· Clinical Research ·

Comparison of contrast sensitivity based on the surgical results for intermittent exotropia

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Abstract

● AIM: To compare contrast sensitivity (CS) based on the surgical results for intermittent exotropia (IXT) and to examine the relationship between CS and photophobia.

● METHODS: Medical records of the patients who underwent bilateral lateral rectus muscle recession for IXT between 4 and 12 years old were reviewed retrospectively. They were categorized based on the surgical results; successful correction group (*n*=36) and overcorrection group (esotropia ≥10 PD at 3mo postoperatively, *n*=18). Using CGT-2000 test for CS was performed binocularly, and subjective reports of photophobia was investigated preoperatively and at 3mo postoperatively. Objective photophobia was defined as a significant decrease in CS in the presence of glare.

● RESULTS: Preoperatively, there was no difference in CS between the groups. Postoperatively, under mesopic conditions, significant improvement of CS was observed at 6.3°, 4°, and 2.5° in the successful correction group and at 6.3° and 4° in the overcorrection group, regardless of glare. Under photopic conditions, at all visual angles except 0.64°, improvement in CS was noted in both groups while CS worsened significantly at 0.64° in the overcorrection group postoperatively. At all visual angles under photopic conditions postoperatively, regardless of glare, CS in the overcorrected group was significantly worse than that in the successful correction group, and CS was significantly decreased by addition of glare in both groups. All patients except one (96.4%) in the successful correction group and 8 patients (61.5%) in overcorrection group showed improvement of photophobia postoperatively, which correlated with CS under photopic conditions (*P*=0.001, 0.03).

● CONCLUSION: After surgery for IXT, CS under photopic conditions improve at all visual angles except 0.64°, while CS is significantly worse in the overcorrection group postoperatively at 0.64°. Subjective photophobia have significant correlation with CS under photopic conditions, and may be used as an objective indicator of photophobia.

● KEYWORDS: contrast sensitivity; intermittent exotropia; overcorrection; photophobia; success

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INTRODUCTION

It is thought that photophobia appears to prevent pain caused by constriction of the pupil by trigeminal nerve stimulation, acting as a protective mechanism against harmful short wavelengths[1-4]. In patients with strabismus, it is believed that bright light stimulates the retina and interferes with fusion, resulting in manifest strabismus, and photophobia that closes the eyes appears to avoid diplopia and visual confusion. However, no clear mechanism has been elucidated. The contrast sensitivity (CS) test is a method for displaying the spatial resolution of the visual system, the results of which could be abnormal in various diseases including amblyopia, optic neuritis, cataract, glaucoma, strabismus, brain lesion, *etc*[5-6]. Previous studies have examined photophobia patterns based on the subjective symptoms of patients with intermittent exotropia (IXT)[7]. Chung *et al*[7] reported changes in photophobia using CS test before and after surgery in patients with IXT, and normal controls. Their studies are based on previous reports suggesting that change in CS before and after cataract or refractive surgery is directly affected by presence and absence of glare. Meanwhile, no study examined the change of CS and its relationship with photophobia according to results of strabismus surgery. This study was undertaken to compare the change of CS and evaluate the relation of CS and photophobia in patients with successful correction and overcorrection after surgery for IXT.

SUBJECTS AND METHODS

Ethical Approval This study was approved by the Institutional Review Board (IRB) of Inje University Haundae Paik Hospital, Busan, South Korea (Approval number: 2018-02-008-002). Written informed consent was waived due to the retrospective nature of the study.

Medical records of patients who underwent bilateral lateral rectus muscle recession (BLR) for basic type IXT by one surgeon (Lee SJ) between August 2017 and March 2018 were reviewed retrospectively. Patients between 4y (deemed able to cooperate in the CS test) and 12y (who had the potential to develop binocular visual function) were included.

In order to remove bias derived from type of IXT, only the basic type [difference in angle of deviation ≤10 prism diopters (PD) between distance and near] IXT was evaluated. To compare the CS according to the alignment of IXT, the patients were divided into two groups according to the alignment after BLR at 3mo postoperatively: 1) successful correction group (with exophoria ≤8 PD or esophoria ≤4 PD at both distance and near, *n*=36); 2) overcorrection group (with esotropia ≥10 PD at distance and near, *n*=18).

Patients with history of paralytic strabismus, restrictive strabismus, amblyopia, ocular abnormality, hyperopia or myopia ≥6 diopters (D), astigmatism ≥2 D, previous ocular surgery (including strabismus surgery), nystagmus, congenital deformity, neurologic abnormality, chromosomal disorder, or systemic diseases were excluded from the study.

Age, sex, best corrected visual acuity (BCVA; logMAR), spherical equivalent, preoperative stereopsis (Titmus test), and binocular status (Worth 4 dot, W4D) were recorded. Preoperative and postoperative angle of deviation were measured at a distance of 30 cm (near) and 6 m (far) using alternate prism cover test. Preoperative and postoperative subjective photophobia symptoms were reported by the patients or their guardians. These included frequent eye blinking, severe frowning, and face turn when bright light was present.

The CS test using CGT-2000 (Takagi Seiko Co., Ltd., Tokyo, Japan) was performed preoperatively and 3mo postoperatively. The CS was measured binocularly at 6 spatial frequencies (6.3°, 4°, 2.5°, 1.6°, 1°, and 0.64°) under mesopic [average luminance of 5 candelas/square meter (cd/m^2)] and photopic conditions (average luminance of 100 cd/m^2) with refractive correction. To provide glare stimulus, 12 circularly aligned white lights (light-emitting diodes, LED) with a brightness of 40 000 lx under mesopic conditions and 100 000 lx under photopic conditions were added. The test was carried out in the order as follows: mesopic without glare, mesopic with glare, photopic without glare, and photopic with glare. In CS test, photophobia was defined as a statistically significant decrease in test results with glare.

Statistical Analysis Statistical analysis was performed using SPSS software version 12.10 (SPSS Inc., Chicago, IL, USA). Independent *t*-test and Chi-square test were used to compare the CS with presence or absence of glare at each spatial frequency and to compare the CS difference between groups. The CS before and after BLR were compared using the paired *t*-test. The concordance of preoperative subjective photophobia symptoms and CS results obtained at the visual angle with the highest reduction due to glare was evaluated by Run test. Considering the lower prevalence of postoperative photophobia, resolution of subjective photophobia symptoms and CS result obtained at the visual angle having no difference due to glare was evaluated by Run test. A *P*-value less than 0.05 was considered as statistically significant.

RESULTS

Baseline Characteristics of Study Subjects A total of 54 patients were included in the study. The mean age was 7.3±1.8 (4-12)y and 41 (75.9%) patients were female. All patients had a BCVA (logMAR) of 0 and the average spherical equivalent was -0.5±2.1 (-5.8 to +5.7) D. Preoperative stereopsis was 112.9±95.0 seconds of arc (40 to 800 seconds of arc), and 18 patients (33.3%) showed suppression. There were 36 patients in the successful correction group, and 18 in the overcorrection group at 3mo postoperatively. Twenty-eight patients (77.8%) in the successful correction group and 13 (72.2%) in the overcorrection group complained of preoperative photophobia. There were no significant differences in age, sex, BCVA, refractive error, stereopsis, suppression, or prevalence of photophobia between the groups (Table 1).

The angle of deviation was marked as "+" for exodeviation and "-" for esodeviation. In the successful correction group, the angle of deviation changed from +32.7±7.5 (+18 to +50) PD preoperatively to +0.3±3.1 (-4 to +8) PD at 3mo postoperatively. In the overcorrection group, the preoperative angle of deviation was +31.7±4.5 (+25 to +40) PD which changed to -15.0±3.4 (-18 to -10) PD postoperatively. There was no significant difference in preoperative angle of deviation between the two groups; the angle of deviation at 3mo postoperatively showed statistically significant differences (*P*<0.001). In the overcorrection group, 16 patients (88.9%) were treated with alternating patching treatment while 2 patients (11.1%) were prescribed prism glasses. Six patients who did not respond to patching were prescribed prism glasses in addition to alternating patching treatment.

Preoperative Comparison of CS Between Groups and Between Presence and Absence of Glare There was no significant difference in CS between the successful correction group and overcorrection group under both mesopic and photopic conditions, regardless of glare (mesopic without glare, mesopic with glare, photopic without glare, photopic with glare: *P*=0.880, 0.996, 0.978, and 0.948, respectively). Under mesopic conditions, there was no significant difference in CS by glare stimuli (*P*=0.697 and 0.840 for the successful correction and overcorrection groups, respectively). CS under photopic conditions tended to decrease at all visual angles

Table 1 Comparison of preoperative baseline characteristics between groups according to the result of bilateral rectus muscles recession in intermittent exotropia mean±SD (range)

Variables	Successful correction group	Overcorrection group	*P*
Totally (*n*)	36	18	
Age (y)	7.4±2.0 (4 to 12)	7.0±1.6 (5 to 10)	0.87[a]
Sex (F/M)	26/10	15/3	0.65[b]
BCVA (logMAR)	0	0	
Spherical equivalent (diopter)	-0.4±2.3 (-5.75 to +5.63)	-0.7±1.6 (-5.63 to +0.88)	0.18[a]
Stereopsis (seconds of arc)	110.3±136.2 (40 to 800)	96.7±39.3 (40 to 200)	0.45[a]
Suppression (*n*)	11	7	0.54[b]
Preoperative angle of deviation (PD)	+32.7±7.5 (+18 to +50)	+31.7±4.5 (+25 to +40)	0.1[a]
Subjective report of photophobia (patients)	28 (77.8%)	13 (72.2%)	0.67[b]

BCVA: Best corrected visual acuity; "+" means exodeviation; [a]The comparison was performed by using Fisher's exact test. [b]The comparison was performed by using Mann-Whitney *U* test.

Table 2 *P*-value of change in contrast sensitivity before and after bilateral rectus muscle recession

Visual angle (°)	Mesopic without glare	Mesopic with glare	Photopic without glare	Photopic with glare
Successful correction group				
6.3	0.009	0.046	0.003	0.017
4	0.012	0.001	0.001	0.026
2.5	0.022	0.049	0.001	0.004
1.6	0.064	0.897	0.002	0.002
1	0.554	0.124	0.018	0.041
0.64	0.864	0.658	0.057	0.578
Overcorrection group				
6.3	0.042	0.034	0.001	0.039
4	0.017	0.027	0.001	0.029
2.5	0.066	0.054	0.001	0.043
1.6	0.485	0.545	0.003	0.044
1	0.658	0.721	0.012	0.675
0.64	0.590	0.445	0.003	0.002

Paired *t*-test.

with addition of glare although with no statistical significance (P=0.459 and 0.533 for the successful correction and overcorrection groups, respectively; Figures 1A-1B, 2A-2B). Preoperative photophobia was reported by 28 patients (77.8%) in the successful correction group and 13 patients (72.2%) in overcorrection group which was not significantly correlated with the CS (P=0.383 and 0.763 under mesopic conditions, P=0.166 and 0.228 under photopic conditions for the successful correction and overcorrection groups, respectively).

Comparison of CS before and after BLR In the successful correction group, CS significantly improved postoperatively at 6.3°, 4°, and 2.5° under mesopic conditions, regardless of glare, while there was no significant difference at 1.6°, 1°, and 0.64°. In the overcorrection group, under mesopic conditions regardless of glare, CS significantly improved postoperatively at 6.3°, 4°, improved with no significant difference at 2.5°, and decreased with no significant difference at 1.6°, 1°, and 0.64° (Figure 1, Table 2).

Under photopic conditions without glare, both groups showed significant improvement in CS at all visual angles except 0.64° postoperatively. At 0.64°, there was significant worsening of postoperative CS in the overcorrection group while no difference was noted in the successful correction group. Under photopic conditions with glare, postoperative CS significantly improved at all visual angles except 0.64° in the successful correction group and at 6.3°, 4°, 2.5°, and 1.6° in the overcorrection group. The latter showed no significant difference in CS at 1°, and a significant decrease at 0.64° (Figure 2, Table 2).

Postoperative Comparison of CS Between Groups and Between Presence and Absence of Glare Postoperatively under mesopic conditions without glare, significant difference in CS between groups was found at 6.3°, 4°, 2.5°, and 1.6° (all P<0.01). With addition of glare stimuli, the absolute value of CS decreased in both groups at 6.3°, 4°, 2.5°, and 1.6°, with a non-significant difference between the groups (Figure 1C-1D).

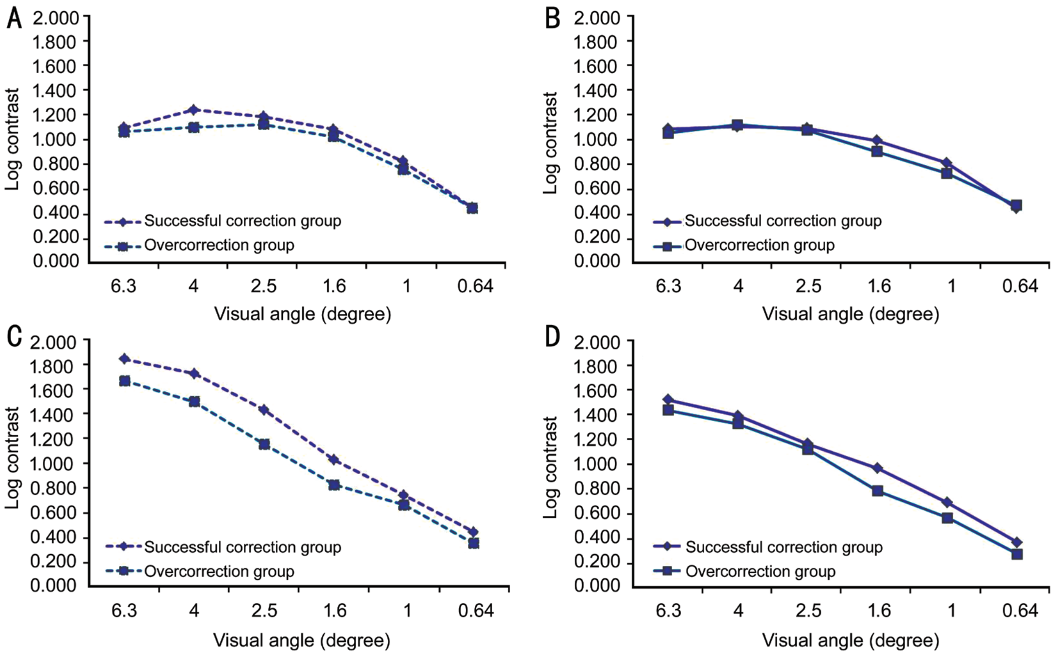

Figure 1 CS test under mesopic conditions A: Preoperative CS without glare; B: Preoperative CS with glare; C: Postoperative CS without glare; D: Postoperative CS with glare.

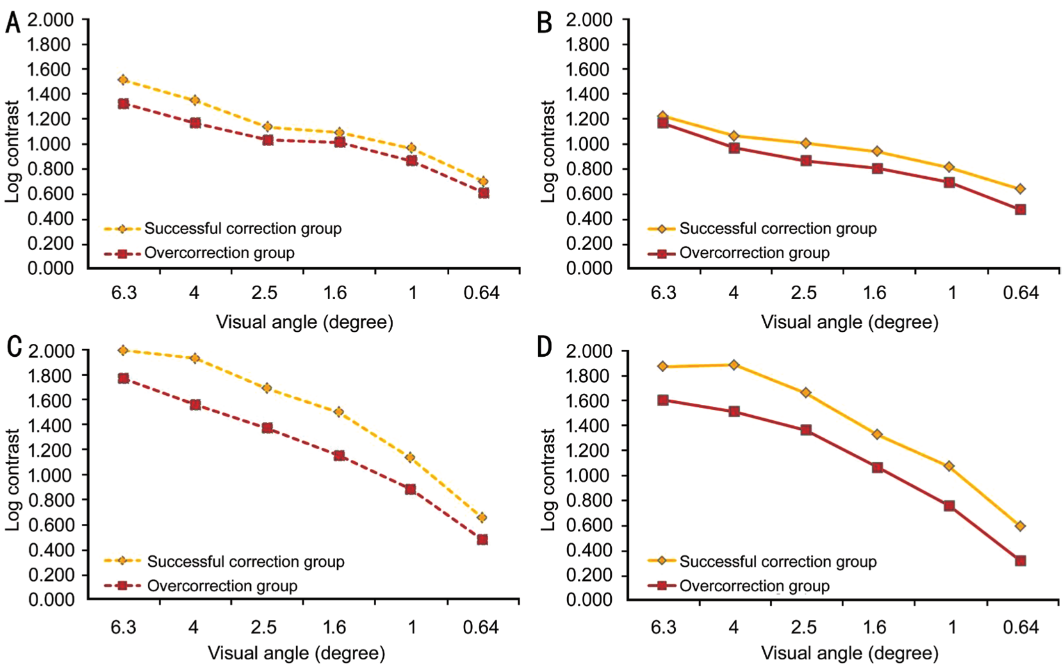

Figure 2 CS test under photopic conditions A: Preoperative CS without glare; B: Preoperative CS with glare; C: Postoperative CS without glare; D: Postoperative CS with glare.

Under photopic conditions, CS in the overcorrection group was significantly worse than that in the successful correction group at all visual angles (all $P<0.001$). In both groups, CS significantly decreased at all visual angles when glare was added, with significant difference in CS between the groups (all $P<0.001$; Figure 2C-2D).

All patients except one (96.4%) in the successful correction group and 8 patients (61.5%) in the overcorrection group showed improvement in photophobia postoperatively, which correlated with CS under photopic conditions ($P=0.001$ and 0.03 for the successful correction and overcorrection groups, respectively). No significant correlation was found between subjective symptom and CS under mesopic conditions ($P=0.66$ and 0.09 for the successful correction and overcorrection groups, respectively).

DISCUSSION

IXT is the most common form of exotropia, and patients often complain of blurred vision, ocular fatigue, headache, diplopia, and photophobia. The reported prevalence of photophobia in IXT varies from 54% to 65.5%[8-10]. However, the mechanism has not been clarified and only a few hypotheses were suggested. Some claim that diplopia and binocular photophobia are caused by an inability to suppress under bright light[10]. Others have claimed that, outdoors, there is insufficient stimulus to trigger convergence so fusion is blocked by light stimulus, leading to manifest strabismus, and this loss of control on alignment could be related to photophobia[11-12]. Likewise, children with exotropia often complain of photophobia under bright light[13], which is consistent with the findings of this study where the CS changed depending on the absence or presence of glare under photopic conditions. Further, improvement of CS after BLR at all visual angles except 0.64° under photopic conditions in both groups corresponds with previous studies as well.

The study results are distinct from those of Chung *et al*[7], which showed statistical agreement of CS under mesopic conditions with subjective photophobia in the children with IXT. These differences can be explained by the difference in setting value on CS test. Previous studies usually performed CS test using Optec 6500 vision testing system, under the setting of a background luminance of 3 cd/m^2 for mesopic conditions and 85 cd/m^2 for photopic conditions, and glare stimuli of 1 lx and 10 lx, respectively. Consequently, the difference in intensity of glare light on the background luminance was greater under mesopic conditions, and contraction of ciliary muscle by glare stimuli improved CS more prominently under photopic conditions, leading to lesser difference in CS by addition of glare under photopic conditions[2]. Our study was performed using CGT-2000 under a background luminance of 5 cd/m^2 and glare stimuli of 40 000 lx for mesopic conditions and a luminance of 100 cd/m^2 and glare stimuli of 100 000 lx for photopic conditions, a more intense glare, resulting in prominent difference under photopic conditions. Also, previous studies were based on spatial frequencies of 1.5, 3, 6, 12, 18 cycles per degree (cpd) while this study was conducted under visual angles of 6.3, 4, 2.5, 1.6, 1, and 0.64 degrees, deviating the test results to lower spatial frequency, equal to a larger visual angle. This might lower the difference between CS under mesopic conditions with and without glare.

Under mesopic conditions without glare, postoperative CS at larger and intermediate visual angles was significantly worse in the overcorrection group than in the successful correction group. The absolute value of CS decreased in both groups with addition of glare, and the difference between groups decreased to non-significant levels. It is a plausible speculation that CS at small visual angles reflect central visual acuity and high visual function. However, additional studies are needed to clarify the difference with the current study.

Meanwhile, Chung *et al*[7] reported that CS was significantly lower at intermediate and larger visual angles under both mesopic and photopic conditions in the patients with IXT than in normal subjects, and improved significantly at intermediate visual angles under mesopic conditions with glare after strabismus surgery. Our study also showed postoperative improvement in CS at larger visual angles and no significant difference at smaller visual angles under mesopic conditions in both groups. Improvement of CS at intermediate visual angle (2.5°) in the successful correction group was also noted.

Under photopic conditions, CS significantly improved postoperatively at all visual angles except 0.64° in both groups. At 0.64°, postoperative CS was significantly decreased in the overcorrection group and was similar in the successful correction group. Previous studies have reported that CS worsened after intraocular surgeries[14-15], and theorized that it might be due to decreased postoperative central visual acuity. However, postoperative CS worsened even in the patients with good postoperative visual acuity, indicating causative factors such as surgical stress or high visual functions other than visual acuity[16]. Lew *et al*[12] analysed the factors associated with binocular photophobia in IXT and found that it was more common when the angle of exodeviation was greater than 25 PD and stereoacuity worse than 60 seconds of arc. On this basis, they claimed that the distance angle of strabismus reflects the strabismus condition better than the near angle, and photophobia involves high-level visual functions like stereoacuity rather than diplopia or exotropia itself[12]. Sjöstrand[17] reported a decrease in CS at all spatial frequencies in anisometropic amblyopia and decrease in CS only at high spatial frequencies in amblyopia with esotropia, with no correlation between visual acuity and CS[15]. In addition, Jones *et al*[18] performed animal studies which showed damaged function of spatial CS of X-cells of the lateral geniculate neuron only at high spatial frequencies in esotropia comparing to normal controls. Therefore, postoperative CS decrease at a high spatial frequency of 0.64° under photopic conditions in the overcorrection group could be partially explained by decreased CS at high spatial frequencies, and impaired stereopsis and high visual function in esotropia patients comparing to normal controls[19-22]. Further studies are needed to elucidate the effect on CS, especially, at high spatial frequency in esotropic patients without amblyopia and to investigate the prevalence and clinical presentation of photophobia in esotropia.

Under photopic conditions regardless of visual angle and glare, the successful correction and overcorrection groups showed significant difference in postoperative CS, which correlated with subjective photophobia. Lew *et al*[12] reported that photophobia also improved in cases of under-correction after exotropia correction surgery if angle of deviation decreased to 15 PD or less. Chung *et al*[7] also reported improvement in glare disability even in unsatisfactorily under-corrected IXT after strabismus surgery. These results imply that decrease in angle of deviation improves suppression or fusion, leading to alleviation of photophobia, which is more related to the extent of exodeviation rather than the presence of exotropia. However, a larger angle of exodeviation does not always coincide with more severe photophobia. Patients have variable levels of photophobia threshold, and the symptom can be prominent in exodeviation exceeding a certain degree or vanish below a certain degree. Prominently worse postoperative CS in the overcorrection group both under mesopic and photopic condition is thought to be related to decreased stereopsis and high visual function due to esodeviation. Further studies on the correlation between CS and decreased binocularity in overcorrection are needed.

The first limitation of this study was a small study sample size. Secondly, some of the pediatric patients could not clearly describe their subjective symptoms. Consequently, the difference in preoperative and postoperative photophobia symptoms was not clearly identified in some cases. Symptoms such as frequent blinking, eye frowning, and face turn were checked based on parental observation; some studies have stated that expression of these symptoms do not necessarily correspond to photophobia[23].

Nevertheless, there was noticeable improvement in photophobia following reduction in angle of exodeviation after surgery for IXT, and the postoperative photophobia was significantly correlated with CS under photopic conditions. In conclusion, it is expected that the CS test under photopic conditions in this study setting can be used as an objective indicator of photophobia.

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