The study of cerebral autoregulation in patients with severe carotid artery stenosis or occlusions

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Abstract

To our knowledge, there is no recognized gold standard for determining automatic regulation of the cerebral blood flow to pinpoint whether the cerebral blood flow autoregulation (CA) is damaged in patients with severe carotid artery stenosis or occlusion. To evaluate the prognosis of stroke, we used transcranial Doppler combined with posture changes to monitor the CBFV on the bilateral middle cerebral arteries (MCAs). Our conclusions are that the CA is damaged in patients with severe carotid artery stenosis or occlusion, and symptomatic patients have poorer cerebral blood flow autoregulation than asymptomatic ones. The blood flow compensatory mechanism is incomplete, and the supine-standing CBFV changes influence the prognosis of the stroke.

Keywords: internal carotid artery, cerebral blood flow autoregulation, prognosis.

1 Introduction

The internal carotid artery is an important source of blood supply for the cerebral hemispheres; atherosclerosis caused by severe internal carotid artery stenosis or occlusion (ICASO) is a major cause of ischemic stroke. Internal carotid artery stenosis results in a decrease in blood flow, and the main impact on the brain is low perfusion. Patients with internal carotid artery stenosis or occlusion may have various compensatory mechanisms. Some may have no clinical symptoms, some show nerve function defects, and some have medium to severe neurologic deficits. The differences in the clinical manifestations are due to the degree of cerebral

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ischemia; the occurrence of cerebral ischemia is closely related to the ability of cerebral blood flow to autoregulate. Nowadays, a beat-to-beat pressure detector monitors the vascular reactivity so as to reflect the cerebral blood flow autoregulation (CA). It is popular but expensive and the method and analytical process is complex. Considering transcranial Doppler (TCD) is cheaper and more convenient, we use TCD combined with posture changes to monitor the cerebral blood flow velocity (CBFV) changes in the patient's bilateral middle cerebral arteries (MCAs). Timely and accurate evaluation of CA is important for guiding the diagnosis, treatment, and prognosis for cerebrovascular diseases [1, 2].

1.1 Materials

Sixty-one patients with severe carotid artery stenosis or occlusion (37 males, 24 females, age range 36–88 years, average age 58 years) recruited in the outpatient unit of the Department of Neurology at the First Hospital of Jilin University, between January 2010 and June 2011, participated in this study. Inclusion criteria: Severe stenosis (70–99%), PSV 230cm/s, EDV 100cm/s, PSV stenosis segment:distal segment 4.0, a distal segment presenting with low flow velocity, high resistance, and eddy currents. Occlusion with the extracranial segment of the unilateral internal carotid artery lumen filling with hypoechoic, isoechoic, or heterogeneous echo pattern cannot obtain a blood flow signal; the proximal segment presents low speed and high resistance changes. Exclusion criteria: Subjects with known lung disease (asthma, chronic bronchitis, pulmonary fibrosis, etc.), severe arrhythmia (cannot obtain stable TCD curve from supine to standing), orthostatic hypotension or iatrogenic hypotension (cannot move from supine to standing position independently).

1.2 Methods

Subjects with severe carotid artery stenosis or occlusion were diagnosed by using carotid ultrasound (HD11, Phillips) and TCD (EMS-9, Delica, China). The study selected patients with severe carotid artery stenosis or occlusion and divided the patients into injured and uninjured groups. These groups were further subdivided into two groups (symptomatic and asymptomatic groups) according to whether they had a history of stroke or TIA in the past 3 months. A comparison was then made of the blood flow velocity changes in the MCA as well as the duration of each waveform in the patient's uninjured and injured side during a change from a supine to an upright position. To observe whether there were CA changes, we compared the CBFV differences and the duration of the x-w spike between the injured and uninjured side. Additionally, we made regular stroke recovery follow-ups and gave MRS scores to see whether supine-standing CBFV changes are related to stroke recovery.

1.3 Statistics

We used SPSS version 17.0 to calculate the data. Measurement data are presented as mean ± SEM. Paired sample *T*-test or the independent sample *T*-test was used to compare CBFV changes within and between both groups,

Table 1: Supine and Standing CBFV for Bilateral MCA.

Group	Supine CBFV	Standing CBFV	Supine-Standing CBFV Changes
Injured	53.05 ± 18.714	46.57 ± 16.751	5.97 ± 5.727
Uninjured	72.26 ± 22.652*	68.56 ± 21.867**	3.70 ± 3.442***

Annotation: *CBFV of the injured side compared with the contralateral in supine position. CBFV is lower than the contralateral side, $p < 0.001$.
**CBFV of the injured side compared with the contralateral in upright position CBFV is lower than the contralateral side, $p < 0.001$.
***The CBFV changes from supine to upright differed between the two groups. The injured side displayed greater CBFV changes than the contralateral, $p < 0.005$.

Table 2: Duration of X-W Spike for the Injured Side and Uninjured Side in Severe Carotid Artery Stenosis or Occlusion Patients.

Group	n	Duration of X-W Spike (s)
Injured side	61	22.42 ± 4.769
Unijured side	61	21.12 ± 4.394*

Annotation: Comparing the duration of the X-W spike between the injured and uninjured side, $p < 0.001$. The difference is statistically significant.

Table 3: CBFV Changes in Symptomatic and Asymptomatic Group (injured Side).

Group	n	Supine-Standing CBFV Changes (Injured Side)
Asymptomatic	29	2.76 ± 3.388
Symptomatic	32	8.59 ± 5.639
p		<0.05

Annotation: Supine-standing CBFV changes in the symptomatic group are larger than in the asymptomatic group, $p < 0.05$. The difference is statistically significant.

respectively, and the level of significance was $p < 0.05$ (Tables 1–3). Nonparametric correlation analysis was used for the correlation between the outcome of stroke and the supine-standing CBFV changes on the injured side (Figures 1 and 2).

2 Result

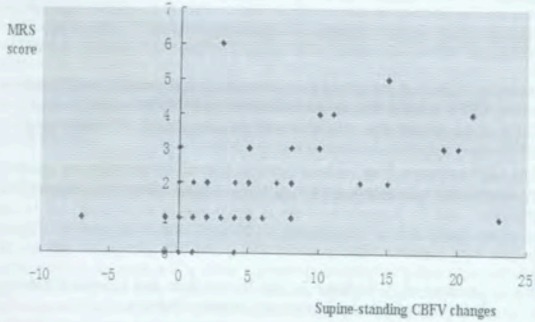

Figure 1: The relationship between supine-standing CBFV changes and the prognosis of stroke. Annotation: Through correlation analysis methods, the supine-standing CBFV changes in the injured side showed a positive correlation with MRS score for the prognosis of patients (p = 0.0005, r = 0.43350, when r □ 0 is statistically significant).

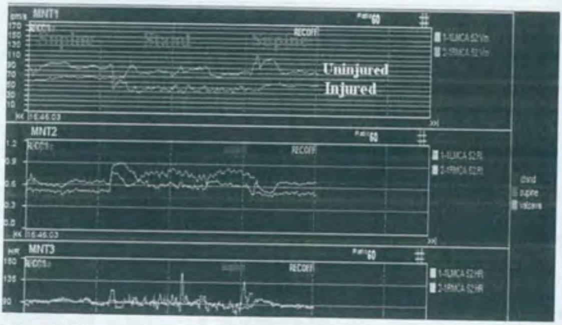

Figure 2: The supine-standing CBFV curve of a patient with severe (70–99%) stenosis of the right internal carotid artery.

3 Discussion

The examination of supine to standing CBFV is to monitor the CBFV changes of the MCA when moving rapidly from a supine to a standing posture. The result of this is called the CBFV curve. This curve mainly includes three important waveforms: when subjects stand abruptly, the CBFV abruptly increases and then decreases, which forms a spike wave defined as the X spike; an automatic adjustment of blood pressure during standing forms the W spike; and an H spike occurs after the patient has switched to a supine posture [3]. The regulation of blood pressure is accomplished within 30 s, and the CBFV autoregulation curves for the bilateral MCA are consistent. The supine to standing CBFV changes measured by performing TCD have been used, not only in Parkinson disease patients, but also as the auxiliary diagnosis for chronic anxiety [4] and progressive facial hemiatrophy [5], where autonomic dysfunction is equal.

In patients with severe carotid artery stenosis or occlusion, the blood pressure response mechanism is not timely with postural or hemodynamic changes, resulting in an inability to maintain a cerebral blood flow (CBF) balance. The patient therefore experiences dizziness, vertigo, nausea, vomiting, and other cerebral hypoperfusion symptoms during this response time.

Blood perfusion distal to severe carotid artery stenosis is often reduced; whether the collateral circulation is established or not plays an important role in the ability of the intracranial arteries to activate self-regulation to compensate. Poor collateral circulation is often related primarily to patients' intracranial hemodynamic status, such as MCA ischemia, which is then followed by various clinical manifestations because of insufficient blood supply. The clinical manifestations and prognosis in patients with severe carotid artery stenosis or occlusion are various; in severe cases massive cerebral infarction may occur, in less severe cases, there may be no clinical symptoms. To provide early, important evidence for effective prevention and treatment measures, we use TCD combined with posture changes to monitor the hemodynamic changes for the severe carotid artery stenosis or occlusion patients in order to determine prognosis for ischemic cerebrovascular disease.

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