Improvement of Binocular Summation in Intermittent Exotropia Following Successful Postoperative Alignment

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Abstract

Purpose: To investigate the improvement of binocular summation (BiS) for the high (100%) contrast and different low contrasts (10%, 5%, 2.5%) and the relationship of BiS with stereopsis and central fusion in patients with intermittent exotropia (IXT) after strabismic surgeries.

Design: Prospective study

Participants: Seventy-six patients with IXT aging 9 to 40 years with poor control at distance before strabismus surgeries.

Methods: To analyze preoperative and postoperative BiS records and the proportions of patients with different BiS for the high (100%) contrast and the low contrasts (10%, 5%, 2.5%). The score of visual acuity (log Mar) was recorded when patient recognizing the full line with full refraction correction. BiS was classified into three situations depending on whether binocular visual acuity (BVA) was better, worse or equal to that of the better-seeing eye. The results of distant random dots stereograph(RDS) were grouped into A, unable to recognize; B, moderate, $200'' \leq RDS \leq 400''$ and C, good, $RDS < 200''$.

Results: The patients with binocular summation were increased from 9.2% to 40.8% for 100%contrast, from 17.1% to 53.9% for 10% contrast, from 21.1% to 76.1% for 5% contrast, from 21.1% to 72.4% for 2.5% contrast after surgeries, respectively. Tested using 2.5% contrast, (1) more patients presented binocular summation in the groups B and C ; (2) postoperative improvements of BVA in group B(1.5 ± 1.03 lines) and group C (1.57 ± 1.26 lines) differed significantly with that in the group A (0.74 ± 1.00 line); (3) more patients presented binocular summation and the improvement of BVA was 1.43 ± 1.16 lines in the group with central fusion after surgeries.

Conclusions: BiS for high contrast and different low contrasts can be improved in IXT after successful surgical treatment. It may be associated with obtaining central fusion, recovering stereopsis at distance and good alignment after the surgeries. BiS for 2.5% contrast was improved significantly and sensitive to the good stereopsis and central fusion. Improvement of BiS, particularly for low contrast, has benefit for the daily activities in the real environment. BiS could be as supplementary assessment of binocular function for the patients with IXT before and after treatment.

Introduction

The characteristic of IXT is intermittent divergent misalignment, presenting firstly at distance fixation. The binocular vision is destroyed gradually in IXT at distance and then at near. Traditionally, the clinicians test patients with Bagolini lenses, Worth-4-dot test, Titmus and random dots stereograph (RDS) to evaluate the binocular vision function. All tests introduce an artificial situation that may affect the test results to a greater or lesser degree.

Binocular summation is defined as the superiority of visual function for binocular over monocular viewing. As natural condition of seeing, binocular visual acuity (BVA) is important for the activities in daily life. But it is neglected in the clinic examination. Binocular summation is affected by the age, interocular difference of monocular vision and the presence of strabismus [3]. The mean binocular summation (BiS) for the low contrast decreased significantly and even was inhibited in strabismic patients [4]. Binocular inhibition for 1.25% contrast was related with diminished quality of life in the strabismic patients [5]. The proportion of strabismic patients with binocular summation was improved from 21–30% for 2.5% contrast and from 13–26% for 1.25% contrast after surgeries. Simultaneously, the proportion of patients with binocular inhibition decreased both in high and in low contrast levels after surgeries[6].

Improved BiS is thought as a functional benefit from the surgical correction of strabismus. In the previous study, esotropia had less effects on the improvement of BiS after surgeries than exotropia[6]. However, BiS has not been investigated well as the binocular function in patients with IXT. Our study is to probe the BiS improvement in IXT after strabismic surgery and its relationship with the traditional examinations of binocular vision.

Subjects And Methods

Patients

All study procedures adhered to the Declaration of Helsinki for research involving human subjects. The study protocol was approved by Institutional Review Board (IRB) of Tianjin Eye Hospital (TJEH). Waiver of informed consent and approval of the protocol were granted by TJEH-IRB. Seventy-six patients with IXT underwent strabismic surgeries from October 2017 to April 2019. There were 30 female and 46 male patients, aged 9 to 40 years. All the enrolled patients with IXT could be alignment at near but lacked stereopsis at distance tested by random dots stereograph(RDS) and no central fusion tested by Worth-4-dot test at 3 m before surgeries. We excluded the patients with amblyopia, anisometropia, nystagmus, vertical deviation, dissociated deviation, mental maldevelopmental and neurological abnormalities. No subjects had previous strabismus surgery.

Examinations

All the patients were examined by the same ophthalmologist. Deviations were measured by prism-alternative cover test in the primary position and in 9-gaze. The assessments of binocular vision were taken while patients wearing spectacles with full refraction correction, which included Bagolini lens test, Worth-4-dot test (standard flashlight projecting at 3 m for central fusion), Titmus test and distant Random Dots Stereograph (P/N 1006, Vision assessment Corporation, Illinois, USA), .

High Contrast (100%) Visual Acuity and Low Contrast (10%, 5%, 2.5%) Visual Acuity were tested using LEA numbers acuity tests (Part B courtesy Good-Lite Company, Streamwood, IL.) at 3 m in a dim room. All patients underwent BVA and monocular visual acuity tests in the different contrasts at preoperative and postoperative visits. The score of visual acuity (log Mar) was recorded when patient recognizing the full line. We calculated BiS score as the differences between BVA and monocular visual acuity. BiS score was classified into three situations: (1) $\text{BiS} \geq 1$, BVA better than that of the better-seeing eye at least 1 line, called binocular summation; (2) $\text{BiS} \leq -1$, BVA worse than that of the better-seeing eye at least 1 line, called binocular inhibition; (3) $-1 < \text{BiS} < 1$, called equality. The results of distant RDS were grouped into: A, nil, unable to recognize; B, moderate, $200'' \leq \text{RDS} \leq 400''$ and C, good, $\text{RDS} < 200''$. The results of Worth-4-dot test at distance were central fusion, central suppression and diplopia.

Statistical analysis

The postoperative BiS scores in different groups were compared using t-test and one-way ANOVA. The preoperative and postoperative proportions of patients with different BiS were compared using the Fisher exact test. All data were analyzed with SPSS version 20.0 (IBM, Armonk, NY, USA). P values less than .05 were deemed statistically significant.

Results

The preoperative exo-deviations ranged from 20 PD to 65PD at near and from 20 PD to 60PD at distance. The postoperative deviations ranged from 4 PD esophoria to 10 PD exotropia in the primary position in all the patients at the follow-up visiting 2 to 3 months after surgeries.

Preoperative and postoperative BiS for different contrasts in patients with IXT

There were significant differences between preoperative and postoperative proportions for all contrasts (Fisher exact test, $P = 0.00$ for all contrast levels) (**Table 1.**) There were also significant differences in postoperative proportions of patients with different BiS scores for four contrasts (Fisher exact test, $P = 0.01$). By pairwise comparison, significant differences presented between 100% and 5% contrast and also between 100% and 2.5% contrast (Fisher exact test, $P = 0.022$, 0.001 , respectively). However, there was no difference between other groupings ($P = 0.273$ between 100% and 10% contrast, $P = 0.096$ between 10% and 5% contrast, $P = 0.057$ between 10% and 2.5% contrast, and $P = 0.429$ between 5% and 2.5% contrast, respectively).

Postoperative BiS in groups with different RDS at distance

Table 2 showed the numbers of the patients with different BiS score in three groups depending on the results of postoperative distant RDS. The proportions for 2.5% contrast differed significantly among three groups ($P = 0.001$). Tested using 2.5% contrast LEA visual chart, more patients presented binocular summation in the group B (85.7%) and C (86.4%) than that in group A (46.1%).

The average BiS records for high and low contrasts were shown in Table 3. Tested by 2.5% contrast, there was significant different in the postoperative BiS scores of three groups ($P = 0.01$).

Relationship of BiS score and Worth-4-dot test

15 patients had central suppression and 61 obtained binocularly central fusion after surgeries tested by standard Worth-4-dot flashlight projecting at 3 m. The numbers of patients with different BiS scores and the average BiS records for high and low contrasts were showed in Table 4 and Table 5. The number of patients having binocular summation at 2.5% contrast significantly increased (80.3%) in patients having central fusion, comparing with that in patients without central fusion (40%) ($P = 0.005$). The average BiS record at 2.5% contrast differed significantly between the patients with and without central fusion ($P = 0.01$).

Discussion

Binocular summation is the superiority of visual function for binocular over monocular viewing. BiS was calculated as a ratio between the binocular score and the better-eye score, which was close to the estimated 1.4 in normal subjects in laboratory measures,[8]. The improvement in visual acuity for binocular viewing at high contrast is 7% in average [8]. BiS for low contrast improves approximately 40% or greater in normal participants. 10% contrast is thought a more sensitive measure of both monocular and binocular visual function in multiple sclerosis and retrobulbar neuritis, which is associated with brain MRI lesion burden. Reductions in vision specific quality of life were associated with lower scores for the low contrast[9, 10]. In children, 65.7% had binocular summation and 28.6% had binocular equivalency and 5.7% had binocular inhibition,[11]. The age, visual acuity of the better eye, interocular difference of monocular vision and stereoacuity affect BiS,[3, 10, 12].

Binocular interaction was affected by the presence of strabismus. The BiS was more sensitivity in the low contrast than that in the high contrast. Pineles et al found the mean BiS was lower in the strabismic patients than control participants for 2.5% and 1.25% contrasts. But there was no significant difference in BiS for 100% contrast. The mean BiS of 0.9 for 1.25% contrast in strabismic patients demonstrated binocular inhibition,[4]. Anika reported that the average BiS score of -2.14 letters for 1.25% contrast in the strabismic patients. It might explain blur vision complained by the strabismic patients that cannot be demonstrated by the routine examinations. Binocular inhibition for 1.25%

contrast was associated with decreased quality of life,[5]. Jaffer et al reported BiS for high contrasts was not associated with stereoacuity but that for the 2.5% contrast was significant related with both near and distance stereoacuity,[13]. Melinda found that subnormal BiS for 1.25% contrast in Strabismic amblyopes was similar to that in strabismic patients before surgeries. Strabismus surgery also had effect on the improvement of low-contrast BiS in Strabismic amblyopes,[14]. The proportion of patients with BiS was increased from 21–30% for 2.5%contrast and from 13–26% for 1.25%contrast after surgeries, respectively. The proportion of patients with binocular inhibition was decreased postoperatively for all contrast levels,[6].

Although stereoacuity and BiS for low contrast are correlated, they might be differentially affected by strabismus. Having measurable preoperative stereoacuity, older onset of strabismus, and larger preoperative deviation were factors of improved BiS after the surgeries,[14]. In these previous studies, the enrolled subjects had all subtypes of strabismus. BiS might be more affected in esotropia than that in exotropia,[15, 16]. The patients with infantile esotropia and childhood-onset strabismus had deeper suppression than patients with other subtypes so that they had less effect on BiS scores from strabismus surgery,[6]. The patients with IXT could maintain some degree of binocular visual function. Stereoacuity at distance was variable in 42% patients,[17]. Deterioration in near stereoacuity at 1 to 2 years follow-up is infrequent in IXT [18]. Chang reported binocular inhibition presented in 39.2% patients with IXT for 100% contrast. Distance BVA correlated with a decreased distance stereoacuity but not with the size of the deviation. It might be helpful in assessing the deterioration of alignment in IXT,[14]. Jeong found binocular CS summation ratio was correlated to control scale in IXT and might be a useful method in assessing binocular visual function in IXT,[20]. We supposed BiS in IXT should be effect on more obviously than other type of strabismus. However, The improvement of BiS for the high and low contrasts in IXT, as the functional benefit from the surgical treatment has not been investigated well in the previous study.

In our series, the proportions of patients with binocular summation were significantly increased for all the contrasts (100%, 10%, 5% and 2.5%) after surgeries. More patients obtained binocular summation at 5% and 2.5% contrast after surgeries. We considered that our results of surgical effect on BiS were better than that in the previous studies because only the patients with IXT were enrolled, excluding other subtypes of strabismus, amblyopia, anisometropia, nystagmus, and mental maldevelopment. The postoperative improvement of BVA for 2.5% contrast differed significantly among three groups of the patients with different distant RDS and between the groups with and without central fusion. We suggested that BiS for 2.5% contrast might be sensitive for binocular vision in all the contrasts.

In our series, the binocular summation also presented in some patients without stereopsis or central fusion. Viewing at 10° eccentric to the fovea reduced VA about 8 ETDRS lines. A manifest strabismus causing an image to fall extra fovea (non-corresponding retinal location) in the deviated eye, might lead to interocular difference and therefore decrease BiS, or even produce binocular inhibition [6, 12]. Therefore, we supposed that good alignment after strabismic surgeries might improve BiS in those without stereopsis or central fusion. Although the improvement of BiS was most evident at low contrasts, it was also present at high contrast in some patients with a good alignment after surgery.

There are several limitations in our study. We didn't analyze the relationship between BiS and the result of Bagolini lens tests because there were only four patients had suppression tested by Bagolini lens after surgeries. We didn't investigate the relationship between BiS and the near stereopsis tested by Titmus. The postoperative examinations were taken at 2 to 3 month after surgeries so all the patients had good outcomes after surgeries. Further study is required to investigate BiS improvement in long term.

In conclusions, the BiS for the high and low contrasts could be improved in IXT after surgical treatment. It might be associated with obtaining central fusion, recovering stereopsis at distance and good alignment after the surgeries. Improvement of BiS, particularly for 2.5% contrast, has benefit for the daily activities in the real environment and

increasing the quality of life. We suggest the BiS could be as supplementary assessment of binocular function for the patients with and without stereopsis and central fusion before and after surgeries to evaluate the improvement of vision function in the real environment.

Declarations

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Competing interests None declared.

Patient consent Not required.

Ethics approval The Institutional Review Board of Tianjin Eye Hospital approved this retrospective study of the medical records of the patients.

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Tables

.. The numbers and proportions of the patients with different BiS Scores before and after strabismic Surgeries.

	100%contrast visual acuity			10%contrast visual acuity			5%contrast visual acuity			2.5%contrast visual acuity		
	BiS≥1 n (%)	-1<BiS<1 n (%)	BiS≤-1 n (%)	BiS≥1 n (%)	-1<BiS<1 n (%)	BiS≤-1 n (%)	BiS≥1 n (%)	-1<BiS<1 n (%)	BiS≤-1 n (%)	BiS≥1 n (%)	-1<BiS<1 n (%)	BiS≤-1 n (%)
Preoperative	7 (9.2%)	60 (78.9%)	9 (11.8%)	13 (17.1%)	57 (75.0%)	6 (7.9%)	16 (21.1%)	54 (71.1%)	6 (7.9%)	16 (21.1%)	54 (71.1%)	6 (7.9%)
Postoperative	31 (40.8%)	42 (55.3%)	3 (3.9%)	41 (53.9%)	33 (43.4%)	2 (2.6%)	51 (76.1%)	21 (27.6%)	4 (5.3%)	55 (72.4%)	20 (26.3%)	1 (1.3%)
P Value		0.00			0.00			0.00			0.00	

, preoperative; Post-op, postoperative; n, number; BiS, binocular summation

.. The numbers of the patients with different BiS Scores after strabismic Surgeries.

	100%contrast visual acuity			10%contrast visual acuity			5%contrast visual acuity			2.5%contrast visual acuity		
	BiS≥1 n	-1<BiS<1 n	BiS≤-1 n	BiS≥1 n	-1<BiS<1 n	BiS≤-1 n	BiS≥1 n	-1<BiS<1 n	BiS≤-1 n	BiS≥1 n	-1<BiS<1 n	BiS≤-1 n
Group A (n=26)	8	17	1	12	14	0	13	12	1	12	14	0
Group B (n=28)	14	13	1	16	12	0	21	6	1	24	4	0
Group C (n=22)	9	12	1	13	7	2	17	3	2	19	2	1
P	0.661			0.220			0.079			0.001		

n, number; BiS, binocular summation

Table3. The average BiS records (x±s) for high contrast and different low contrast in three groups after strabismic surgeries.

	100% contrast	10% contrast	5% contrast	2.5% contrast
Group A	0.32±0.68	0.32±0.62	0.63±1.10	0.74±1.00
Group B	0.41±0.57	0.5±0.56	0.93±0.81	1.5±1.03
Group C	0.46±0.66	0.61±0.97	1.05±0.95	1.57±1.26
F	0.28	1.03	0.38	4.70
P	0.80	0.36	0.68	0.01

.. The numbers of the patients with different BiS Scores in the groups with and without central fusion after strabismic Surgeries.

	100%contrast visual acuity			10%contrast visual acuity			5%contrast visual acuity			2.5%contrast visual acuity		
	BiS $\geq$ 1	-1<BiS<1	BiS $\leq$ -1	BiS $\geq$ 1	-1<BiS<1	BiS $\leq$ -1	BiS $\geq$ 1	-1<BiS<1	BiS $\leq$ -1	BiS $\geq$ 1	-1<BiS<1	BiS $\leq$ -1
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Supression (n=15)	3	11	1	8	7	0	8	6	1	6	9	0
Central fusion (n=61)	28	31	2	32	27	2	43	15	3	49	11	1
P		0.164			1.000			0.392			0.005	

n, number; BiS, binocular summation

Table 5. The average BiS records for high and different low contrasts in patients with and without central fusion after strabismic surgeries.

	100% contrast	10% contrast	5% contrast	2.5% contrast
Central Fusion	0.42 $\pm$ 0.62	0.52 $\pm$ 0.60	0.93 $\pm$ 0.88	1.43 $\pm$ 1.16
Suppression	0.33 $\pm$ 0.38	0.33 $\pm$ 0.67	0.56 $\pm$ 0.92	0.56 $\pm$ 0.88
F	0.05	0.05	0.05	6.75
P	0.82	0.82	0.83	0.01*