Original article

Surgical treatment of patientswithconvergent concomitant strabismus: clinical effectiveness and long-term outcomes

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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: Thestudy 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 underwenttraditionalsurgicalintervention(controlgroup), and102 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.Inthe remotepostoperativeperiod,thecorrect eyeposition was preserved in 46 children (49.5%) in the main group vs.5children (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%) childrenin 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.

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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.[1]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.[2]It is not unusual for children with visual impairments to have autism-like behavior anddelayed semantic and pragmatic skills.[3,4]

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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million children and irreversible and/ or severe visual impairments– in1.4million children.[5]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.[6]

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.[7]

Oculomotor pathology, namely, binocular vision disorders and strabismus (S),[8] plays an essential role in the overall structure of childhood ocular diseases.S occurs in 2% of children between 4 and 10 years old.[9,10]The prevalence of S differs across different ethnic groups, with esotropia (concomitant strabismus) being more prevalent in whites,[11] and exotropia – in East Asian and African-American populations.[12]

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.[13,14]Slow reading (due to unstable attachment), difficulties in performing motion and visual tasks (balance control, grip) are associated with S.[15]Quite often, S results in psychological problems assuch children can be discriminated against. They are less likely to be accepted by their peers and may experience work problems as adults.[12,14]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.[16]The primary aim of surgical treatment is to restore the correct eye position in orbit.[17]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.[18,19]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.[20]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.[19,20]Another method of surgical correction is to create plication, which is less traumatic than resection but adequate for small deviation angles (DA).[21]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 hypocorrectionamounts to 20 to 40%.[22,23]

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 recessionofthedirectoculomotormuscles,buttheyarebasedsolelyontheir own clinical experience and observation results. At that, the calculation was carried out empirically.[18,19]Studies on improving surgical treatment techniques and developing the dosage schemes for resection 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 ofconvergent 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 dividedintotwogroups:Group1(control)consistedof57children(32girls(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.

Inclusioncriteria wereage4to8years, the diagnoses ofconvergent concomitantstrabismus,strabismic angle of 8° or more, first strabismus surgery, informed consent to participate in the study signed by a parent (legal guardian of thechild).

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 30thday 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 functionalscotomaandbifovealfusion (BFF) (on synoptophore), visual character (on a four-point test), examination of eyeball mobility, andassessment 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 themuscle-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 ofmillimeters.

When resecting the LRM, its tendon is crucialto 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,withDAupto15°, themagnitudeofLRMresectionwas4.5-5.0mm,at 15-20°– 5.5- 6.0mm,at 20-25°– 6.5-7.0mm,at 25-30°– 7.5-8.0mm,over30°– 8.5-9.0mm.IftheLRM 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≤5mm,theNPMresectionvalueshall be increasedby0.5mm. Besides,itshould also be increased by 0.4-0.5 mm if the duration of S ≥4years.

icalprocessing of theobtaineddatawasperformedusingMicrosoftExcel 2013 (Microsoft, USA) and SPSS 13.0. The null hypotheses were tested at $p < 0.05$. Quantitative features were compared using Mann-Whitney-Wilcoxon U-criterion, qualitative characteristics, and their occurrence frequency were compared using odds ratio (OR)calculation.

Compliance with ethical norms and principles

The study protocol and the informed consent form for participation in the study were approvedbythe MedicalEthicsCommitteeattheI.M.SechenovFirst MoscowStateMedicalUniversity (Protocol № 3 of 18.03.2019).Onlychildrenwhoseparent(legalguardian) signed informed consent for the child'sparticipationinthestudywereincluded.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),theCouncilofEuropeConvention onHumanRightsandBiomedicine(of 04.11.1986),the CouncilofEuropeConventiononHumanRightsandBiomedicine(of 12.12.2006), and the Council of Europe Guidelines on BiomedicalResearch.

Results

Analysis of strabismus types revealed that among the control patients, 48 children (84.2 %) had alternating S, 9children (15.8 %) had monolateralS, and 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, 2children (3.5%) had emmetropicS, and 4 children (7.0%) had myopia. In the main group, 92 children (90.2%) had hyperopic S, 3children (2.9%) had emmetropicS, 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°in8children (14.0%),morethan30°– inchildren 6(10.5%). Inthemaingroup, DAwasupto10°in7children (6.9%),10-15°in18children (17.7%),15-20°in32 children (31.4%),20-25°in23children (22.5%),25-30°in13children (12.7%),more than 30° – in 9 (8.8 %) children. The comparison groups did not differ statistically (p>0.05) concerningstrabismus type, refraction, and DAvalue.

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 differenceof (p<0.05). Hypo-effect in the main group was notedin17 (16.7%) childrenversus 25 (43.9%)children in the control group with a statistically significant inter group difference of (p<0.05).Also,1child (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) (Table1).

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

The effect	Control group (n=57)		Maingroup (n=102)		OR	CI
	Abs.	%	Abs.	%		
Correcteyeposition, number of children	84	82.3	30	52.6	4.2*	2.03-8.70
Hypoeffect, number of children	17	16.7	25	43.9	3.91*	1.87-8.17
Hypereffect, number of children	1	1.0	2	3.5	3.67	0.33-41.42
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 eyepositionversus19 (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 hada residual deviation of 6-10°, and 11 children (10.8%) to whom a DAinitially 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 performedfor 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 preservedin 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 observedin 29 children (31.2%) and 15-20° in 15 children (16.1%). Secondary deviation developed in 3children (3.2%) in the main groupversus7children(14.6%)inthecontrolgroup(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 43 children (89.6%) in the control group (OR = 71.38, 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 35children,binocular–in6children) versus12children(25.0%)ofthecontrolgroup (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 secondaryS and residual DA (OR = 3.18, 95% CI [1.54-6.56], p<0.05).

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

The effect	Control group (n=48)		Maingroup (n=93)		OR	CI
	Abs.	%	Abs.	%		
Correcteyeposition, number of children	46	49.5	5	10.4	8.42*	3.06-23.14
Secondarydeviation, number of children	3	3.2	7	14.6	5.12*	1.26-20.81
Increase in the residual DA, number of children	10	10.8	3	89.6	71.38*	22.94-222.10
Achieved binocular cooperation, number of children	41	44.1	12	25	2.37*	1.09-5.11
Repeated surgical intervention performed	32	34.4	30	62.5	3.18*	1.54-6.56
Note. * differences are statistically significant compared to the control group (p<0.05).						

Discussion

The main objective of this study was to improvet heefficacyofsurgicaltreatmentofCCSinchildrenaged4-8years.A modified method of surgical treatment was proposed to solve this problem, suggestinga dosed resection of LRM and recessions of IRM. Thevolumeofthese manipulations dependsonDA,Sduration,featuresofLRMattachment, and distance from the LRM to the limbus. This differentiated approach

is more effective asitallows taking into account the in individual characteristics of each child. Also, the need for such a differentiated approach in LRM recession is essentialasthe distance further for more than 11 mm away from the limbus can result in thedivergent secondaryS in the future. Moreover, this distance moves the LRM beyond the equator of the eyeball. The need to correct the magnitude of IRM ten donresectiondependingonthe 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 endotendinosus 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 thecontrol 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%)versus30children(52.6%)(OR=4.20,95%CI [2.03-8.70],$p<0.05$). In the early postoperative period, asignificantlyhigher ($p<0.05$) proportion of children in the control group demonstrated a hypo-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 childrenisevidenced byastatistically significantinter group differencein the proportion of children in which the correct eye position was preserved in the long-term period (49.5% of cases versus 10.4%(OR=8.42,95%CI[3.06-23.14],$p<0.05$)), binocular cooperation was achieved in 44.1%ofcasesversus25.0%(OR=2.37,95%CI[1.09-5.11],$p<0.05$)).Ofnoless 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],$p<0.05$).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 effortson 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.[24] Another study conducted in Greece involving 109 children alsodemonstrated the efficacy of IRM recession and resection of LRM at CCS,inwhich normaleyepositionwasachie vedin89.9%ofcases. However,itshouldbenotedthat inthisstudy,onlyan 8-weekfollow-upofchildrenaf tersurgery wasper formed; long-term results were not considered.[25]

Aznauryan et al. performed a similar study in Russia.[26]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 strengtheningoperation) wasapplied.The STRABO program was employed tocalculatethedosageofthesurgery, whereapart from DA, the length of the anteroposterior axis of the eyeball was taken into account. Oney earaftertheoperative treatment, correct eye position and stable binocular vision were achievedin 57 (100.0 %) operated children.Ittestifiest The effectiveness of thedosedtechnique (withan application of STRABO program) of recession and plication (resection) at nonaccommodative CCS.[26]

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 positionoftheeyes(in49.5%ofcasesversus10 .4%(OR=8.42,95%CI[3.06-23.14], $p<0.05$).0.05)), achieve binocular cooperation (in 44.1 % of cases versus25.0% (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 (in3.2% ofcasesversus14.6% (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.

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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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