cerebral small vessel disease, even though it cannot directly visualize penetrating arterioles. This approach enables evaluation of hemodynamics in the basilar and vertebral arteries—key components of the posterior circulation. In the context of CSVD, PI and EDV are the most informative parameters. A PI greater than 1.2–1.3 is interpreted as a marker of increased distal resistance, typical of cerebral microangiopathy, while a reduced EDV indicates compromised diastolic filling and impaired microperfusion.

According to our data, TCD demonstrates a sensitivity of 76.9% and specificity of 81.3% in detecting indirect signs of CSVD. Diagnostic accuracy can be improved by using a multidisciplinary approach that incorporates clinical symptoms (cognitive decline, gait disturbances, lacunar strokes) and MRI findings (leukoaraiosis, subcortical lacunes). Advantages of the transforaminal approach include independence from the temporal window (relevant in elderly patients), access to posterior circulation assessment, non-invasiveness, and suitability for dynamic monitoring of therapeutic effects, particularly antihypertensive treatment. Limitations include operator dependence, restricted spatial resolution, and limited specificity, as similar Doppler findings may also occur in large-vessel atherosclerosis, intracranial hypertension, or other conditions. Nonetheless, TCD via the transforaminal approach should be considered a valuable tool in the comprehensive evaluation of patients with suspected CSVD, particularly when MRI is unavailable or when serial hemodynamic monitoring is required.

Conclusions: Transcranial Doppler ultrasonography demonstrates sufficient sensitivity (76.9%) and specificity (81.3%) for the diagnosis of cerebral small vessel disease.

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