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ORIGINAL ARTICLE

Effects of Obstructive Carotid Artery Disease on Ocular Circulation and the Safety of Carotid Artery Stenting

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Background The aims of this study were to examine the ophthalmic artery flow changes in patients with obstructive carotid artery disease, evaluate the orbital blood flow changes after carotid artery stenting and assess the safety of carotid stenting procedure by using transorbital colour and spectral Doppler sonography.

Methods Thirty-one consecutive patients scheduled for carotid stenting with severe internal carotid artery stenosis (>60%; the study group) and 30 control subjects were included. Ophthalmic artery (OA) Doppler sonography was performed in the control group and study group before and after stenting. Peak systolic velocity (PSV), end-diastolic velocity (EDV), pulsatility index (PI), and resistive index (RI) and systolic/diastolic ratio (S/D) in the ophthalmic artery were recorded. Statistical comparisons were made between controls and study group before stenting and before and after stenting in the study group.

Results Comparison between control and study group before stenting revealed a statistically significant decrease in OA PSV (51.5 ± 14.5 vs. 39.7 ± 19 cm/sec, p= 0.008) and EDV (15.2 ± 4.5 vs. 11.3 ± 5.7 cm/sec, p=0.004) in the study group. Differences in PI (1.3 ± 0.14 vs. 1.36 ± 0.4, p=0.47), RI (0.7 ± 0.04 vs. 0.75 ± 0.21, p=0.19), and S/D (3.5 ± 0.6 vs. 3.6 ± 1, p= 0.5) ratio were not statistically significant between groups. Peak systolic velocity (39.7 ± 18.9 vs. 51.3 ± 22.2 cm/sec, p <0.001), RI (0.75 ± 0.21 vs. 0.81 ± 0.13, p=0.16) and S/D ratio (3.6 ± 1 vs. 4.6 ± 1.5, p= 0.001) were found to be significantly increased in the study group after stenting compared to baseline. There were no statistically significant differences in EDV and RI EDV(11.3 ± 5.7 vs. 11.7 ± 5.7 cm/sec, p=0.66), PI (1.36 ± 0.4 vs. 1.6 ± 0.6, p =0.047) after stenting.

Conclusions Ophthalmic artery flow parameters were significantly lower in patients with severe carotid artery stenosis compared to control, indicating compromised ocular blood flow in severe carotid stenosis. Flow indicators significantly improved after stent implantation suggesting the importance of revascularisation in restoring ocular blood flow and safety of carotid stenting.

Keywords Carotid artery stenosis • Carotid artery stenting • Retrobulbar blood flow • Ophthalmic artery • Colour Doppler ultrasonography of eye

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Introduction

According to statistics, approximately 500,000 new and 200,000 recurrent stroke cases are reported annually in the United States and stroke appears to be the third leading cause of death. Carotid disease constitutes 5–12% of treatable causes of stroke. Randomised trials comparing medical therapy to surgical revascularisation (NASCET—The North American Symptomatic Carotid Endarterectomy Trial, ECST—European Carotid Surgery Trial, VA CSP 309) in both symptomatic and asymptomatic patients who have carotid stenosis greater than 50–60% strongly favour revascularisation for the prevention of cerebrovascular events. [1] While carotid endarterectomy (CEA) appeared as the first line revascularisation method, carotid artery stenting (CAS) started to gain popularity with the advancement of interventional methods and stent technology (i.e filters or other distal protection devices, nitinol alloy stents).Though early studies comparing CAE to CAS directly (SPACE—The Stent-Protected Angioplasty versus Carotid Endarterectomy, EVA 3S) had disappointing results for carotid stenting, other studies (SAPPHIRE—Stenting and Angioplasty With Protection in Patients at HIgh Risk for Endarterectomy, CREST—The Carotid Revascularization Endarterectomy versus Stenting Trial) have tried to restore the credibility of carotid stenting [2–5]. The main concern inhibiting extensive use of percutaneous methods is the higher incidence of distal embolisation and stroke or transient ischaemic attack (TIA) compared to the surgical method [2,3]. The debate still continues and guidelines for carotid stenting as a first line therapy are generally limited to the patients who are unsuitable candidates for surgery (i.e hostile or radiated neck, high surgical risk) [1]. Colour Doppler imaging (CDI) of the ophthalmic artery (OA) is a safe, non-invasive and reproducible method of evaluating orbital blood velocity [6–8]. In obstructive carotid artery disease (OCAD), ocular blood flow is significantly reduced due to reduced or reversed OA flow in a fashion similar to that of subclavian steal syndrome [9,10]. Consequently, in the presence of OCAD, there is a significant risk of cerebral and ocular TIAs, proportional to the severity of carotid stenosis [10,11]. Decreased blood flow velocities and increased resistivity indices at the OA have been demonstrated with CDI in patients with OCAD associated with ophthalmic manifestations, including amaurosis fugax, ischaemic ocular pain, iris or anterior chamber angle neovascularisation and optic disc atrophy or oedema, but there are no conclusive data in visually asymptomatic OCAD patients [9–11]. Considering the importance of early OCAD diagnosis and appropriate management in the prevention of cerebral and ocular ischaemic attacks, it may be useful to explore retrobulbar haemodynamic changes in patients with OCAD before and after carotid stenting. Findings could provide evidence for the value of retrobulbar CDI in the treatment of patients undergoing CAS in the future.

The ophthalmic artery originates from the ICA and constitutes the main supplier of blood to the eye. It also supplies blood to additional territories such as the lacrimal gland, extraocular muscles, paranasal sinuses as well as the forehead and scalp. Due to its extensive collateral network with other arterial suppliers, critical eye function could be maintained to some extent if the ophthalmic artery is affected by disease. In the presence of OCAD, a decrease in flow to the OA may be attributed to the severity of OCAD if there is no other illness affecting the OA [12–18]. There are limited studies on the safety and reliability of carotid stenting using sensitive methods such as cranial MR (magnetic resonance) imaging or retrobulbar blood flow. Colour Doppler imaging of ophthalmic artery is a safe, non-invasive and reproducible method of evaluating orbital blood velocity [6–8]. This study is designed mainly to answer these questions: How is retrobulbar flow affected in patients with OCAD? Does internal carotid artery stenting improve the ophthalmic artery flow dynamics to help prevent ocular ischaemic sydromes? Finally, it is aimed to test the safety and reliability of carotid stenting for which some safety concerns still exist. Theoretically, in the case of embolic phenomena affecting the OA territory during stenting procedures, the measurement of blood flow in the retrobulbar area would be expected to show a decrease due to embolic obstruction of the OA.

Materials and Methods

Patient Selection

This was a prospective, non-randomised trial. We conducted this study between January 2015 and August 2015. Patients who had suspected (i.e vague symptoms that may be associated with cerebral ischaemia) or true transient ischaemic attack or stroke or asymptomatic patients who have carotid stenosis greater than 60% were included in the study. During this period, all patients who decided to have carotid stenting according to carotid angiography were recruited to the study without selection bias. Patients who had findings of carotid stenosis greater than 50% in Colour Doppler ultrasonography (CDU) were referred to the CA for definitive diagnosis. If carotid angiography correlated with carotid Doppler ultrasonography findings in high grade stenosis (i.e 50% in symptomatic or 60% in asymptomatic patients), the decision for intervention was made according to the guidelines [1]. When CA findings did not correlate with CDU (i.e stenosis detected by CDU was greater than 50–60% and stenosis detected by CA was lower than 50–60%), it was decided not to intervene and medical treatment was started [1]. Carotid angiography is used as the gold standart for decision-making because vessel edges and lesion definition are reasonably better in angiographic evaluation than CDU. When the decision for intervention was made, patients were examined preprocedurally by the CDI to evaluate OA flow. After Doppler evaluation of the eye, patients were admitted to the interventional suit and carotid stenting was performed. Before discharge, CDI of OA was repeated to compare pre-stent and post-stent values. All patients were successfully stented and recruited to the study. There were 31 stented OCAD patients (25 males, 6 females; mean age: 65±10 years) and 30 control

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