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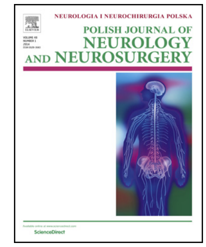

Original research article

What influenced the lesion patterns and hemodynamic characteristics in patients with internal carotid artery stenosis? A retrospective study

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ABSTRACT

Objectives: This study aimed to explore the dynamic changes of lesion patterns and hemodynamic characteristics in patients with internal carotid artery stenosis (ICAS).

Patients and methods: Patients who had suffered an acute ischemic stroke in the distribution of ipsilateral ICAS were included. Computed tomography (CT) and transcranial doppler ultrasound (TCD) were conducted to evaluate the degree of ICAS and the hemodynamic characteristics of the intracranial and extracranial arteries.

Result: A total of 424 patients were included in the study. With the aggravation of ICAS, blood velocity in ipsilateral ICA was increased, while blood flow in the ipsilateral middle cerebral artery (MCA) was decreased. In the same degree of ICAS, patients with opened communicating arteries showed relatively higher blood perfusion in MCA compared with those without communicating arteries. In the average stage of ICAS, small lesions ($D = 0$–1.5 cm), middle lesions (1.5 cm $< D \leq 3.0$ cm) and large lesions ($D > 3.0$ cm) commonly existed. The number of small and large lesions significantly increased when the blood flow of ipsilateral MCA decreased. In the same degree of stenosis, the number of small lesions and large lesions, and the total area of all lesions, evidently increased with the decrease of ipsilateral MCA blood velocity.

Conclusion: Hypoperfusion is an independent risk factor for ischemic lesions in patients with ICAS. Whether or not the communicating arteries are open influences the blood flow of the intracranial arteries. TCD was a convenient and rapid tool to assess intracranial perfusion and vascular compensatory status.

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1. Introduction

Ischemic stroke is one of the most common causes of acquired disability, dementia and death, with significant psychological and economic burden [1]. Two basic mechanisms are proposed to account for ischemic events in carotid artery occlusive disease: (1) emboli from carotid plaque and (2) hypoperfusion in distal arteries [2–4]. However, most of these studies mainly focused on severe stenosis (≥70%) [3–8]. Dynamic change of lesion characteristics and artery hemodynamic characteristics in all degrees of ICAS has not been demonstrated.

The hemodynamic character of the intracranial cerebral hemisphere depends predominantly on the degree of ICAS [9,10]. However, many other factors, such as individual difference, openness of communicating arteries, and formation of new vessels, might also influence the blood velocity of intracranial arteries. TCD is a widely used, noninvasive method for the evaluation of hemodynamics in extracranial arteries and intracranial arteries [8]. Combined with CT angiography (CTA), TCD could more accurately reflect the blood flow of the intracranial arteries. Thus, in this study, we included patients who underwent CTA and TCD to evaluate the blood perfusion in distal cerebral arteries and communicating arteries, rather than the degree of ICAS itself.

Patients tend to go to the hospital mostly because of symptomatic lesions. However, from CT scanning or magnetic resonance imaging (MRI), we know that many patients have suffered asymptomatic or mild symptomatic lesions before they go to a doctor. These lesions may influence their cognitive function or other latent functions [11,12]. Therefore, we also aimed to collect all lesions detected by past medical histories, CT scanning, MRI and diffusion-weighted imaging (DWI) to get a more detailed description of these lesions.

2. Patients and methods

2.1. Inclusion and exclusion criteria

We retrospectively reviewed 2801 patients who had suffered acute cerebral ischemia confirmed by DWI scanning from 2010 to 2016. Inclusion criteria: patients with unilateral ICAS (0%–99%) or complete occlusion of internal carotid artery (ICA) (100%), as confirmed by CTA. Exclusion criteria: patients with other brain pathology (such as tumors, idiopathic or hereditary artery diseases, or multiple sclerosis), bilateral ICAS, carotid endarterectomy, internal carotid artery stent implantation, intracranial artery stenosis, potential cardiac sources of embolism, heart failure, nonatherosclerotic vasculopathies, and hematologic diseases. Patients were divided into 4 groups according to the degree of ICAS (0%–49%, 50%–69%, 70%–99%, and 100%). This study was approved by the ethics committee of the Dalian Central Municipal Hospital. Written or telephoned informed consent was obtained from all patients.

2.2. Data collection

A total of 424 patients were included in the study. All patients had undergone both DWI examination (Philips Achieva 3.0 T magnetic resonance system, Philips Healthcare, USA, 5 mm-thick slices) and CT scanning (Discovery HD750, GE Medical Systems, USA, 5 mm-thick slices) to find the responsible foci of acute stroke. The number of ischemic lesions (lesions that were not distributed in the same branch artery or were isolated from each other were counted as two or more) and the diameter of lesions were analyzed by two professional investigators blinded to both clinical and image data. Ischemic lesions were divided into small lesions (≤1.5 cm in diameter, according to the Adams classification [13]), middle lesions (1.5–3.0 cm in diameter), and large area infarcts (>3.0 cm). The area of every lesion was estimated as (major axis multiply by minor axis)/2 cm^2. The total area of all lesions was also calculated to present the degree of brain damage. Lesions were also divided into acute lesions and old lesions as well as symptomatic lesions and asymptomatic lesions.

CTA was conducted by contrast-enhanced, high-speed CT (Discovery HD750, GE Medical Systems, USA). The image of CTA was evaluated by professional investigators blinded to clinical and image data. The degree of stenosis was evaluated as mild stenosis (0%–49%), moderate stenosis (50%–69%), severe stenosis (70%–99%) and complete occlusion (100%) according to the North American Symptomatic Carotid Endarterectomy Trial method [14]. From the image of CTA, we also assessed the opening of the anterior communicating artery or posterior communicating artery.

Among the 424 patients, 374 had undergone a detailed TCD examination to evaluate the hemodynamic status of the bilateral intracarotid artery, bilateral MCA, bilateral anterior cerebral artery (ACA), Willis circle, and supratrochlear artery using the GE Vivid 3 Ultrasound system (GE Medical Systems, USA), equipped with a 2 and 4-MHz probe. Sixty patients failed to receive a complete result because of an unsatisfactory transtemporal and transorbital window. The M1 segment of MCA was detected through the transtemporal window, while the A1 segment of ACA was measured through the transorbital or transtemporal window. An opened, closed or congenital defective Willis circle was evaluated through the blood direction of the ipsilateral A1 segment of ACA, blood velocity of the contralateral A1 segment of ACA, blood velocity of the P1 segment and P2 segment of the bilateral posterior cerebral artery, and the pressing test of the carotid artery. Blood direction of the supratrochlear artery was also examined to estimate the openness of the ophthalmic artery and traffic between the internal and external carotid artery. We calculated the difference of bilateral MCA blood velocity to evaluate the degree of hypoperfusion in ipsilateral intracranial arteries.

2.3. Assessment of baseline characteristics

Baseline data including age, sex, diabetes, hypertension, hyperlipemia, and smoking history were collected to analyze the risk factors of ICAS.

2.4. Statistical analyses

Statistical analyses were performed with IBM SPSS Statistics version 20 (SPSS Inc., Chicago, Illinois). Values were expressed as the means ± SD. Analysis of variance was used to compare continuous variables between groups. Correlation analysis was

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