Original article
Surgical treatment of patients with convergent concomitant strabismus: clinical effectiveness and long-term outcomes

Olga Savinova¹, Marat Suleymenov², Zauresh Utelbayeva³, Tatyana Degtyarevskaya⁴, Ekaterina Rusanova⁵

Abstract

Objective: The study aimed to evaluate the clinical efficacy, early and long-term outcomes of a modified surgical treatment method of convergent concomitant strabismus in children. Materials and methods: The study enrolled 159 children (88 girls (55.3%) and 71 boys (44.7%)) aged 4 to 8 years (mean age, 6.05 ± 0.82 years) suffering from convergent concomitant strabismus. Of a total number, 57 children underwent traditional surgical intervention (control group), and 102 children underwent surgical intervention with the proposed modified approach (main group). Results and Discussion: In the distant timeframe (1-3 years after surgery), 141 children were examined. In the remote postoperative period, the correct eye position was preserved in 46 children (49.5%) in the main group vs. 5 children (10.4%) in the control group (OR = 8.42, 95% CI [3.06-23.14], p<0.05). A secondary deviation occurred in 3 main group children (3.2%) compared to 7 control group children (14.6%) (OR = 5.12, 95% CI [1.26-20.81], p<0.05). In the long-term period, 32 (34.4%) children in the main group and 30 (62.5%) in the control group required repeated surgery to eliminate secondary divergent strabismus and residual deviation angle (OR = 3.18, 95% CI [1.54-6.56], p<0.05). Conclusion. Thus, the proposed modified surgical treatment method of convergent concomitant strabismus in children is more effective than traditional methods.

Keywords: angle of deviation; convergent concomitant strabismus; resection of the external forward oculomotor muscle; the recession of the internal oculomotor muscle.

Introduction

It is known that the visual body receives over 80% of the information. This ability can doubtless be called the most important among other analyzers because, thanks to the visual analyzer, there is stimulation to integrate information from different sensory organs. The optical analyzer is essential for children in terms of cognitive and social development and acquiring speaking, drawing, reading, and writing skills. Visual impairment in childhood results in developmental psychomotor disorders, negatively impacting their overall well-being. It is not unusual for children with visual impairments to have autism-like behavior and delayed semantic and pragmatic skills.

Visual pathology is pretty frequent in children. Thus, about 19 million children worldwide have visual impairments. Refractive disorders are present in 12

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millions of children and irreversible and/or severe visual impairments in 1.4 million children. With such unfavorable statistics, it is even more pessimistic that 79% of children with visual impairment have not been examined by an ophthalmologist in the last year, and 39% of them have never been examined at all. 

Factors associated with visual impairment in children include maternal alcohol consumption, premature birth, Cesarean section, large head circumference at birth, heredity, female gender, being of the white race, long hours of TV and smartphone viewing, watching TV at a distance of less than 2 meters, living in a low-income family. 

Oculomotor pathology, namely, binocular vision disorders and strabismus (S), plays an essential role in the overall structure of childhood ocular diseases. S occurs in 2% of children between 4 and 10 years old. The prevalence of S differs across different ethnic groups, with esotropia (concomitant strabismus) being more prevalent in whites, and exotropia – in East Asian and African-American populations. 

Strabismus is a significant medical and social problem. It is not only a cosmetic defect but, more importantly, is accompanied by severe impairment of mono- and binocular functions in children. Slow reading (due to unstable attachment), difficulties in performing motion and visual tasks (balance control, grip) are associated with S. Quite often, S results in psychological problems as such children can be discriminated against. They are less likely to be accepted by their peers and may experience work problems as adults. That is why it is essential to detect strabismus in time and begin treatment quickly and correctly.

Surgery plays a vital role in treating S as it helps achieve the desired aesthetic and functional effect. The primary aim of surgical treatment is to restore the correct eye position in orbit. Typically, operations on the oculomotor muscles, which are in a hyperfunction state, are performed first. However, the major problem is that surgery on the right muscles can increase the eye gap. Operations involving weakening of the strong muscle are more effective, while the antagonistic muscle, on the contrary, is reinforced, which provides a more reliable and stable result. Right muscle resections were a common type of strabismus. Yet, they have many drawbacks: disruption of muscle innervation, their structure (anatomical and morphological), traumatic operation, its multi-step nature. Another method of surgical correction is to create plication, which is less traumatic than resection but adequate for small deviation angles (DA). The major problem often encountered during the postoperative period is the residual strabismus angle (RSA). Thus, following surgical correction of S, the rate of recurrence or hyporeaction amounts to 20 to 40%.

So far, the choice of the optimum surgical treatment technique for S remains topical. The choice of access to oculomotor muscles is questionable as well. Many researchers propose their schemes for dosing the magnitude of resection and recession of the direct oculomotor muscles, but they are based solely on their own clinical experience and observation results. At that, the calculation was carried out empirically. Studies on improving surgical treatment techniques and developing the dosage schemes for recession and recession of the direct oculomotor muscles in children with strabismus are highly relevant.

The study aims to examine clinical efficacy, early and long-term outcomes of a modified method for surgical treatment of convergent concomitant strabismus in children.

**Material and Methods**

The study enrolled 159 children (88 girls (55.3%) and 71 boys (44.7%) aged 4 to 8 years (mean age is 6.05 ± 0.82 years) suffering from convergent concomitant strabismus (CCS). The children involved in the study were divided into two groups: Group 1 (control) consisted of 57 children (32 girls (56.1%) and 25 boys (43.9%)) with CCS who underwent surgery by traditional method; Group 2 (main) included 102 children (56 girls (54.9%) and 46 boys (45.1%)) with CCS who underwent surgery using an approach suggested in this study. Over the long period (1-3 years after surgery), 141 children (48 children in the control group and 93 in the main group) were examined.

Inclusion criteria were age 4 to 8 years, the diagnoses of convergent concomitant strabismus, strabismic angle of 8° or more, first strabismus surgery, informed consent to participate in the study signed by a parent (legal guardian of the child).

Exclusion criteria were previous surgery, hyperopia ≥6.0 D, astigmatism ≥3.0 D, visual acuity of the worse seeing eye less than 0.2, vertical strabismus >4°; A, V, or X syndromes, acute or chronic in acute stage inflammatory eye disease, congenital eye anomalies, other serious eye disorders, acute somatic pathology,
chronic somatic pathology in the acute or sub/decompensation stage, oncopathology, mental illness. Examination and analysis of the results were performed before surgical intervention, the day after it, on the 10th and 30th day after surgery, and in the long-term period (1-3 years after surgery). The range of examination included the study of complaints and medical history, detailed physical examination, laboratory tests (general clinical blood and urinalysis, biochemical blood examination), electrocardiography, and comprehensive ophthalmological examination.

The ophthalmological examination included visometry, ophthalmometry, ophthalmoscopy, refractometry, echobiometry, biomicroscopy, Hirshberg test, as well as determination of functional scotoma and bifoveal fusion (BFF) (on synoptophore), visual character (on a four-point test), examination of eyeball mobility, and assessment of convergencenature.

The proposed surgical intervention implied a dosed resection of lateral rectus muscle (LRM) (the amount of resection depended on the duration of S, deviation angle (DA), and the width of the muscle-tendon) and recession of the internal rectus muscle (IRM) (recession size depended on the position of the muscle attachment, distance from the limbus to the internal rectus muscle). If DA is up to 15°, the placement of IRM is recommended from the limbus at a distance of 8 mm, at DA of 15-25°–9 mm, at 25-30°–10 mm, over 30°–11 mm. When performing surgical intervention during the IRM recession, it is necessary to measure the distance from the limbus to this muscle, move a muscle towards the equator of the eyeball by the missing number of millimeters to the recommended number of millimeters.

When resecting the LRM, its tendon is crucial to don’t bedeformedand positioned on the horizontal part of the hook to enable an accurate measurement of its width. The initial point of resection is near the anterior attachment line of the tendon fibers to the sclera. When calculating the magnitude of LRM resection, the magnitude of DA, the width of the LRM tendon, and the duration of S shall be considered. Thus, with DA up to 15°, the magnitude of LRM resection was 4.5-5.0 mm, at 15-20°–5.5-6.0 mm, at 20-25°–6.5-7.0 mm, at 25-30°–7.5-8.0 mm, over 30°–8.5-9.0 mm. If the LRM tendon width is >9 mm, muscle resection is not recommended due to the high risk of injury to the ends of the muscle fibers. In addition, if the LRM tendon width is ≤5 mm, the LNP resection value shall be increased by 0.5 mm. Besides, it should also be increased by 0.4-0.5 mm if the duration of S ≥4 years.

Compliance with ethical norms and principles

The study protocol and the informed consent form for participation in the study were approved by the Medical Ethics Committee at the I.M. Sechenov First Moscow State Medical University (Protocol № 3 of 18.03.2019). Only children whose parent/legal guardian signed informed consent for the child's participation in the study were included. The study is guided by the International Ethical Guidelines for Biomedical Research Involving Human Subjects (prepared by the Council for International Organizations of Medical Sciences), the Declaration of Helsinki (1964-2013), ICH GCP Principles (1996), EU Council Directive 609 (of 24.11.1986), the Council of Europe Convention on Human Rights and Biomedicine (of 04.11.1986), the Council of Europe Convention on Human Rights and Biomedicine (of 12.12.2006), and the Council of Europe Guidelines on Biomedical Research.

Results

Analysis of strabismus types revealed that among the control patients, 48 children (84.2 %) had alternating S, 9 children (15.8 %) had monolateral S, in 25 children (43.9 %), one eye was fixating more often. In the main group, 85 children (83.3 %) had alternating S, 17 (16.7 %) - monolateral, and 27 children (46.1 %) had one fixating eye more often. Distribution by refraction type in the control group was as follows: 51 children (89.5 %) had hyperopic S, 2 children (3.5 %) had emmetropic S, and 4 children (7.0 %) had myopia. In the main group, 92 children (90.2 %) had hyperopic S, 3 children (2.9 %) had emmetropic S, 6 children (5.9 %) had myopia, and 1 child (1.0 %) had mixed astigmatism. The distribution of the children included in the study over the magnitude of DA and refraction was as follows: In the control group, the magnitude of DA up to 10° was revealed in 5 (8.8 %) children, 10-15° – in 9 (15.8 %) children, 15-20° in 17 children (29.8 %),
20-25° in 12 children (21.1 %), 25-30° in 8 children (14.0 %), more than 30°– in children 6 (10.5 %). In the main group, DA was up to 10° in 7 children (6.9 %), 10–15° in 18 children (17.7 %), 15–20° in 32 children (31.4 %), 20–25° in 23 children (22.5 %), 25–30° in 13 children (12.7 %), more than 30° in 9 (8.8 %) children. The comparison groups did not differ statistically (p > 0.05) concerning strabismus type, refraction, and DA value.

Results analysis of surgical CCS treatment showed that the proposed modified method was more effective. Thus, in the early postoperative period, the correct eye position was achieved in 84 (82.3 %) children in the main group versus 30 (52.6 %) children in the control group with a statistically significant intergroup difference (p < 0.05). Hypo-effect in the main group was noted in 17 (16.7 %) children versus 25 (43.9 %) children in the control group with a statistically significant intergroup difference of (p < 0.05). Also, 1 child (1.0 %) in the main group and 2 children (3.5 %) in the control group had a hypereffect without a statistically significant intergroup difference (p > 0.05) (Table 1).

Table 1. Comparison of surgical treatment effectiveness of convergent concomitant strabismus in children

<table>
<thead>
<tr>
<th>The effect</th>
<th>Control group (n=57)</th>
<th>Main group (n=102)</th>
<th>OR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct eye position, number of children</td>
<td>84 82.3%</td>
<td>30 52.6%</td>
<td>4.2*</td>
<td>2.03-8.7</td>
</tr>
<tr>
<td>Hypo-effect, number of children</td>
<td>17 16.7%</td>
<td>25 43.9%</td>
<td>3.91*</td>
<td>1.87-8.17</td>
</tr>
<tr>
<td>Hypereffect, number of children</td>
<td>1 1.0%</td>
<td>2 3.5%</td>
<td>3.67</td>
<td>0.33-41.42</td>
</tr>
</tbody>
</table>

Note. * differences are statistically significant compared to the control group (p < 0.05).

On day 10 after surgery, 72 children (70.6 %) in the main group demonstrated correct eye position versus 19 (33.3 %) children in the control group (OR = 4.80, 95% CI [2.39–9.63], p < 0.05). On day 10 after surgery, 23 (22.5 %) children in the main group had a residual deviation of 6–10°, and 11 children (10.8 %) to whom a DA initially was greater than 30° had a residual DA of 15–20°.

An analysis of the long-term surgery outcomes (1–3 years after intervention) was performed for 141 patients (48 children in the control group and 93 children in the main group) (Table 2). In the remote postoperative period, the correct eye position was preserved in 46 children (49.5 %) in the main group versus 5 children (10.4 %) in the control group (OR = 8.42, 95% CI [3.06–23.14], p < 0.05). Among children in the main group, DA of 6–10° was observed in 29 children (31.2 %) and 15–20° in 15 children (16.1 %). Secondary deviation developed in 3 children (3.2 %) in the main group versus 7 children (14.6 %) in the control group (OR = 5.12, 95% CI [1.26–20.81], p < 0.05). Residual DA in the long-term period increased in 10 children (10.8 %) in the main group versus 25 children (24.4 %) in the control group (p < 0.05) in 95% CI [22.94–222.10], p < 0.05). In the long-term period, 41 children (44.1 %) of the main group managed to achieve binocular cooperation (simultaneous vision was formed in 35 children, binocular–in 6 children) versus 12 children (25.0 %) of the control group (all 12 children formed simultaneous vision) (OR = 2.37, 95% CI [1.09–5.11], p < 0.05). As a result, in the long-term period, 32 (34.4 %) patients of the main group and 30 (62.5 %) patients of the control group required repeated surgical intervention to eliminate divergent secondary S and residual DA (OR = 3.18, 95% CI [1.54–6.56], p < 0.05).

Table 2. Comparison of long-term surgical outcomes in children with CCS

<table>
<thead>
<tr>
<th>The effect</th>
<th>Control group (n=48)</th>
<th>Main group (n=93)</th>
<th>OR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct eye position, number of children</td>
<td>46 49.5%</td>
<td>5 10.4%</td>
<td>8.42*</td>
<td>3.06-23.14</td>
</tr>
<tr>
<td>Secondary deviation, number of children</td>
<td>3 3.2%</td>
<td>7 14.6%</td>
<td>5.12*</td>
<td>1.26-20.81</td>
</tr>
<tr>
<td>Increase in the residual DA, number of children</td>
<td>10 10.8%</td>
<td>3 89.6%</td>
<td>71.38*</td>
<td>22.94-222.10</td>
</tr>
<tr>
<td>Achieved binocular cooperation, number of children</td>
<td>41 44.1%</td>
<td>12 25%</td>
<td>2.37*</td>
<td>1.09-5.11</td>
</tr>
<tr>
<td>Repeated surgical intervention performed</td>
<td>32 34.4%</td>
<td>30 62.5%</td>
<td>3.18*</td>
<td>1.54-6.56</td>
</tr>
</tbody>
</table>

Note. * differences are statistically significant compared to the control group (p < 0.05).

**Discussion**

The main objective of this study was to improve the efficacy of surgical treatment of CCSS in children aged 4–8 years. A modified method of surgical treatment was proposed to solve this problem, suggesting dosage resection of LRM and recessions of IRM. The volume of these manipulations depends on DA, S duration, features of LRM attachment, and distance from the LRM to the limbus. This differentiated approach
is more effective as it allows taking into account the individual characteristics of each child. Also, the need for such a differentiated approach in LRM recession is essential as the distance further for more than 11 mm away from the limbus can result in the divergent secondary S in the future. Moreover, this distance moves the LRM beyond the equator of the eyeball. The need to correct the magnitude of IRM tenon resection depending on the tendon width (measured at surgery) and the duration of S is because with time, atrophy of the elastic components of the tendon develops on the side opposite to the deviation of the eye at S. The width of the tendon can also be used to judge the magnitude of endotendinous indirectly.

The great efficacy of the proposed technique for surgical CCS correction on the day after surgery is evidenced by a statistically significant intergroup difference (p<0.05) in the main group (children operated on using the proposed technique) and the control group (children operated on using the traditional technique). At that, the normal position of the eyeballs was observed (see Table 1) in 84 children (82.3%) versus 30 children (52.6%) (OR = 4.20, 95% CI [2.03-8.70], p<0.05). In the early postoperative period, the greater effect compared to the main group: 25 (43.9%) children versus 17 (16.7%) children (OR = 3.91, 95% CI [1.87-8.17], p<0.05). This also indicates the lower effectiveness of the traditional technique.

In the author’s opinion, the positive effect was preserved in a significant number of children even in the long-term period after surgery of 1-3 years (Table 2). In particular, the greater effectiveness of the modified surgical treatment technique of CCS in children evidenced by statistically significant intergroup difference (57.4% of cases versus 10.4% (OR = 8.42, 95% CI [3.06-23.14], p<0.05), binocular cooperation was achieved in 44.1% of cases versus 25.0% (OR = 2.37, 95% CI [1.09-5.11], p<0.05). Of no less importance is the fact that secondary deviation developed less frequently in children after the modified surgical treatment of CCS compared to traditional surgery (in 3.2% of cases vs. 14.6% (OR = 5.12, 95% CI [1.26-20.81], p<0.05), increased residual DA (in 10.8% of cases versus 89.6% (OR = 71.38, 95% CI [22.94-222.10], p<0.05), and significantly less frequently a repeated surgery was required (in 34.4% of cases versus 62.5% (OR = 3.18, 95% CI [1.54-6.56], p<0.05)).

The results of this study are comparable to the results of similar research efforts on the efficacy of IRM recession and LRM resection in CCS. In particular, a survey conducted in the United States found that dosed resection of the LRM is technically straightforward, effective, and less traumatic than traditional medial resection. Besides, it does not lead to disruption of the ciliary circulation. Another study conducted in Greece involving 109 children also demonstrated the efficacy of IRM recession and resection of LRM at CCS, in which normal eye position was achieved in 89.9% of cases. However, it should be noted that in this study, only an 8-week follow-up of children after surgery was performed; long-term results were not considered.

Aznauryan et al. performed a similar study in Russia. The authors examined the efficacy of their proposed technique for the surgical treatment of concomitant non-accommodative S in which a typical recession of IRM was performed (with a weakening purpose). As an alternative to resection, the LRMPlication (as a strengthening operation) was applied. The STRABO program was employed to calculate the dosage of the surgery, where apart from DA, the length of the anteroposterior axis of the eyeball was taken into account. Oney eraftertheoperative treatment, correct eye position and stable binocular vision were achieved in 57 (100.0%) operated children. It testifies the effectiveness of the dosed technique (with application of STRABO program) of recession and plication (resection) at nonaccommodative CCS.

**Conclusions**

The proposed modified method of surgical treatment of convergent concomitant strabismus in children is more effective compared to the traditional method. In the long-term period, this method helps preserve the correct position of the eyes (in 49.5% of cases versus 10.4% (OR = 8.42, 95% CI [3.06-23.14], p<0.05), 0.05), achieve binocular cooperation (in 44.1% of cases versus 25.0% (OR = 2.37, 95% CI [1.09-5.11], p<0.05)). With application of the modified surgical treatment, secondary deviation developed less frequently compared to traditional surgery (in 3.2% of cases versus 14.6% (OR = 5.12, 95% CI [1.26-20.81], p<0.05), residual deviation angle increased (in 10.8% of cases versus 89.6% (OR = 71.38, 95%
CI [22.94-222.10], p<0.05), and repeated surgery was required significantly less frequently (in 34.4% of cases versus 62.5% (OR = 3.18, 95% CI [1.54-6.56], p<0.05).

**Prospects for further research**

Study of the clinical effectiveness of surgical intervention for vertical strabismus in children.

**Funding.** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Conflict of interest.** The authors declare no conflicts of interest.

**Ethical clearance:** The study protocol and the informed consent form for participation in the study were approved by the Medical Ethics Committee at the I.M. Sechenov First Moscow State Medical University (Protocol № 3 of 18.03.2019). Only children whose parent (legal guardian) signed informed consent for the child’s participation in the study were included.

**Authors’ contribution:**

Data gathering and idea owner of this study: MS, ZU, and TD;

Study design: ZU, TD, and ER;

Data gathering: MS, TD, and ER;

Writing and submitting manuscript: MS, ZU, and ER;

Editing and approval of final draft: MS, ZU, TD, and ER.

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**References**


