Near and Distance Stereoacuity in Hyperopic Anisometropic Amblyopia Patients Treated after 6 Years of Age

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Abstract

Background Hyperopic anisometropic amblyopia is considered to have worse prognosis in stereoacuity especially when the treatment is begun at late childhood. The present study investigated both near and distance stereoacuity in hyperopic anisometropic amblyopia patients who began treatment after 6 years of age and had good visual acuity in the amblyopic eye.

Methods Ten hyperopic anisometropic amblyopia patients who began their treatment after 6 years of age and improved the visual acuity of their amblyopic eye to over 0.9 were included. The age at which a patient started wearing spectacles corresponded to the age of treatment onset, whereas the number of months required to reach the best corrected visual acuity was considered as the period of treatment. Near and distance stereoacuity were measured. We performed correlational analyses between stereoacuity scores and several other variables, such as the age at which stereoacuity was measured, the binocular refractions differences, the age of treatment onset, and the period of treatment.

Results The age of treatment onset ranged from 6 to 8 years. With the exception of two patients, all subjects obtained near stereoacuity better than 100 sec and distance stereoacuity better than 120 sec following treatment. Stereoacuity scores did not significantly correlate with the age of treatment onset or with the binocular refraction differences. Stereoacuity scores (both near and distance) significantly positively correlated with the period of treatment.

Conclusion The stereoacuity of our patients reached normal levels following treatment. These findings suggested that anisometropic amblyopia should be treated aggressively even in patients older than 6 years of age.

Background

Amblyopia is reported to be caused by the formation of an inadequate visual image on the fovea, which in turn results in poor visual acuity in the affected eye ¹. In fact, any factor that interferes with foveal image formation during the sensitive period for visual development can cause amblyopia. Among the various etiologies of amblyopia, anisometropia is a significant risk factor ^{2,3}. Anisometropic amblyopia results from the unequal refractive error in both eyes. Spherical hypermetropic anisometropia has been associated with higher rates of amblyopia than other forms of anisometropia ^{4,5}. Spherical hypermetropic anisometropia results in a more pronounced deterioration of binocularity than does cylindrical hypermetropic anisometropia or myopic spherical anisometropia, as evidenced by the higher rates of monofixation and the poorer near stereoacuity ⁶.

Stereoacuity arises from the horizontal retinal image disparity between the two foveae. This retinal disparity gives rise to the sensation of depth ⁷. An inverse relationship between the strength of the anisometropia and stereoacuity measures has been well established ^{8,9}, and a reduction in stereoacuity has been previously reported in anisometropic amblyopia patients ¹⁰.

Although it has been agreed that amblyopia treatment is less effective in older children, there is no consensus regarding specific age limits. The gold standard of treatment for hyperopic anisometropia amblyopia is a prescription of spectacles based on the cycloplegic examination followed by an occlusion or atropine penalization for the sound eye. It has been reported that compliance is an important factor for the successful outcome in the treatment for amblyopia because the treatment itself could disturb daily activities of patients, such as reading ¹¹. In addition, there have been publications suggesting that patients' ages are also important factors that limit visual prognosis. It has been reported that the visual acuity improved in 70% ¹² when the treatment began before 7 years of age while in only 20% when it was initiated after 7 years of age ¹³. However, it remains undetermined how the late treatment affects the improvement of stereoacuity.

The purpose of the present study was to investigate both near and distance stereoacuity in hyperopic anisometropia amblyopia patients who began treatment after 6 years of age and had good visual acuity in the amblyopic eye. To our knowledge, this is the first study investigating distance stereoacuity in children with hypermetropic anisometropic amblyopia who began their treatment after 6 years of age.

Methods

Ten hypermetropic anisometropic amblyopic patients who visited our clinic after 6 years of age and improved their visual acuity of amblyopic eye to over 0.9 were included in this study. All patients had a corrected visual acuity under 0.5 for the amblyopic eye and over 1.2 for the sound eye as measured with an angular visual acuity chart at their first visit. All patients were diagnosed with hyperopic anisometropic amblyopia based on the cycloplegic examination results. Treatment consisted in the prescription of spectacles followed by part-time occlusion therapy of the sound eye. Informed consent was obtained from all patients and the study adhered to the tenets of the Declaration of Helsinki. Approval from the institutional human experimentation committee was also granted.

Included patients were further examined to assess their near and distance stereoacuity when the visual acuity of the amblyopic eye showed an improvement over 0.9 measured with a cortical visual acuity chart. The age at which a patient started wearing spectacles corresponded to the age of treatment onset, whereas the number of months required to reach the best corrected visual acuity was considered as the period of treatment.

Patients wore their regular spectacles under Polaroid lenses when assessed with the stereoacuity tests. Near stereoacuity was measured with the Titmus Stereo Test (Stereo Optical Inc., Chicago) at a distance of 40 cm. and distance stereoacuity was measured with NIDEK SC-1600 Stereo Charts (NIDEK Co. Tokyo) at a distance of 5 m.

Both the difference between and the correlation between near and distance stereoacuity scores were investigated. The correlation between stereoacuity scores and the age of treatment onset, the correlation between stereoacuity scores and the age at which it was measured, the correlation between stereoacuity

scores and binocular refraction differences, and the correlation between stereoacuity scores and period of treatment were also examined.

Near and distance stereoacuity scores were compared with a paired t-test and the aforementioned correlations were analyzed with regression coefficients. A statistical significance was set as the P value was less than 0.05.

Results

The clinical characteristics of the patients are listed in Table 1. The age of treatment onset ranged from 6 to 8 years, with a mean of 6.9 ± 0.9 years. The age at which stereoacuity was measured ranged from 6 to 13 years, with a mean of 10.2 ± 2.6 years. The binocular refraction differences ranged from 1.25 to 4.50 D, with a mean of 2.38 ± 0.93 D. The period of treatment ranged from 2 to 82 months, with a mean of 20.75 ± 23.98 months. All patients obtained near stereoacuity scores better than 100 sec and distance stereoacuity scores better than 120 sec, with the exception of two patients. The first had a near stereoacuity score of 400 sec and a distance stereoacuity score of 600 sec, whereas the second had a near stereoacuity score of 140 sec and a distance stereoacuity score of 240 sec.

There was a significant positive correlation between near and distance stereoacuity ($R = 0.97$, $P < 0.0001$), indicating that patients with better near stereoacuity tended to also have better distance stereoacuity. There were no significant correlations between stereoacuity scores and the age of treatment onset (Fig. 1), nor were there significant correlations between stereoacuity scores and the age at which stereoacuity was measured (Fig. 2). Stereoacuity scores did not correlate with binocular refraction differences either (Fig. 3). Stereoacuity scores were, however, significantly positively correlated with the period of treatment ($R = 0.96$, $P < 0.0001$ for near stereoacuity and $R = 0.98$, $P < 0.0001$ for distance stereoacuity, Fig. 4), indicating that patients with shorter treatment durations tended to have better near and distance stereoacuity.

Discussion

Although there was variation regarding the binocular refraction differences and the age of treatment onset, the majority of the patients in this study reached normal levels of near and distance stereoacuity. Stereoacuity has previously been shown to positively correlate with visual acuity^{14,15}. It has also been suggested that in amblyopia the selectivity of V1 monocular neurons can shift away from the amblyopic eye and that the number of binocular neurons can be reduced^{16,17}. These changes could provide the neural mechanism that links deficits observed in visual acuity and in stereoacuity. Stereoacuity, crowding effects, and impaired recognition of closely spaced objects, have all been shown to correlate with inter-ocular differences, especially in children with poor stereoacuity¹⁸. All the patients in this study reached a corrected visual acuity over 0.9 as measured with a cortical visual acuity charts. The reduction of the inter-ocular differences for contour interactions may contribute to the good stereoacuity.

Correcting anisometropia with anisometropic glasses can induce differences in the binocular retinal image size, a phenomenon called aniseikonia. It has previously been suggested that aniseikonia can impair image fusion and stereopsis¹⁹. Furthermore, previous reports have indicated that binocularity compensation limits are in the range of 3%- 5%^{20,21}. However, anisometropia has not been previously reported to affect bifoveal fusion²². Indeed, the stereoacuity of patients wearing anisometropic glasses has been reported to be clinically normal and the glasses were not shown to significantly affect binocularity²³. The fact that in this study the majority of the patients developed good stereoacuity supports these findings.

Previous reports have shown that the visual acuity of anisometropic amblyopic patients treated with occlusion therapy is similar to that of those treated with atropine penalization²⁴. Because occlusion therapy is often believed to disturb binocularity, the patients included in this study were treated with part-time occlusion. Our findings suggest that part-time occlusion does not disrupt the development of binocularity.

Two of the 10 patients in the present study still had poor near and distance stereoacuity following treatment. Both patients began treatment relatively late (after 7 years of age) and had relatively larger binocular refraction differences compared with the other patients (2.75D and 4.50D). Indeed, these factors are considered important risk factors for poor stereoacuity. However, one of our other patients began treatment after 8 years of age, and two other patients had binocular refraction differences that were larger than 2.75D, yet all three of them still developed good stereoacuity. Furthermore, the two patients with poor stereoacuity reached their best corrected visual acuity more than 24 months after beginning treatment. It has been reported that visual acuity improvement in amblyopic patients was dramatically drops off after 2 years of treatment²⁵. These two patients also demonstrated poor treatment compliance by coming to the clinic for treatment on an irregular basis. Indeed, good compliance has been reported to be an important factor to ensure a successful outcome following amblyopia treatment¹¹. Therefore, longer durations of treatment and poor treatment compliance by patients can be considered as risk factors that hinder the success of the treatment.

Conclusions

Although the patients in this study began amblyopia treatment after 6 years of age, stereoacuity (near and distance) were found to improve when their visual acuity improved. These findings suggest that anisometropic amblyopia should be treated aggressively even in older patients.

Declarations

- **Ethics approval and consent to participate**

Verbal informed consents were obtained from all patients' parent or guardian where participants are under 16 years old. According to the ethnic policies of our institutional human experimentation

committee, verbal consents were approved as this research was non-interventional and non-invasive.

The study adhered to the tenets of the Declaration of Helsinki.

Approval from the institutional human experimentation committee was also granted (Clinical Experimental Committee of Saitama Medical Center, Dokkyo Medical University, No.1965).

- **Acknowledgements:** not applicable
- **Consent for publication**
- **Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- **Competing interests**

The authors declare that they have no competing interests.

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- **Authors' contributions**

RH have made substantial contributions to the conception, design of the work, analysis and interpretation of data. **RH** have also drafted the work.

SH have made substantial contributions to the conception, design of the work **and examined the patients included.**

SM have drafted the work and substantively revised it.

All authors read and approved the final manuscript.

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Table

Table: The clinical characteristics of patients included

Age of treatment onset	Age of stereoacuity measurement	VA of sound eye	VA of amblyopic eye	VA of amblyopic eye	Refractive differences	Duration of treatment	Near stereoacuity	Distance stereoacuity
(years)	(years)		at the first visit	at the last visit	(D)		(sec)	(sec)
6	11	1.2	0.3	1.2	1.25	2	40	60
6	6	1.2	0.4	0.9	2.00	10	80	120
6	7	1.2	0.3	0.9	2.75	13	40	120
6	12	1.2	0.3	0.9	2.00	3	40	60
7	8	1.5	0.4	1.5	1.50	15	40	60
7	13	1.2	0.4	1.2	2.75	82	400	600
7	13	1.2	0.4	1.2	2.25	5	50	60
8	13	1.5	0.5	1.2	4.50	24	140	240
8	10	1.2	0.5	1.2	3.25	6	100	60
8	9	1.2	0.5	1.2	1.50	13	80	120

Figures

Figure 1

Figure 1

The correlation between stereoacuity scores and age of treatment onset There were no significant correlations between stereoacuity scores and age of treatment onset.

Figure 2

Figure 2

The correlation between stereoacuity scores and the age at which stereoacuity was measured. There were no correlations between stereoacuity scores and the age at which stereoacuity was measured.

Figure 3

Figure 3

Correlation between stereoacuity scores and binocular refraction differences Stereoacuity scores were not correlated with binocular refraction differences

Figure 4

Figure 4

Correlation between stereoacuity scores and the period of treatment Stereoacuity scores were significantly positively correlated with the period of treatment, indicating that patients with shorter treatment durations tended to have better near and distance stereoacuity.