Investigation of Hemodynamic Changes in the Ophthalmic Artery using Color Doppler Imaging after Strabismus Surgery

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Purpose: We investigated hemodynamic changes in the ophthalmic artery (OA) using color Doppler imaging (CDI) after two horizontal rectus muscles surgery.

Methods: Eyes of the surgical group (n=18) underwent surgery on two horizontal rectus muscles, and the control group was the contralateral eyes. CDI of the OA was performed before operation and on postoperative days (POD) 1, 7 and 30. Peak systolic (Vmax), end diastolic (Vmin), and mean (Vmean) blood flow velocities were measured, and resistivity index (RI) and pulsatility index (PI) were calculated.

Results: Vmax, Vmin and Vmean were significantly higher, and RI and PI were significantly lower in the surgical group than in the control group on POD 1 ($p<0.05$). In the surgical group, Vmax, Vmin and Vmean were significantly higher, and RI and PI were significantly lower, on POD 1 than those mesured on other days ($p<0.05$).

Conclusions: We showed that surgery on the two horizontal rectus muscles increased OA blood flow during the early postoperative period. *Korean Journal of Ophthalmology 19(3):208-212, 2005*

Key Words: Anterior ciliary artery, Color Doppler imaging, Hemodynamic change, Ophthalmic artery, Strabismus

Fundus fluorescein angiography, arteriography, venography, ophthalmodynamometry, pneumoplethysmography, oculo-oscillodynamography, laser Doppler velocitometry and color Doppler imaging (CDI) have all been used to investigate orbital and ocular hemodynamics.[1-3] In 1989, Erickson et al. introduced CDI, which has since been used to investigate orbital and intraocular diseases and changes in ocular hemodynamics.

Compared to other methods, CDI does not require ocular compression, fluorescein injection or mydriasis that is necessary to investigate the blood flow of the eyeball. Furthermore, the applications for CDI have recently been expanded to observe the blood flow change of the eyeball after surgical precedures such as scleral buckling, trabeculectomy and optic nerve decompression.[4-7] Various experiments have been performed to investigate changes of ocular blood flow using CDI.

Regillo et al[4] found the diminution of blood flow in the central retinal artery after scleral buckling and Santos et al.[5] reported the diminution of blood flow in the ophthalmic artery (OA) with intraocular pressure elevation after scleral buckling. Additionally, Trible et al[6] observed decreased mean and end diastolic blood flow in the central retinal artery and short posterior ciliary arteries with the diminution of intraocular pressure after trabeculectomy. Mittra et al[7] found that optic nerve decompression increased blood flow to the optic disc using CDI.

One of the important complications of strabismus surgery is anterior segment ischemia, in which the possible sequence of events is hypoperfusion, tissue hypoxia, cell death and inflammatory response.[8] In this study, we used CDI to evaluate hemodynamic changes in OA of the eye that underwent recession and resection on two horizontal rectus muscles.

Materials and Methods

Our study comprised the 18 patients who underwent recession and resection on two horizontal rectus muscles in one eye among those who underwent strabismus surgery at the Chungnam National University Hospital from April, 2003 to May, 2004. All cases were primary surgery. The surgical group was defined as the eyes which underwent recession and resection on two horizontal rectus muscles, and the

Received: February 18, 2005 *Accepted*: July 14, 2005

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* The authors had no commercial or proprietary interest in the material used in this study.

control group was defined as the contralateral eyes of the same patients. General anesthesia was performed in three patients under 13 years of age. The other patients received retrobulbar anesthesia which consisted of 1 to 1.5 ml of 2% lidocaine with epinephrine 1:200,000 being injected into the retrobulbar space and gentle digital massage being performed for approximately 5 minutes. All operations were performed by means of fornix incisions.

Exclusion criteria for the study included any other ocular surgery, orbital trauma or ocular inflammation and patients ages under 6 years old. Antibiotic drops were prescribed postoperatively without other medications.

CDI was performed on both eyes four times after informed consent had been obtained: before surgical correction, and on postoperative days (POD) 1, 7 and 30. Neurovision 500 (Multigon Ltd., U.S.A.) model was used for CDI, with 4 MHz linear phase transducer. The velocity parameters were measured in centimeters per second. Each examination was performed by the same examiner and took ten to fifteen minutes. From two separate surveys, the clearer OA wave was selected as the result. The patients rested for 5 minutes to maximize cardiac stability before the examination and they lay in a supine position during the examination. Ultrasonographic transmission gel was applied to the eyelids to avoid pressure on the eyeball for increased accuracy. Through this method, we measured peak systolic (Vmax), end diastolic (Vmin) and mean (Vmean) blood flow velocities (Fig. 1), and these were introduced to calculate the resistivity index (RI) and the pulsatility index (PI).

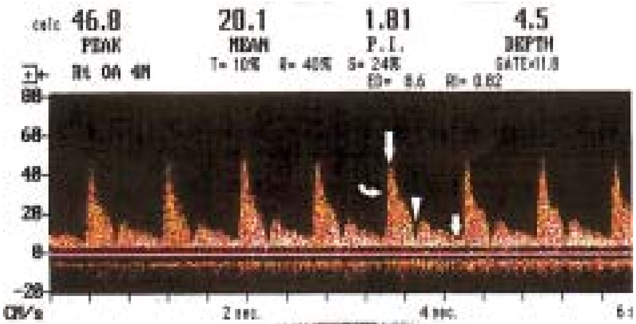

Fig. 1. Color Doppler waveform of the ophthalmic artery showing initial steep systolic velocity rise (curved arrow), and notched "incisure" in middownslope (arrowhead). Only such waves were selected to measure the blood flow velocity parameters. The highest value of the wave is the peak systolic blood flow velocity (long straight arrow) and the lowest value of the wave is the end diastolic blood flow velocity (short straight arrow).

The formulae to calculate RI and PI are as follows[9]:

RI=1-Vmin/Vmax

PI=Vmax/Vmean-Vmin/Vmean

Comparison of flow velocity parameters between the two groups was evaluated using Mann-Whitney U Test and comparison of blood flow velocity parameters with the lapse of time in the same group was evaluated using Wilcoxon signed rank test. The level of significance was set at $p<0.05$.

Results

The surgical group comprised 7 right eyes and 11 left eyes. The patients consisted of 10 males and 8 females and

Table 1. Demographics of the subjects

	Surgical group	Control group
Number of eyes	18	
Male : Female	10 : 8	
Right : Left	7 : 11	11 : 7
Mean age (years)	25.22±16.5	
Age range (years)	7~56	

Table 2. Comparison of mean(±SD) preoperative and postoperative blood flow velocity parameters in the ophthalmic artery between surgical and control groups

Parameter		Preoperation	POD 1	POD 7	POD 30
Vmax	Surgical group	43.33±7.16	54.91±6.49	43.78±6.79	42.84±9.44
	Control group	44.01±8.76	44.52±9.23	43.35±8.91	44.62±8.19
	p-value	0.72	0.00*	0.74	0.42
Vmin	Surgical group	8.63±1.16	13.74±1.43	8.61±1.18	8.91±1.59
	Control group	8.81±1.83	8.62±1.85	8.67±2.11	8.73±1.77
	p-value	0.96	0.00*	0.84	0.46
Vmean	Surgical group	16.76±3.86	22.61±3.18	16.86±3.11	16.83±3.77
	Control group	17.50±3.25	17.18±2.82	17.06±3.53	17.14±3.25
	p-value	0.52	0.00*	0.74	0.96
RI	Surgical group	0.79±0.04	0.74±0.04	0.79±0.04	0.78±0.05
	Control group	0.79±0.05	0.80±0.04	0.80±0.05	0.80±0.06
	p-value	0.61	0.00*	0.74	0.31
PI	Surgical group	2.08±0.31	1.83±0.27	2.11±0.38	2.06±0.56
	Control group	2.00±0.36	2.07±0.39	2.02±0.31	2.09±0.36
	p-value	0.56	0.03*	0.4	0.72

*: statistically significant difference between surgical and control groups.

their age ranged from 7 to 56 years with a mean age of 25.22 ±16.5 years (Table 1).

Preoperative blood flow velocity parameters between the two groups were statistically similar ($p>0.05$). However, there were significant differences in the postoperative blood flow velocity parameters of OA. On POD 1, Vmax, Vmin and Vmean were significantly higher, and RI and PI were significantly lower, in the surgical group than in the control group ($p<0.05$). These significant differences of blood flow velocity parameters between the two groups were not observed at POD 7 or after, from which time the blood flow velocity parameters between the two groups were statistically similar ($p>0.05$) (Table 2).

In the surgical group, Vmax, Vmin and Vmean of OA were significantly higher, and RI and PI were significantly lower, on POD 1 than before surgery ($p<0.05$). Vmax, Vmin and Vmean were significantly lower, and RI and PI were significantly higher, on POD 7 than on POD 1 ($p<0.05$). No significant change of blood flow velocity parameters was noted between POD 7 and POD 30, between preoperation and POD 7, and between preoperation and POD 30 ($p>0.05$). After POD 7, the OA blood flow had decreased close to the preoperative level (Figs. 2, 3).

In the control group, no significant changes were noted in the blood flow velocity parameters throughout the whole examination period ($p>0.05$).

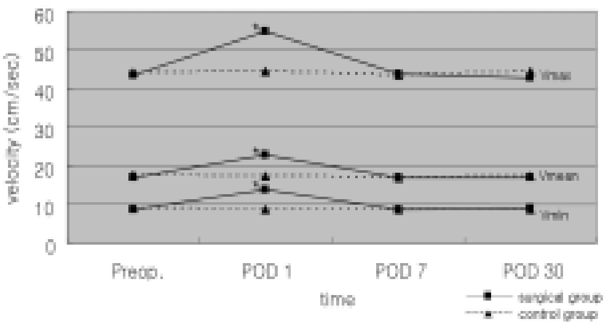

Fig. 2. The change of peak systolic (Vmax), end diastolic (Vmin) and mean (Vmean) blood flow in the ophthalmic artery in both groups with the lapse of time.
*: significantly different compared to the values measured at other examination times in the surgical group.

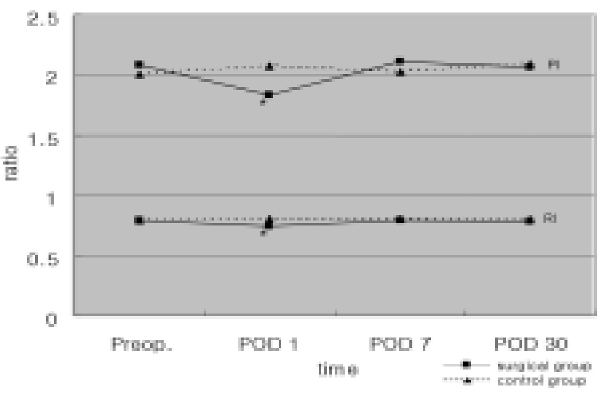

Fig. 3. The change of resistivity index (RI) and pulsatility index (PI) in the ophthalmic artery in both groups with the lapse of time.
*: significantly different compared to the values calculated at other examination times in the surgical group.

Discussion

The major blood supply to the eye comes from the OA. Blood supply for the anterior segment, including the iris and ciliary body, is maintained through the long posterior and anterior ciliary arteries. The two long posterior ciliary arteries, which have an intrascleral course beneath the horizontal rectus muscles, are estimated to provide less than 30% of the blood supply to the anterior segment of the eye.[10,11] Although relatively common anatomical variations,[12] the medial rectus and both vertical rectus muscles typically carry two anterior ciliary arteries, whereas the lateral rectus muscle carries only one.[13] The anterior ciliary artery provides 70~80% of the anterior segment blood supply, and thus occlusion of the long posterior ciliary arteries alone is not enough to cause an ischemic change in the anterior segment of the eye.[10,14] During the strabismus surgery in which the anterior ciliary arteries can be injured, surgical manipulation of the rectus muscles can cause ischemic injury to the anterior segment of the eye.[15] The main risk factors for anterior segment ischemia of the eye are advanced age, vertical rectus muscle surgery, atherosclerosis, blood dyscrasias, and circulatory disorders including carotid artery disease.[15-20] Despite the uncertainty about both the number and combination of rectus muscles that can be simultaneously operated on safely,[10,18-20] it is considered that there is little risk of anterior segment ischemia of the eye in simultaneous, both horizontal rectus muscles surgery in healthy patients with previously unoperated eyes.[21]

Although a useful method to measure the anterior segment blood flow,[14,22-24] iris fluorescein angiography is invasive whereas, CDI is non invasive, pain free, and has no potential risk for the patients.[25] However, blood flow measurement with CDI might be limited because the anterior ciliary arteries are not large enough to be visualized accurately. However, as the anterior ciliary arteries originated from OA, measuring OA blood flow can possibly indicate the hemodynamic alterations of the anterior ciliary arteries after rectus muscles surgery.

In this study, compared to the control group, on POD 1 Vmax, Vmin and Vmean were increased and RI, PI were decreased in the surgical group that underwent recession and resection on two horizontal rectus muscles. These results indicate increased blood flow and decreased vascular resistance, both of which are expected in inflammatory conditions.[26,27] Therefore, the observed stabilization of blood flow velocity parameters from POD 7 might have resulted from a reduction of inflammation. In addition, the blood flow increase in the early postoperative period showed the reduced risk of anterior segment ischemia of the eye that can develop after strabismus surgery. A study by Peter et al.[28] revealed that color Doppler ultrasound measurements were not significantly changed in the OA of primate eyes at 30 minutes after retrobulbar administration of 1.5 to 2 ml of 2% lidocaine with 1:200,000 epinephrine. Because we examined all patients more than 24 hours after the operation, we thought that retrobulbar injection did not influence OA blood flow. We regarded that the two methods of anesthesia presented with the same condition at examination time.

A study by Pelit et al.[29] showed similar results to ours, but their CDI examination was restricted to POD 7. In comparison, our study measured OA blood flow until POD 30 and all conditions of the study eyes were matched with the control eyes as the contralateral eyes were assigned as the controls.

Bayramlar et al.[30] examined patients who had undergone operation on two horizontal rectus muscles and investigated the OA blood flow characteristics at the preoperative period, POD 7 and POD 30. Although, they reported no significant changes on OA blood flow between the preoperative and postoperative periods, they did not measure OA blood flow on POD 1 and this may have caused the absence of significant differences.

In a CDI study on Asians, Tane and Hashimoto.[31] reported a mean Vmax of OA of 46.58±1.48 cm/sec. Among Koreans, Han et al.[32] reported 38.12±6.42 cm/sec and Hong et al.[33] reported 42.72±6.72. In our study, the mean Vmax of OA in the control group was 43.33±7.15, which was similar to Hong's report. This comparison suggests that the blood flow measurements in this study were relatively accurate.

CDI is a safe and non-invasive technique without permanent disturbances of ocular structures and the energy used during color coding (5 to 59 mW/cm^2) is only slightly higher than in conventional B-mode ultrasonography.[34,35] Lizzi et al.[36,37] proved that CDI is not usually harmful on ocular structures and that there is still an extraordinarily wide safety margin up to the ultrasound energy levels that have led to cataract formation or retinal lesions in animal experiments (>100 W/cm^2).

In conclusion, our results show that recession and resection on two horizontal rectus muscles may increase OA blood flow during the early postoperative period. In this study, the surgical group consisted of patients who had undergone both horizontal rectus muscles surgery in one eye. Therefore, further CDI studies dealing with vertical rectus muscles and oblique muscles surgery are needed to better elucidate the OA blood flow after strabismus surgery.

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