EVALUATION OF CEREBRAL PERFUSION AND CEREBRAL HEMODYNAMICS CHANGES IN PATIENTS WITH SYMPTOMATIC CAROTID ARTERY STENOSIS BEFORE AND AFTER STENTING BY DSA PARAMETRIC IMAGING

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ABSTRACT

Objective: Investigating the DSA parametric imaging’s value of application in evaluating the changes of cerebral perfusion and cerebral hemodynamics changes before and after stenting in subjects having symptomatic carotid artery stenosis.

Patients and methods: From March 2006 to March 2017, 30 patients admitted to our hospital with unilateral carotid artery bifurcation stenosis were selected as the subjects. After stenting treatment, the effect of carotid artery stenting on intracranial blood flow was quantitatively evaluated according to the comparisons before and after stenting by using the iFLOW post processing technique with DSA scan.

Results: After operation, the brain peak value and the max slope rates of time - gray scale curves of ipsilateral operation in brain of the subjects were considerably more when compared to those prior to operation (P<0.05), and the time to peak, mean transit time and circulation time of ipsilateral operation were significantly decreased (P<0.05). After operation, the peak value, time of appearance of peak, the time to peak, mean transit time and circulation time of contralateral operation in brain of patients were significantly higher than those of before operation, and there was a considerable variation with probability less than 0.01. After operation, the peak value of posterior circulation was considerably less compared to that before operation with probability less than 0.05, however, the time of appearance of peak, the time to peak, mean transit time and circulation time were significantly higher than before operation, the difference was significant (P<0.05).

Conclusion: The evaluation of cerebral hemodynamics changes after stenting, by using the post processing function of iFLOW, according to the quantitative comparison of blood flow velocity in the same part of intracranial vessels before and after operation, is accurate and reliable.

Keywords: Symptomatic carotid artery stenosis, Stenting, Cerebral perfusion, Cerebral hemodynamics, DSA parametric imaging.

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Introduction

The carotid artery divides at the throat as internal and external carotid artery which supplies blood to brain and face respectively. Formation of plaque at the division leads to narrowing of the artery which is called stenosis. As the artery narrows, the flow of blood to brain is restricted. If plaque breaks off and lodges on blood vessel wall and temporarily restricts blood flow causing transient ischemic attack, or permanent leading to thromboembolic stroke. Carotid artery disease or stenosis is the cause for 15% to 20% of stroke. The risk of stroke from carotid stenosis can be evaluating the degree of stenosis through imaging. The carotid stenosis is either removed by open surgery (carotid endarterectomy) or carotid stent placement. Compared with carotid endarterectomy, carotid stenting is less invasive.

The dynamics of hemodynamic changes after the carotid endarterectomy or stenting is limited. Hyperperfusion Syndrome (HPS) is a complication...
Incorporation criteria:
All patients who participated in the study were eligible for the following criteria:
- Through the whole brain angiography, patients were confirmed the existence of severe internal carotid artery stenosis and willing to undergo carotid stent implantation surgery;
- Asymptomatic, degree of stenosis > 70%;
  symptomatic, stenosis > 50%; NASCET stenosis = (1 - the internal carotid artery’s narrowest width / the normal internal carotid artery’s narrow diseased distal diameter) × 100%;
- Clinical data and imaging data were complete;
- Patients are willing to undergo minimally invasive surgery;
- Patients were informed of this study and signed informed consent.

Methods

Preoperative examination
All patients were examined for preoperative neurological signs and cognitive function, necked blood color Doppler ultrasound, TCD, head and neck CTA or head and neck MRA noninvasive imaging examination. All patients underwent preoperative aortic arch and total cerebral angiography, including external carotid artery, vertebral artery, bilateral common carotid artery, basilar artery angiography, aortic arch angiography and internal carotid artery.

Premedication
Antiplatelet therapy with aspirin 100 mg/d and clopidogrel mg/d for preoperative 3d was administered to all patients. Patients with general medical complications were treated with conventional drugs. The risks of Contrast Induced Nephropathy (CIN) in patients were evaluated with pulmonary arteriography, identified high-risk patients and hydrated them to protect renal function.
All the patients were treated with 1~1.5 ml·kg\(^{-1}\)·h\(^{-1}\) at six~twelve h before operation, the total amount was about 1000 ml. Patients fasted for 6 hours before operation, and given local anesthesia.

**Operation method**

The surgery was performed under the SIMENS dual C-arm angiography, and the patients underwent carotid artery stenting under local anesthesia. Systemic heparinization and review angiography was done to confirm the location of the stenosis, degree, length and collateral circulation in ischemic region. The stenosis and stenosis length were determined, and the appropriate balloon and stent were selected. The 8F guide catheter or 7F long sheath was used to implant the common carotid artery of the proximal vessel. When the catheter was in place, the double C-arm was used to select the full-cranial image and the orthostatic image of the incision of the brain. The angiographic parameters were recorded. After angiography, position parameters of operating table were reset to zero. The distal cerebral protection device was selected through the stenosis segment under the path guidance, pre-expansion were selected for severe stenosis, displacement and expansion pressure of saccule were observed in the expansion, and the blood pressure, heart rate and nerves of patients were observed closely.

After the pre-expansion, the successes of the stent implantation were determined by the stent implantation and radiography, and distal protection device was carefully recovered. If the stent is placed, there was still a narrow >30%, the saccule was used for posterior expansion in the stent before the recovery of distal protection device, then the operating table was moved to the zero parameter, then the double C arm was used to select the Tang’s position image of the whole brain and the normotopia carotid and cerebral panoramic imaging, the parameters of contrast agent injection were consistent with before stenting. Stent position and blood flow status were observed. Intraoperative ECG monitoring was carried on during the surgery, and changes of blood pressure and heart rate were noticed. After the operation, the catheter sheath was removed and the Abbott Proglide suture was used to suture the femoral artery puncture point to stop bleeding. The local pressure dressing was performed after the bleeding, and the blood flow of the lateral side of the puncture and the pulse of the dorsalis pedis artery were observed.

**Data collection**

The posterior radiography and postoperative angiography were post-processed by the iFLOW post-processing function of Siemens angiography. Then, three points were selected on the post-processing image to measure the peak time of the blood flow. The location of the selected points, the location of the catheter, and the imaging parameters were consistent before and after the operation, the measured values were compared. The selected points in this study were Siphon segment of internal carotid artery, central cerebral artery and initial part of pericallosal artery.

**Statistical methods**

For all statistical analysis, SPSS 20 statistical software were used. Measurement of data took place using mean standard deviation. The two groups data were analyzed by t test, when probability was less than 0.05, it signified considerable difference and when probability was less than 0.01, it signified an even more considerable difference.

**Results**

**Preoperative and postoperative ipsilateral brain monitoring parameters**

The results showed that the brain peak value and the max slope rates of time - gray scale curves of ipsilateral operation in brain of patients were considerably more compared to the ones prior to operation with the probability less than 0.05, and the time to peak, mean transit time and circulation time of ipsilateral operation were considerably reduced with probability less than 0.05 (Table I).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before operation</th>
<th>After operation</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak value</td>
<td>107.4±5.29</td>
<td>114.9±6.38</td>
<td>8.276</td>
<td>0</td>
</tr>
<tr>
<td>Max slope rate</td>
<td>1.22±0.21</td>
<td>2.04±0.29</td>
<td>22.687</td>
<td>0</td>
</tr>
<tr>
<td>Time of appearance of peak value</td>
<td>40.32±1.82</td>
<td>40.28±2.88</td>
<td>0.083</td>
<td>0.934</td>
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<tr>
<td>Time to peak</td>
<td>35.83±1.29</td>
<td>31.32±2.98</td>
<td>9.821</td>
<td>0</td>
</tr>
<tr>
<td>Mean transit time</td>
<td>61.48±2.93</td>
<td>26.48±3.28</td>
<td>49.385</td>
<td>0</td>
</tr>
<tr>
<td>Circulation time</td>
<td>36.47±7.47</td>
<td>31.03±6.59</td>
<td>3.49</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table I: The parameters of ipsilateral operation of brain (n=50).

**Preoperative and postoperative contralateral brain monitoring parameters**

The results revealed that, after operation, the peak value, time of appearance of peak, the time to peak, mean transit time and circulation time of contralateral operation in brain of patients were signifi-
cantly higher than those of before operation, and there was a considerable variation with probability less than 0.01 (Table II).

Preoperative and postoperative posterior circulation monitoring parameters

This study suggested that, after operation, the peak value of posterior circulation was considerably less compared to the one prior to operation with the probability less than 0.05, however, the time of appearance of peak, the time to peak, mean transit time and circulation time were significantly higher than before operation, the difference was significant (P<0.05) (Table III).

Typical case diagram

Li Shuxiu, male, 76 years old, was diagnosed as: severe left internal carotid artery proximal stenosis; multiple intracranial artery stenosis: right internal carotid artery and right distal A1 segment of anterior cerebral artery stenosis; hypertension grade 3, very high risk; acute cerebral infarction; middle lobe of the right lung pleural micro nodules lesion (Figure I).

Seldinger method was used to puncture the right femoral artery, and the Cordis 8F catheter sheath was fixed.

The initial segment of patients with left internal carotid artery stenosis, inserted into the right internal carotid artery and left vertebral artery angiography, multi angle projection; found the left internal carotid artery proximal stenosis, > ninety percent stenosis and left internal carotid artery’s initial segment contrast filling defect; and the right internal carotid artery part that is visible, right anterior cerebral artery A1 segment stenosis, review CT had no obvious postoperative intracranial hemorrhage.

Table II: The parameters of the contralateral operation of brain (n=50).

<table>
<thead>
<tr>
<th></th>
<th>Before operation</th>
<th>After operation</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak value</td>
<td>104.38±2.03</td>
<td>114.32±4.21</td>
<td>15.038</td>
<td>0</td>
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<tr>
<td>Max slope rate</td>
<td>2.34±0.47</td>
<td>2.20±0.38</td>
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<td>0.242</td>
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<tr>
<td>Time of appearance of peak value</td>
<td>36.38±3.82</td>
<td>42.98±4.12</td>
<td>8.047</td>
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<tr>
<td>Time to peak</td>
<td>36.37±3.29</td>
<td>41.29±5.19</td>
<td>5.662</td>
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<tr>
<td>Mean transit time</td>
<td>47.08±4.98</td>
<td>54.19±4.12</td>
<td>7.982</td>
<td>0</td>
</tr>
<tr>
<td>Circulation time</td>
<td>32.37±2.38</td>
<td>38.30±1.99</td>
<td>12.757</td>
<td>0</td>
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</table>

Table II: The parameters of the contralateral operation of brain (n=50).

Discussions

At present, carotid artery stenting, carotid endarterectomy and medical treatment are the main methods of treatment of carotid artery stenosis. Carotid artery plaque stripping surgery used in treating carotid artery stenosis, has been recognized as the best treatment for carotid artery stenosis, known as the “the gold standard” of surgical treatment of carotid artery stenosis(6-8). However, patients in the perioperative period often have local hematoma, infection and nerve injury and other complications, so the operation is not perfect(9, 10). Carotid endarterectomy has the difficulty in the operation of second cervical vertebra stenosis. Meanwhile, there are some patients who cannot tolerate surgery. So, the carotid artery stenting due to its minimally invasive operation and high success rate has been gradually increasing in recent years(11-13).

The safety of endovascular treatment of carotid artery stenosis has been improved significantly with the improvement of the performance of the imaging devices and the carotid artery stent implantation, as well as the improvement of endovascular treatment techniques(14, 15). In recent years, some researchers have pointed out that, in the treatment of carotid artery stenosis, carotid artery stenting is safer and can replace the intimal plaque peeling surgery as a common surgical treatment of carotid artery stenosis(16).
There are many methods for assessing hemodynamic changes before and after carotid stenting, such as CT perfusion imaging, high-frequency Doppler ultrasonography, but the assessment of the clinical efficacy of carotid stenting has been lack of quantification Indicators\(^\text{17}\). iFLOW, as a reprocessing technique that evaluates hemodynamic changes, has entered the clinical market where clinicians can assess the peak time of contrast development in the region of interest and automatically calculate the time between two points of the selected intracranial blood vessel (Such as the common carotid artery bifurcation to the internal artery bifurcation), and can automatically draw the coordinate map for clinical calculation of cerebral hemodynamic changes before and after treatment, so as to evaluate the therapeutic effect, and can confirm early tumor angiogenesis, Better display of vascular malformations of the arteries\(^\text{18, 19}\). iFLOW software is a digital quantitative analysis software that can be integrated in the Siemens Artis vascular imaging system. The parameters of hemodynamics changes are analyzed by real-time processing of dynamic DSA data and color coding\(^\text{20, 21}\).

The software analyzes the angiographic data through the Siemens quantitative analysis software Syngo iFLOW VC21\(^\text{22}\), and calculates the time interval from the image acquisition to the peak value of the gray value according to each pixel value of the DSA image, that is, the peak time is indicated the speed of local blood flow velocity\(^\text{23}\). Then, the peak time for color coding, the shorter time of the arteries tend to warm colors and the longer time of the veins tend to cool color\(^\text{24, 25}\).

In general, if one side appears the stenosis in internal carotid artery, often cause the artery distal perfusion pressure decreased, and there is pressure difference between the front and rear circulation, the traffic branch and leptomeningeal open, and the anterior and posterior branches of the traffic flow from the healthy side to the narrow side\(^\text{26}\). Some scholars have used this function to diagnose cerebrovascular disease, and some scholars use this function to analyze obstructive blood flow of lower extremity, but no scholar has used this function to compare and analyze the hemodynamics before and after carotid artery stenting. Open traffic can effectively increase the narrow side of the blood flow. Studies have pointed out that in many metabolic processes, the traffic branches play a very important role, and there was a significant negative correlation between stroke and anterior traffic open\(^\text{27-28}\). It was shown by the research outcomes that when the carotid artery stenting in the treatment of stenosis lesions, can increase the diameter of blood vessels, increase the perfusion pressure of brain tissue, increase blood flow velocity, reduce the pressure difference of the carotid artery lateral perfusion and the anterior and posterior circulation pressure difference, significantly reduce the corresponding collateral circulation branch flow, and may even close the collateral circulation, mainly realized as collateral circulation development becomes shallow or even disappear. In addition, reducing the pressure gradient between cerebral artery and vein after operation, can effectively increase the cerebral blood flow velocity, deepen brain tissue staining.

In summary, the evaluation of cerebral hemodynamics changes after stenting, by using the post processing function of iFLOW, according to the quantitative comparison of blood flow velocity in the same part of intracranial vessels before and after operation, is accurate and reliable.

References


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