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Original Article

Diagnostic significance of transcranial doppler combined with carotid ultrasound in patients with cerebral ischemic stroke

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Abstract: Objective: To explore the diagnostic value of transcranial doppler (TCD) combined with carotid ultrasound (CU) in cerebral ischemic stroke (CIS). Methods: A total of 68 patients with CIS who were treated in our hospital from September 2018 to September 2020 were selected as the research group, and another 68 patients with non-CIS admitted during the same period were selected as the reference group. Both groups underwent TCD and CU examinations to compare their diagnostic values. Results: There were no distinct differences concerning clinical data such as gender ratio, age, BMI value, smoking history, residence, and complications between the two groups ($P > 0.05$). The carotid artery intima-media thickening was reported at a markedly higher rate in the research group compared to the reference group ($P < 0.001$). It was indicated by the CU examination that the degree of carotid artery stenosis in the research group was more severe compared with the reference group ($P < 0.05$). The patients in the research group experienced more severe intracranial artery stenosis relative to the reference group by the TCD examination ($P < 0.05$). The plaque morphology of the research group was predominantly irregular, and the internal echoes were predominantly hypoechoic. The plaque morphology in the reference group was predominantly regular, and the internal echoes were predominantly isoechoic. There was remarkably higher incidence of the research group (78%) with ulcer as compared to the reference group ($P < 0.05$), and no marked difference was observed in the incidence of calcification ($P > 0.05$). The combined diagnostic approach was superior to TCD and CUS alone in the terms of accuracy, sensitivity and specificity ($P < 0.001$). Conclusion: TCD combined with CU can greatly improve the diagnostic efficiency of CIS, and provide more evidence for clinical therapy. It deserves promotion and use.

Keywords: Transcranial doppler ultrasound, carotid ultrasound, cerebral ischemic stroke, diagnostic significance

Introduction

Cerebral ischemic stroke (CIS) is a rapidly progressing cerebrovascular disease characterized by cerebrovascular damage and focal (or overall) damage to brain tissue due to several factors; it has a high morbidity, recurrence, and mortality [1, 2]. Clinical studies have shown that this disease remains the leading cause of death in China, and its onset predominantly happens in winter. Meanwhile, the peak time is concentrated near the midday period [3]. Epidemiological studies have found that it is more likely to occur in males than in females, and in urban areas compared to rural areas, and the incidence is rising annually. For CIS patients, early diagnosis and treatment can reduce the disability rate and mortality of CIS patients to a great extent. At present, multi-slice spiral CT, digital subtraction angiography (DSA) and other techniques are mostly used for the diagnosis of diseases in clinical practice. The above diagnostic techniques, in spite of their strengths in the detection of the degree of atherosclerosis in arterial vessels of patients, cannot be repeated within a short period of time, and thus it is a challenge to accurately capture changes in their conditions and that affects clinical treatment [4-6]. In recent years, with the advancing medical diagnostic techniques, the application of transcranial doppler (TCD), carotid ultrasound (CU) and other diagnostic techniques has emerged. TCD uses the weak part of human skull as the examination acoustic window and uses the Doppler effect to explore the hemodynamics of cerebral low artery. It is a non-invasive ultrasonic detection technique. As one of the effective means to

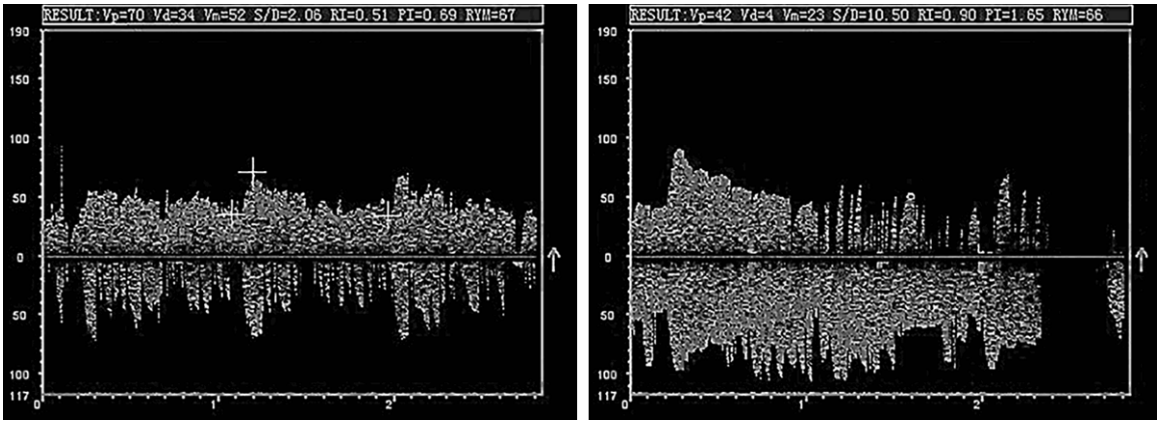

Figure 1. TCD indicates that bilateral internal carotid artery end-middle cerebral artery flow rate increased significantly, accompanied by spectrum disturbance, vortex formation, consider bilateral internal carotid artery end-middle cerebral artery stenosis; neck pressure test confirmed the right anterior cerebral artery, bilateral posterior cerebral artery compensation; decreased cerebrovascular elasticity.

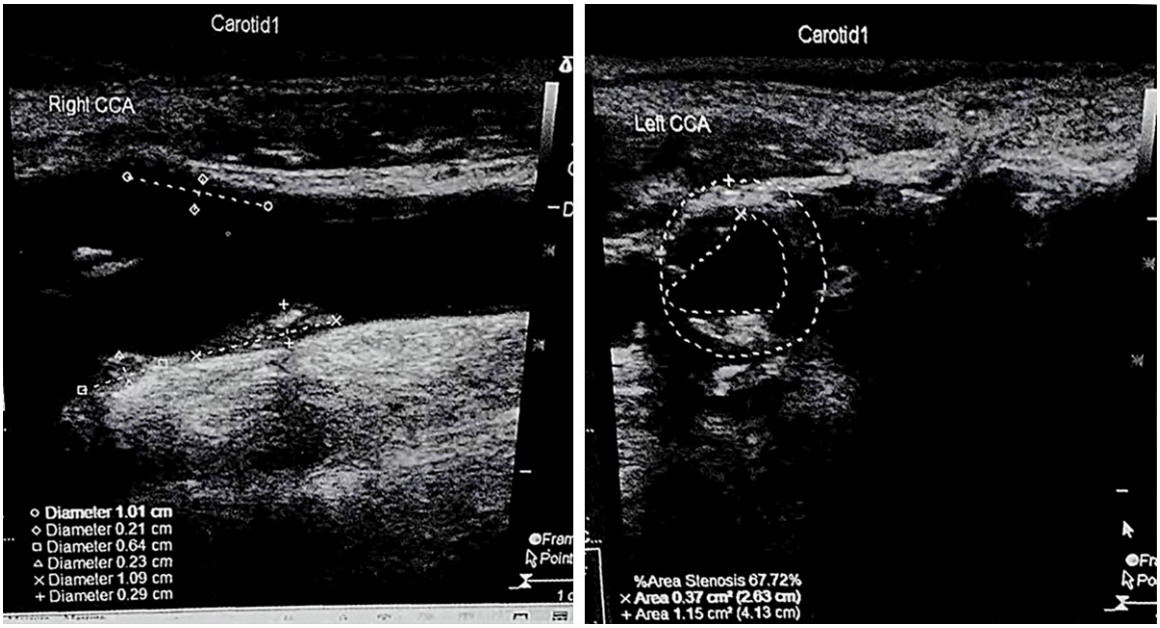

Figure 2. CU prompts a bilateral carotid and vertebral arteriosclerosis; several multiple atherosclerotic plaques on both sides of the neck; mild stenosis of the lumen at the bulb of the right common carotid artery; moderate stenosis of lumen at bulbous plaque of common carotid artery at left side.

diagnose and evaluate carotid artery disease in patients, CU plays a key role in the treatment and prevention of atherosclerosis [7-9]. Therefore, the present trial was undertaken to further investigate the clinical value of TCD combined with CU for CIS.

Materials and methods

General data

A total of 68 patients with CIS who were treated in our hospital from September 2018 to September 2020 were selected as the research group, and another 68 patients with non-CIS admitted during the corresponding period were selected as the reference group. The TCD and CU of a typical case were shown in **Figures 1** and **2**.

Inclusion criteria

① The patients in the research group were eligible for the diagnostic criteria of CIS [2, 3]; ② There was no cerebral infarction or vascular lesion by head CT in the reference group; ③

This study was approved by the Ethics Committee of the hospital, and the patients and their families had an intimate knowledge of the purpose and procedure of this experimental study, and signed the informed consent form.

Exclusion criteria

① Those with cerebral infarction caused by cerebral hemorrhage, arteriovenous malformation and other factors; ② Those with mental and other cognitive impairment or communication disorders; ③ Those with unclear temporal window display.

Methods

TCD diagnosis: Belse color Doppler ultrasound diagnostic instrument (manufacturer: Xuzhou Belse Electronic Technology Co., Ltd.) was used with the probe frequency set to 1.8 MHz. The subject was placed in the supine position, and the anterior circulation was explored through the temporal window, occipital window, and eye window using a probe: anterior cerebral artery (ACA), posterior cerebral artery (PCA), middle cerebral artery (MCA) and terminal internal carotid artery (TICA); posterior circulation: vertebral artery (VA), basilar artery (BA) and other sites, to capture and record the arterial diameter, peak systolic velocity, hemodynamic parameters of the subjects to determine the level of arterial stenosis of the patients. The determination criteria of intracranial artery stenosis [10] was as follows: 0% for normal, 1-50% for mild, 51-69% for moderate, 70-99% for severe, and 100% for occlusion. Mean blood velocity (Vm): 90-140 cm/s for mild carotid stenosis, 141-179 cm/s for moderate carotid stenosis with a partially filled spectral window accompanied by a coarse murmur, and ≥ 180 cm/s for severe carotid stenosis with a filled spectral window accompanied by a high-intensity coarse murmur. The exploration depth of probe was set to 45-60 mm, and the discontinuous bleeding signal from the MCA was regarded as an occlusion.

CU diagnosis: With VEDENG color Doppler ultrasound diagnostic instrument (manufacturer: Nanjing Vedeng Medical Co., Ltd.), the subject was placed in a horizontal position, the neck was fully exposed, the probe frequency was set to 7.0 MHz, and a longitudinal scan was carried out from the outer edge of the sternocleidomastoid muscle and the clavicle. Furthermore, the vertical distance from the intimal interface of the internal carotid artery and common carotid vessels to the adventitial interface and the medial interface was measured, and the intima-media thickness of the bifurcation was measured to maximize the display of the highest position of the carotid artery, and observe whether there were plaques and their size, echo, location and specific number. The severity of carotid stenosis was classified [11] as mild (≤ 50%), moderate (51-69%), severe (70-99%) and occlusion (100%). Mild stenosis had a peak end-diastolic velocity (EDV) of ≤ 40 cm/s and peak systolic velocity (PSV) of ≤ 125 cm/s; moderate stenosis had EDV of 41-99 cm/s and PSV of 126229 cm/s; severe stenosis had EDV of ≥ 100 cm/s and PSV of ≥ 230 cm/s; no flow signal was considered as occlusion.

Observation indicators

The degree of carotid artery stenosis, carotid artery intima-media thickening and intracranial artery stenosis were statistically analyzed and compared between the two groups.

The accuracy, sensitivity, and specificity of combined diagnosis of TCD and CUS versus TCD and CUS alone were statistically analyzed and compared.

Statistical methodology

The experimental data were statistically analyzed and processed by SPSS 21.0 software, and GraphPadPrism6 (GraphPadSoftware, SanDiego, USA) was used to illustrate the figures. Enumeration data were analyzed by chi-squared test, and expressed as [n (%)]; measurement data were analyzed by t test, and expressed as ($\bar{x}$ ± sd). $P < 0.05$ suggested the presence of statistically significant difference.

Results

Comparison of clinical data in the two groups

There were no distinct differences concerning clinical data such as gender ratio, age, BMI value, smoking history, drinking history, marital status, residence, and complications between the two groups ($P > 0.05$) (**Table 1**).

Table 1. Comparison of clinical data in the two groups [n (%), $\bar{x}$ ± sd]

Category	n	Research group (n=68)	Reference group (n=68)	χ^2/t	P
Gender				0.118	0.731
Male		35 (51.47%)	37 (54.41%)		
Female		33 (48.53%)	31 (45.59%)		
Mean age (year)		62.34±4.52	62.37±4.48	0.039	0.969
BMI (kg/m^2)		21.31±2.08	21.29±2.05	0.056	0.955
Smoking history				0.120	0.729
No		40 (58.82%)	38 (55.88%)		
Yes		28 (41.18%)	30 (44.12%)		
Drinking history				0.031	0.861
No		41 (60.29%)	40 (58.82%)		
Yes		27 (39.71%)	28 (41.18%)		
Marital status				0.697	0.404
Unmarried		64 (94.12%)	66 (97.06%)		
Married		4 (5.88%)	2 (2.94%)		
Residence				0.119	0.730
Town		29 (42.65%)	31 (45.59%)		
Village		39 (57.35%)	37 (54.41%)		
Complications					
Brain edema		16 (23.53%)	17 (25.00%)	0.040	0.841
Pneumonia		16 (23.53%)	14 (20.59%)	0.171	0.679
Urinary tract infection		15 (22.06%)	16 (23.53%)	0.042	0.838
Deep vein thrombosis		21 (30.88%)	21 (30.88%)	0.000	1.000

Table 2. Comparison of the incidence of carotid artery intima-media thickening in the two groups [n (%)]

Group	Intima-media thickening	Normal intima-media
Research group	62 (91.18)	6 (8.82)
Reference group	19 (27.94)	49 (72.06)
χ^2	56.445	
P	< 0.001	

Comparison of the occurrence of carotid artery intima-media thickening in the two groups

The carotid artery intima-media thickening was reported at a markedly higher rate in the research group compared to the reference group (P < 0.05) (**Table 2**).

Comparison of the occurrence of carotid artery stenosis in the two groups

It was indicated by the CU examination that the degree of carotid artery stenosis in the research group was considered to be more severe compared with the reference group (P < 0.05) (**Table 3**).

Comparison of the occurrence of intracranial artery stenosis in the two groups

The patients in the research group experienced more severe intracranial artery stenosis in relative to the reference group, as confirmed by the TCD examination (P < 0.05) (**Table 4**).

Comparison of the occurrence of carotid plaques in both groups

The plaque morphology of the patients in the research group was predominantly irregular, and the internal echoes were predominantly hypoechoic. The plaque morphology in the reference group was predominantly regular, and the internal echoes were predominantly isoechoic. There was remarkably higher incidence of the research group (78%) presenting with ulcer as compared to the reference group (P < 0.05), and no marked difference was observed in the incidence of calcification between the two groups (P > 0.05) (**Table 5**).

Comparison of diagnostic efficacy between combined diagnosis and single diagnosis

The combined diagnostic approach was superior to TCD and CUS alone in the terms of accuracy, sensitivity and specificity (P < 0.05) (**Table 6**).

Discussion

The etiology of CIS is complicated and diverse. It is well known that cerebral arterial embolism, hematological factors, and rheumatoid arthritis are attributable to CIS. In addition, it is also associated with the hypertension, diabetes, and poor lifestyle habits (smoking, staying up late) in patients [12]. Due to the sudden onset of the disease, patients often present with nausea, headache, vomiting, and varying

Table 3. Comparison of the occurrence of carotid artery stenosis in the two groups [n (%)]

Group	Normal or mild	Moderate	Severe	Occlusion
Research group	43 (63.24)	19 (27.94)	4 (5.88)	2 (2.94)
Reference group	59 (86.76)	6 (8.82)	2 (2.94)	1 (1.47)
X^2	10.039	8.283	0.745	0.145
P	0.002	0.004	0.968	0.979

Table 4. Comparison of the occurrence of intracranial artery stenosis in the two groups [n (%)]

Group	Normal or mild	Moderate	Severe	Occlusion
Research group	19 (27.94%)	29 (42.65%)	16 (23.53%)	4 (5.88%)
Reference group	46 (67.65%)	18 (26.47%)	4 (5.88%)	0 (0.00%)
X^2	21.483	3.934	8.411	0.142
P	< 0.001	0.047	0.004	0.854

degrees of disturbance of consciousness and quadriplegia. Theoretically, the ischemic necrosis in local brain tissue is primarily attributable to arterial stenosis or obstruction. However, it was found clinically that due to long-term insufficient blood supply to the brain of most CIS patients, a compensatory reaction mechanism takes shape in their bodies, resulting in collateral circulation to supply brain tissue. Accordingly, it is thought that severe stenosis of arterial vessels will not aggravate the clinical symptoms of patients [13-15]. Mantella et al. [16] stated that hemodynamics at the arterial stenosis in CIS patients are extremely unstable, and that agitation and overexertion may increase the incidence of CIS. Presumably, atherosclerotic plaque combined with arterial stenosis predisposes vulnerable plaques and increases the risk of developing CIS. Therefore, efficient, safe measures should be initiated for the diagnosis of CIS.

The internal structure of the carotid artery in the subjects was clearly shown by the CU, which mostly appears as a hyperechoic, hypoechoic double-line sign, and the intima-media thickening was an early stage in the appearance of atherosclerosis and was closely related to the occurrence of CIS [17]. In this study, the carotid artery intima-media thickening was reported at a markedly higher rate in the research group compared to what was observed in the reference group ($P < 0.001$), suggesting that carotid artery intima-media thickening in patients is crucial in CIS diagnosis. Besides, CU was also found to dynamically monitor the situation of arterial vessels in patients, detect early the size, specific location and internal echo of atherosclerotic plaques in their arterial vessels, and accurately assess the nature of plaques so as to provide theoretical support for clinical therapy. Moreover, the presence of hypoecho within the patient's plaques suggested a more complex lipid composition, which, once irregularly shaped, was presumably related to ulceration of the fibrous cap.

Forjoe et al. [18] have noted in the literature that those with carotid artery stenosis or occlusion have a highly unstable blood flow velocity that predisposes them to atherosclerotic plaque breakdown and eventually induces CIS. As a noninvasive imaging technique for clinical detection of intracranial hemodynamic parameters in patients, TCD is a sign of intracranial vascular lesions when the internal blood flow velocity slows down and the peak deformation becomes dull by measuring the blood flow velocity and spectral morphology in their ACA and MCA, which is of crucial importance for the early diagnosis of the disease [19]. This study showed that patients in the research group had more severe carotid artery stenosis than the reference group as indicated by the CU ($P < 0.05$), presumably there was a correlation between their carotid artery stenosis and CIS. Furthermore, this study confirmed that the accuracy of the combined diagnosis model was significantly higher than CU and TCD alone ($P < 0.001$). Klein et al. [20] found in the study that the clinical diagnostic accuracy of CU combined with TCD (90.84%) showed a markedly higher trend as compared with the CU alone (71.24%) and the TCD alone (69.75%) in patients with hemorrhagic stroke, suggesting that CU combined with TCD could improve the diagnostic accuracy of CIS and upgrade the diagnostic efficacy. However, this study may be biased due to the lack of statistics on the sensitivity and specificity of TCD, CU and TCD combined with CU, and the absence of rigorous diagnostic performance basis.

In conclusion, the combined diagnostic approach can greatly improve the clinical diagnostic efficacy of CIS patients, with exact effect. It deserves promotion and use.

Table 5. Comparison of the occurrence of carotid plaque in the two groups [n (%)]

Group	Morphology		Ulcer	Calcification	Homogeneous echo			Heterogeneous echo
	Regular	Irregular			Hyperecho	Isoecho	Hypoecho	
Research group (n=68)	21 (30.88%)	47 (69.12%)	19 (27.94%)	15 (22.06%)	5 (7.35%)	4 (5.88%)	10 (14.71%)	35 (51.47%)
Reference group (n=68)	45 (66.18%)	23 (33.82%)	4 (5.88%)	13 (19.12%)	2 (2.94%)	10 (14.71%)	2 (2.94%)	6 (8.82%)
X^2	16.956	16.956	11.774	0.180	1.356	2.867	5.850	29.365
P	0.000	0.000	0.001	0.671	0.244	0.090	0.016	0.000

Table 6. Comparison of diagnostic efficacy between combined diagnosis and single diagnosis [% (n)]

Diagnostic approach	Accuracy	Sensitivity	Specificity
CU	71.32% (97/136)	75.00% (51/68)	63.24% (43/68)
TCD	69.85% (95/136)	70.59% (48/68)	66.18% (45/68)
TCD+CU	91.18% (124/136)	94.12% (64/68)	89.71% (61/68)
X^2	17.593	12.952	13.240
P	0.000	0.000	0.000

Disclosure of conflict of interest

None.

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