Binocular Vision and Stereopsis Following Delayed Strabismus Surgery

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Abstract

***Purpose*:** Patients with infantile or childhood strabismus who do not achieve visual axes alignment early in life are believed to have poor prognosis with respect to the stereopsis. This study investigates the binocularity and stereopsis following delayed surgical alignment in patients with congenital and early-onset strabismus.

***Patients & Methods*:** 36 patients aged between 6-30 years participated in this study. The inclusion criteria were: constant horizontal deviation of 30 prism diopters (PD) or more, strabismus onset before age 3 and surgical alignment after age 6 years, alignment to within 10 PD of orthotropia after surgery. All patients were examined comprehensively and four binocularity and stereopsis tests including Titmus, Random dot E, Bagolini lenses and Worth 4-dot test were performed for all.

***Results*:** Of 36 patients, 20 (55.5%) had binocular vision using Bagolini striated glasses, 14 (38.9%) with Titmus test, 12 (33.3%) with Worth 4-dot test and 8 (22.2%) with Random dot E test. The achievement of stereopsis after visual alignment was statistically significant (P=0.008). Of 14 patients with positive Titmus test, 8 (57.1%) had stereoacuity of 200 sec of arc or better.

***Conclusion*:** This study demonstrated that even after delayed alignment of eyes in patients with infantile or early childhood strabismus, some degrees of stereopsis can be achieved in most cases.

***Key words*:** Strabismus, Stereopsis, Binocular Vision, Delayed Alignment

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Introduction

It is believed that surgical alignment of visual axes in visually mature patients, who have a history of congenital or infantile strabismus and did not have binocular vision during the critical period of infancy, cannot restore binocularity and stereopsis. There are limited but a growing number of evidence in the literature on the sensory outcome of delayed surgery in infantile and childhood strabismus. Some researchers have demonstrated the achievement of binocularity and stereopsis following surgery in visually mature patients with infantile or early-onset strabismus.[1-6] *Rosenbaum*[7] believes that fusion is attainable in adults with a large constant deviation present since early childhood. Other functional improvements after strabismus surgery—both before and after visual maturity—such as the positive psychological impact of eye alignment, improved self-esteem, communication skills, and social interaction are well proved.[8,9] Expansion of binocular visual fields is another functional benefit.

Wortham and *Greenwald*[10] have demonstrated an increase in horizontal visual field after surgery in adults with long-standing constant esotropia.

The purpose of this study is to investigate binocularity and the quality of stereopsis following delayed surgery in patients who have had strabismus since early childhood.

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Patients and Methods

All patients who underwent strabismus surgery between 1997 and 1999 in *Nikookari* Eye Hospital of *Tabriz* University of Medical Sciences were selected. Their charts were reviewed and the patients were included in this study if preoperative deviation in primary position was horizontal, constant and measured 30 PD or more, the strabismus onset was before age 3, eye alignment was achieved after age 6 for a minimum of 6 months, and the eyes were aligned to within 10 PD of orthotropia after surgery. Patients with history of neurologic or systemic diseases, which could affect eye alignment, and patients with organic retinal diseases were excluded.

Patients meeting our entry criteria were invited for examination. The following data were extracted from patients' medical charts or were collected through history taking: age, sex, age of onset of strabismus, age at surgical alignment, history of previous strabismus surgery and preoperative measurements of ocular deviation. All of the following examinations were carried out for all of the patients: visual acuity, best corrected visual acuity, biomicroscopic external examination, fundoscopy, cover test, prism cover test and tests of binocularity and stereopsis including: Titmus, Random dot E, Bagolini striated glasses and Worth 4-dot test.

To evaluate gross stereopsis by Titmus, we started with the housefly (threshold 3000 sec of arc). If the patient passed this part, the next parts of this test, including three rows of animals (thresholds: 400, 200 and 100 seconds of arc) and then the circles (threshold from 800 to 40 sec of arc) were presented. When a level failed, the test was stopped. To decrease false positive responses, we occluded one eye and repeated the test, or we turned the plate 90º to block out the stereoscopic effect. The Random dot E test was performed at 1 meter. It contained three cards and a pass or fail response was recorded. Bagolini striated glasses were placed at 45º and 135º before each eye and the patient was asked to fixate a small light and to draw the streaks he or she could see. If the patient drew two streaks crossed in the center the test was positive. In Worth 4-dot test, if bifoveal or peripheral fusion existed, the patient would report four dots.

Results

36 patients, 14 girls and 22 boys, (between 6-30 years) were enrolled in this study. Of these 36 patients, 20 (55.5%) had esotropia, and 16 (44.5%) had exotropia. All patients had an initial deviation between 30 and 90 PD. The onset of strabismus in 20 patients (55.5%) was before 6 months of age and in 16 patients (44.5%) was between 6 months and 3 years of age. 6 patients had deep amblyopia ($VA<^{2}/_{200}$) in one eye and 28 patients had best corrected visual acuity of $^{20}/_{25}$ or better.

The results of Titmus, Random dot E, Bagolini and Worth 4-dot tests are shown in Table 1.

Table 1. Stereopsis tests results for Patients with positive response

Test	Number	%
Random dot E	8	22.2
Titmus	14	38.9
Bagolini	20	55.5
Worth 4-dot	12	33.3

Of 14 patients, who revealed some degree of stereopsis by Titmus, 6 did not pass Random dot E test. Table 2 summarizes the Titmus stereoacuity. Of 14 patients, 6 had fine stereopsis (40-100 sec of arc) and 8 had stereopsis of 140 to 800 sec of arc. Interestingly 8 patients that had achieved stereoacuity of better than 200 using Titmus test, could pass the Random dot E test.

Table 2. Stereoacuity using Titmus test

Stereoacuity (sec of arc)	No of patients	Percent %
40-100	6	42.8
140-200	2	14.3
400	2	14.3
800	4	28.6
Total	14	100

The achievement of stereopsis after successful surgical alignment in our series was statistically significant (P=0.008). There was no statistically significant relationship between the duration of misalignment and recovery of stereopsis (P=0.1). The preoperative measurement of deviation did not significantly affect postoperative stereopsis (P=0.1).

Discussion

Worth[3] believed that patients with congenital esotropia had a congenital defect of fusion and a poor prognosis to develop binocularity. Later other studies showed that by the alignment of eyes in childhood, patients may have the opportunity to develop binocularity.[11-16] Although it is recognized that patients with infantile or childhood strabismus, who do not achieve alignment in early childhood, have a poor prognosis with respect to binocularity, the present study demonstrated that even with large angle and longstanding heterotropia in children, we can expect good stereopsis in some cases.

Kushner and *Morton*[1] demonstrated that of 359 adults who underwent surgery for longstanding constant strabismus, 86% showed binocularity using Bagolini lenses 6 weeks after surgery. Almost all patients developed strabismus in the first 5 years of life and were 21 year or older at the time of surgery. They concluded that regardless of the type and the duration of strabismus, or the depth of amblyopia in the deviating eye, the vast majority of patients developed binocularity. Their study included different types of strabismus including consecutive esotropia, consecutive exotropia and vertical strabismus. Of 106 patients with primary esotropia, 91 (86%) had binocular vision tested by Bagolini lenses. Our study demonstrated that binocularity was achievable in a considerable number of our patients too.

Ball and *Drummond*[2] studied a group of 8 patients with constant large angle heterotropia. The duration of strabismus ranged from 13 months to 40 years and the patients aged 11 to 62 years. They demonstrated remarkably good stereopsis following surgical alignment and found these unexpected results very interesting, given the large preoperative angle of constant deviation, the old age at the time of surgery, the long duration of strabismus, and the presence of fixation preference in six of the patients. Although in most cases the strabismus was longstanding, the onset was not in early childhood except in one patient who was an adult with infantile esotropia and attained stereopsis of 60 sec of arc postoperatively. Of 8 patients, 5 had exotropia which could possibly be intermittent exotropia so the patients had the opportunity to achieve stereopsis.

Morris et al[3] studied 24 strabismus patients with the onset within 2 years of age who underwent surgical correction after 8 years of age. All patients had peripheral fusion in Worth 4-dot testing. Of 24 patients, 12 had history of congenital esotropia with the onset documented before 6 months of age. Twelve patients (50%), 8 of whom were in the congenital group, achieved stereopsis of 200 seconds of arc or better using the Titmus test. This group of patients was similar to our group in terms of age of onset and age at surgery. Although the percentage of patients who gained stereopsis was higher than those in our study, both studies show that stereopsis is achievable in childhood strabismus even following a delayed surgery. The difference between the results can be associated to the fact that the number of data samples in both studies are small, which can result in large error margin. Additionally, the previous surgeries in Morris et al study might have created the opportunity to develop binocularity.

In a retrospective study, *Scott* et al[4] divided their patients, whose age at surgery ranged from 9 to 89 years, into two groups: 1) patients with strabismus onset before visual maturity and 2) patients with strabismus onset after visual maturity. They found that 29% of patients with congenital esotropia (a subtype of the first group) had some sensory fusion measured by Worth 4-dot or Titmus test and the other subtypes of the first group had even higher percentage of patients with stereopsis. In our study 33.3% of all patients had binocularity by Worth 4-dot test and 38.9% by Titmus test.

Gill and *Drummond*[5] demonstrated improvement of stereoacuity following surgery in visually mature patients. Of 187 patients aged 9 to 69 years at the time of surgery, 52% demonstrated some degree of Titmus stereoacuity (from 40 to 3000 sec of arc) postoperatively compared with 35% preoperatively. All patients were aligned to within 15 PD of orthotropia. The patients in this study had different types of strabismus including congenital, acquired paretic and restrictive strabismus with different ages of onset and the stereopsis has not been

reported separately in early childhood and adult strabismus. The relatively high percentage of positive response in Titmus, comparing to our study might be due to the type and age of onset of strabismus.

Mets et al[6] studied improvement of binocularity in a group of patients ranging in age from 16 to 80 years, who had undergone surgical correction of strabismus. Binocularity was measured using Titmus test, Worth 4-dot test or synoptophore. Of 72 patients, 30 (42%) improved in binocular function, 38 (53%) remained the same, and 4 (6%) had decreases in their stereoacuity. Of 30 patients with improved binocularity, 11 had childhood onset of strabismus and of these 11 patients, 4 had esotropia.

We evaluated binocularity using four different tests in all of our patients. Previous studies used only one or two tests in each patient to investigate the binocular vision in their patients. Worth 4-dot test and Bagolini lenses are useful tests to evaluate fusion. Titmus test is used to evaluate stereoscopic acuity since binocularity is not an "all or none" phenomenon. Stereopsis is the most highly developed level of binocularity. Although Titmus test has some monocular cues that may affect interpreting the test results, higher levels of stereopsis are less affected by monocular cues. The examiner can have confidence in reporting stereoacuity scores of 160 sec of arc or better. Monocular form cues may invalidate test results when interpreting scores>160 sec of arc.[17] We tried to reduce false positive responses by repeating the test after turning the plate 90 degree to block out the stereoscopic effect. In our study the proportion of patients who had binocular vision varies with the type of test, with the lowest proportion using Random dot E test and the highest proportion using Bagolini lenses. Bagolini lenses induce the least dissociation and most closely simulate everyday visual circumstances that may be the cause of relatively high proportion. Random dot E test has no monocular cue and may be challenging specially in children. The results for Random dot E test are reported as yes or no and depending on the distance of the cards from the patient the threshold varies. We performed this test at 1 meter so patients with stereoacuity of worse than 200 sec of arc failed. All 8 patients who had stereoacuity of 200 sec of arc or better using Titmus test could pass the Random dot E test. There are also studies supporting that early surgical alignment may promote the development of stereopsis in childhood and infantile strabismus.[11-16]

The present study does not deny the effect of early surgery on stereopsis but shows that even following delayed alignment of eyes in infantile or early childhood strabismus, we can expect some degrees of stereopsis in most cases. Nearly half of our patients had strabismus before 6 months of age and in the rest of them the onset of strabismus was between 6 months and 3 years of age and there was no history of alignment before age 8. Therefore, they did not have the opportunity to gain binocularity during the critical period of functional development of binocular vision. This study indicates that surgical correction of strabismus in such patients is not cosmetic, but rather has functional benefits.

Conclusion

These findings may encourage other investigators to design further studies for evaluating the binocularity in patients with documented congenital strabismus who have not been aligned in early childhood.

Also we observed remarkably variable results in binocularity testing. Some of these tests more closely resemble everyday visual circumstances, others are useful to score the stereoacuity and some others are less dependent on monocular cues. Therefore standards should be developed to evaluate the stereopsis in these patients as well as a method to predict the potential for binocularity in different patients.

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