Retinal vascular diameter changes assessed with a computer-assisted software after strabismus surgery

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Abstract

● AIM: To quantitatively investigate the retinal vascular diameter changes, analyzing the early and long-term effects on the retinal circulation, with 6-month follow-up.

● METHODS: Patients underwent horizontal strabismus surgery were enrolled prospectively. Retinal vessel diameters on color fundus photographs were assessed before and 1, 7d, 6mo after surgery, using a computer-assisted quantitative assessment software. To evaluate the retinal vascular caliber changes, retinal vascular diameters were calculated by means of the Parr–Hubbard formula as the central retinal arteriolar equivalent (CRAE) and central retinal venular equivalent (CRVE). The arteriovenous ratio (AVR) was calculated as CRAE divided by CRVE.

● RESULTS: A total of 154 eyes of 104 consecutive patients were included. Compared with the data before surgery (121.55±24.67), the mean CRAE (131.18±28.29) significantly increased 1d after surgery (P=0.003), but went back to baseline level at 7d (118.89±30.35, P=0.15), and 6mo (123.22±15.32, P=0.60), so did the AVR (P<0.001, P=0.08, P=0.07). As for the mean CRVE, there was no significant difference between those four time points (172.43±33.25, 175.57±36.98, 174.03±40.18, 174.86±20.46, P=1.00).

● CONCLUSION: Strabismus surgery on both lateral and media rectus muscles, or single media rectus muscle may increase retinal blood flow during the early postoperative period, but would return to normal later. The number of transected anterior ciliary arteries rather might be the main cause of retinal hemodynamic changes early after strabismus surgery.

KEYWORDS: retinal blood flow; retinal vascular diameter; strabismus; strabismus surgery

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INTRODUCTION

The potential alteration of retinal blood flow after strabismus surgery has been an interest for ophthalmologists. Since the anterior ciliary arteries, which come from the rectus muscles, are the major source of blood supply (70%-80%) for the ocular anterior segment, and are transected during strabismus surgery, there might be some hemodynamic changes on the anterior segment[1-2].

Retinal arteries and anterior ciliary arteries are originated from the same ophthalmic artery. Some hemodynamic alteration may occur in retinal circulation due to the hemodynamic changes of the anterior segment after strabismus surgery[3-6]. Therefore, it is necessary to pay attention to the possibility of anterior segment ischemia and retinal ischemia, especially for those eyes with risk factors of ocular ischemia, such as ocular ischemic syndrome, retinal arterial occlusion, retinal vein occlusion, and so on.

Color Doppler imaging was used to investigate the orbital blood flow changes after strabismus surgery in several studies, showed conflicting results in terms of whether or not the blood flow of ophthalmic artery changes[7-10]. However, orbital Doppler ultrasonography is a user-dependent and time-consuming imaging method, with poor sensitivity and accuracy in vascular measurements.

Not long before, we performed a study using a computer-assisted quantitative assessment software, evaluated the retinal vascular diameter changes before and 1d after strabismus surgery[3]. It showed that strabismus surgery on horizontal rectus muscles might change retinal hemodynamics by increasing the central retinal arteriolar diameter one day after surgery. This study reported a large number of patients with short-term observation after surgery. However, the long-term trend of the retinal hemodynamic changes and the impact on the retina later after surgery is still unknown.
In our study, we investigate the effects on retinal arteriolar diameter with 6-month follow-up after strabismus surgery for further research.

SUBJECTS AND METHODS

Ethical Approval The Ethics Committee of Beijing Tongren Hospital approved the study protocol, following the tenets of the Declaration of Helsinki. All of the participants gave written informed consent.

Patients Enrollment Consecutive patients underwent strabismus surgery between January 2016 and April 2018 at the Eye Center of Beijing Tongren Hospital were enrolled. The diagnosis of strabismus was made by an experienced surgeon (Fu J). Patients were excluded if: 1) patients had undergone previous ocular surgery, including previous extraocular muscle surgery; 2) patients had systematic diseases which may cause hemodynamic changes in the retina such as diabetes mellitus, hypertension, any other known vascular diseases; 3) patients who underwent or needed to undergo vertical rectus or oblique muscle surgery; 4) patients didn’t finish the 6-month follow-up postoperatively.

Slit-lamp examination and color fundus photographs were evaluated pre- and postoperatively (1, 7d and 6mo after surgery). Signs of anterior segment ischemia were evaluated by slit-lamp examination, characterized by pupillary dilation and distortion, iris atrophy, lens opacities, and hypotonia. Color fundus photographs (45°) of each eye, centered on the optic disk (Diabetic Retinopathy Study standard field 1) and macula (Diabetic Retinopathy Study standard field 2), was taken using the CR6-45NM fundus camera (Canon Inc, Tokyo, Japan) before and 1, 7d, and 6mo after strabismus surgery, as described in the previous study[3].

Strabismus Surgery Horizontal rectus recession (range: 3-8 mm) or resection (range: 4-10 mm) were performed using the standard method and involved transecting the anterior ciliary arteries.

Retinal Vascular Caliber Measurement Computer-assisted quantitative assessment software (IVAN; University of Wisconsin, Madison, WI, USA) was applied to assess the retinal vascular diameters, as described in previous studies[3,11-12]. Average retinal vascular diameters were calculated by means of the revised Parr-Hubbard formula as the central retinal arteriolar equivalent (CRAE) or central retinal venular equivalent (CRVE). The arteriovenous ratio (AVR) was calculated as CRAE divided by CRVE[12-13]. Two trained graders, masked to participant characteristics, performed the vessel measurements on the optic disc-centered images. The largest six arterioles and venules coursing through a zone between 0.5- and 1-disc diameter from the optic disc margin were measured (Figure 1). Images were considered ungradable if the largest six arterioles and venules could not be able to be measured[14] (Figure 2).

RESULTS

Of all the 118 consecutive patients, 6 patients who didn’t finish the 6-month follow-up were excluded. Other 8 patients were excluded because of ungradable fundus images. Ungradable fundus images were due to reflection on retina (6 patients) or...
persistent ointment on corneal after surgery (2 patients). At the last follow up, a total of 154 eyes of 104 patients (88.14%) were analyzed, with 56 males (53.8%). The mean age was 10.45±2.34y (range: 3-14y). Seventy-five patients (72.1%) were diagnosed with exotropia and 29 patients with esotropia.

In all 154 eyes, no sign of anterior segment ischemia or retinal abnormality was found pre- and postoperatively. As for the assessment of variability, the interobserver correlation coefficient was 0.95 (95%CI 0.94-0.99) for CRAE and 0.96 (0.94-0.97) for CRVE. The intraobserver correlation coefficient was 0.97 (95%CI 0.95-0.99) for CRAE and 0.97 (0.96-0.98) for CRVE. Compared with preoperative value (121.55±24.67), the mean CRAE at postoperative 1-day (131.18±28.29) was significantly increased (P=0.003), but returned to preoperative level at postoperative 7-day (118.89±30.35, P=0.15), and 6-month (123.22±15.32, P=0.60). As for the mean CRVE, there were no significant differences between those four time points (preoperative value 172.43±33.25, 1-day 175.57±36.98, 7-day 174.03±40.18, 6-month 174.86±20.46, P=1.00). The AVR at postoperative 1-day was significantly larger than preoperative value (0.75±0.09 vs 0.70±0.07, P<0.001), but turned back to preoperative level on day 7 (0.69±0.09, P=0.08) and 6-month (0.71±0.07, P=0.07; Table 1).

Of those 154 eyes, 84 eyes (54.55%) underwent surgery on single rectus muscle, lateral or medial rectus muscle. The other 70 eyes underwent surgery on both horizontal rectus muscles. For both of the two groups, CRAE and AVR were significant increase at postoperative 1-day, and turned back to preoperative level at 7-day and 6-month (Tables 2 and 3).

We also conducted a comparison of retinal vessels caliber between eyes undergoing single-muscle and 2-muscle surgery. Except for the CRAE of 2-muscle surgery group was a little bit larger than the single muscle surgery group (P=0.02) at 1-day after surgery, there was no significant difference of CRAE, CRVE and AVR between two groups on other time points (Table 4).
Table 3 Comparison of retinal vessels caliber preoperative and postoperative for eyes undergoing 2-muscle surgery

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CRAE-1</th>
<th>P</th>
<th>CRVE-1</th>
<th>P</th>
<th>AVR-1</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operation</td>
<td>119.45±21.75</td>
<td>0.25</td>
<td>169.03±31.20</td>
<td>0.37</td>
<td>0.71±0.08</td>
<td>0.70±0.01</td>
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<tr>
<td>1d post-operation</td>
<td>128.58±26.86</td>
<td>0.02</td>
<td>169.80±35.11</td>
<td>0.41</td>
<td>0.76±0.08</td>
<td>0.75±0.01</td>
</tr>
<tr>
<td>7d post-operation</td>
<td>115.25±24.67</td>
<td>0.20</td>
<td>167.63±34.29</td>
<td>0.62</td>
<td>0.69±0.09</td>
<td>0.66±0.01</td>
</tr>
<tr>
<td>6mo post-operation</td>
<td>114.97±15.93</td>
<td>0.34</td>
<td>175.4±22.12</td>
<td>1.00</td>
<td>0.72±0.07</td>
<td>0.69±0.01</td>
</tr>
</tbody>
</table>

Table 4 Comparison of retinal vessels caliber between eyes undergoing single muscle and 2-muscle surgery

<table>
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<tr>
<th>Parameters</th>
<th>CRAE-1</th>
<th>P</th>
<th>CRVE-1</th>
<th>P</th>
<th>AVR-1</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operation</td>
<td>124.84±4.50</td>
<td>177.96±5.21</td>
<td>0.70±0.01</td>
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<tr>
<td>1d post-operation</td>
<td>137.40±4.22</td>
<td>184.14±5.70</td>
<td>0.95</td>
<td>0.75±0.01</td>
<td>0.001</td>
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<tr>
<td>7d post-operation</td>
<td>123.12±5.88</td>
<td>184.79±7.38</td>
<td>0.69</td>
<td>0.66±0.01</td>
<td>0.03</td>
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<tr>
<td>6mo post-operation</td>
<td>121.82±2.20</td>
<td>175.95±2.84</td>
<td>0.05</td>
<td>0.69±0.01</td>
<td>1.00</td>
<td></td>
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</table>

DISCUSSION

IVAN as a computer-assisted quantitative assessment software, has been used to measure the retinal vascular diameter for evaluating the retinal hemodynamic alterations for about 15y, with great reliability and repeatability[15]. In our previous study, we used this noninvasive approach to evaluate the retinal vascular diameters, showed that CRAE and AVR significantly increased at 1-day after strabismus surgery[3]. And in current study, compared with preoperative values, CRAE and AVR was still significantly increased at 1-day after surgery, but returned to preoperative levels at 7-day and 6-month after surgery. We believed that the early postoperative alterations on the central retinal arteriolar diameter reflected the increase blood flow of retinal circulation.

Some associated articles reported similar changes in ophthalmic arteries or other potentially affected retrolubar arteries[8-11], except Bayramlar et al[7]. Bayramlar et al[7] reported 19 patients who underwent surgery on horizontal rectus muscles, didn’t find any significant change on ophthalmic arteries. However, they evaluate the ophthalmic arteries on postoperative first week rather than the first day. Pelit et al[3] reported that after horizontal rectus surgery, the ophthalmic artery flow on color Doppler imaging was significantly increased at postoperative 1-day but returned to baseline levels by day 7. They presumed that the blood flow increased at postoperative 1-day was partly contributed by inflammation after surgery, and the phenomenon of return to baseline levels at 7-day and later may signify a reduction of inflammation. As one of the branches originated from ophthalmic artery, the blood flow of retinal arteries might be affected. In our current study, retinal arteriolar diameters showed the similar trend. We presume that there might be a compensation process between anterior ciliary arteries, retinal arteries and ophthalmic artery. In this study, there was no sign of anterior segment ischemia pre- or postoperatively. Anterior segment ischemia is a severe complication of strabismus surgery[16]. Some researchers presumed that hemodynamic changes of ophthalmic artery in the early postoperative period might be a compensate that prevent anterior segment ischemia[8,17]. As branches of ophthalmic artery, changes in retinal vessel diameter found in this study may be a contributor to the above compensation process. Hence, for patients with risk factors of ocular ischemia, it is necessary to observe not only the anterior segment ischemic syndrome, but also the retina hemodynamics early after surgery.

In anatomy, except for the lateral rectus, the other rectus muscles (the medial rectus and both vertical rectus muscles) typically carry two anterior ciliary arteries. And the lateral rectus muscle carries only one artery that originates from the lacrimal artery. Due to these characteristics, both of our previous study and current study found that significant increase in this study may be a contributor to the above compensation process. Hence, for patients with risk factors of ocular ischemia, it is necessary to observe not only the anterior segment ischemic syndrome, but also the retina hemodynamics early after surgery.

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Potential limitations of this study should be considered. First, this is a hospital-based study, selective bias could have accentuated some estimates and masked others. Second, the retinal vascular diameters were assessed on routinely taken fundus photographs, which may lead overlooking of the systolic or diastolic effect on retinal vascular diameter. Third, in our study, we supposed to interpret the retinal vessels diameter changes in eyes with anterior segment ischemia. However, there was no patient presented with anterior segment ischemia. Hence, we failed to prove the relation between the risk of development of anterior segment ischemia and retinal vascular diameter changes after strabismus surgery, but only assumptions.

In conclusion, this study showed that strabismus surgery on both horizontal rectus muscles or single media rectus muscle may increase retinal blood flow during the early postoperative period, but would return to normal later. It reminds us that for patients with risk factors of ocular ischemia, it is necessary to observe not only the anterior segment ischemic syndrome, but also the retina hemodynamics early after surgery. We also found that, surgery on lateral rectus muscle played a minor role on postoperative retinal blood flow, because it carries only one anterior ciliary artery, which stated that the number of transected anterior ciliary arteries might be the main cause of retinal hemodynamic changes early after strabismus surgery.

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