The Effects of CAM Vision Stimulator for Bilateral Amblyopia of Different Etiologies

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Bacground: To evaluate the association between bilateral amblyopia and the effects of CAM vision stimulator.

Methods: This retrospective study was carried out between January 1994 and July 2004. The 105 children enrolled were all younger than 7 years old and had bilateral amblyopia. All children wearing full-correction glasses regularly received CAM vision stimulation once per week. The patients' age, initial best corrected visual acuity (BCVA), final BCVA, and the number of CAM sessions needed to achieve a visual acuity (VA) ≥ 0.8 were recorded.

Results: The major cause of bilateral amblyopia was refractive error. In this study, the types of refractive error were classified as astigmatism (> 2.0D, 61 cases), hyperopia (> 3.0D, 17 cases), and myopia (> 4.0D, 12 cases). The myopic group showed significantly poorer visual outcomes than the other children after CAM treatment ($p < 0.05$). However, older children patients had better initial BCVA, and the hyperopic patients had the better outcomes in this study.

Conclusions: CAM treatment for bilateral amblyopia can achieve satisfactory improvement in 3 months in most instances. The myopic group and children younger than 4 years old had worse visual outcomes after CAM treatment.

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Key words: CAM vision stimulator, bilateral amblyopia

Amblyopia is the most common cause of monocular visual impairment in children, young adults and middle-aged adults. The prevalence of amblyopia has been reported in 0.2% to 5.3% of the population.[1]

During the 1960s, animal research showed cortical plasticity was limited to the early years of life. Clinical experience reveals that the treatment of amblyopia is most effective when started as early as possible, and becomes ineffective around the age of 8 years when the sensitive period of cortical visual maturation is considered complete. This therefore is the basis for the urgency to identify children with amblyopia.[2]

Currently, a up to now occlusion is the standard therapy for monocular amblyopia, and it is highly cost-effective. Treatment outcome has been shown to depend on the type of amblyopia, initial visual acuity (VA), compliance, and age at which treatment is started.[3-6]

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Another treatment for monocular amblyopia is the CAM vision stimulator, first described by Banks et al. in 1978. The basis of the CAM vision stimulator is that cell clusters in the visual cortex only respond to rectangular stimuli with a specific orientation, and different clusters respond to different angles of orientation.[7-9] According to the rationale, the CAM vision stimulator may stimulate the maturation of cells in the visual cortex and improve amblyopia.

The treatment of bilateral amblyopia involves wearing full-correction glasses and encouraging near-work training by occlusion or CAM stimulation. However, occlusion therapy in bilateral amblyopia is controversial, and there are no reports regarding the effect of CAM treatment for bilateral amblyopia. Therefore, the aim of our study was to evaluate the effects of CAM treatment in different types of bilateral amblyopia, and the factors affecting visual outcomes.

METHODS

Between Jan 1994 and July 2004, 105 children (57 boys and 48 girls) diagnosed with bilateral amblyopia at the Ophthalmology Department, Kaohsiung Chang Gung Memorial Hospital, Taiwan, were enrolled in this retrospective study. Bilateral amblyopia was defined as an initial best corrected visual acuity (BCVA) $\leqq$ 0.5, in both eyes, using the Snellen chart for detailed statistical calculation, and no interocular difference in the BCVA of two lines. Inclusion criteria consisted of age between 3 and 7 years old, ability to complete the study's visual acuity testing, an initial binocular BCVA $\leqq$ 0.5 with the wearing of optimal correction glasses at the time of enrollment in CAM training. and availability for a follow-up time longer than 3 months. All children had a full ophthalmological examination, and no child had anterior segment or fundus pathology commensurate with the visual acuity. Each child was shown a series of high-contrast square-wave gratings of different spatial frequencies, and treatment was undertaken with the 3 smallest discernible gratings. Each in turn was rotated at one revolution per minute behind a clear Perspex cover on which the child drew or played pencil games under supervision. The session lasted 7 minutes and was repeated at weekly intervals.[10] The VA with glasses was measured after each session. Treatment success was defined as a BCVA $\geq$ 0.8. Therefore, the number of sessions needed to achieve a BCVA $\geq$ 0.8 and the final VA were recorded to evaluate the effect of the CAM stimulator on bilateral amblyopia. The associations between sex, strabismus, age and bilateral amblyopia type with the visual outcome after CAM treatment were analyzed by repeated measures ANOVA. The initial BCVA with the effect of CAM treatment was analyzed by Pearson correlations.

RESULTS

In our case series, 105 children (57 boys and 48 girls) were recorded between Jan 1994 and July 2004. The mean age of the children was 4.91 years old (range, 3-7 years old) and the follow-up interval was 34 months (range, 3-147 months). Amblyopia recurrence were found in 3 children during follow-up after CAM treatment. The definition of successful CAM treatment was achievement of a bilateral BCVA $\geq$ 0.8 and the success rate in our study was 95.2% (100/105). We excluded the 5 children who were treated and did not achieve bilateral success, therefore 100 children remained in the analysis: the average initial BCVA, final BCVA, and number of CAM sessions needed to achieve a BCVA better than 0.8 were 0.39 (range 0.3 to 0.5), 0.93 (range 0.8 to 1.0), and 6.8 (range 2 to 40), respectively. Pearson's correlation (Fig. 1, Table 1) showed that those with better initial BCVAs had better visual outcomes (better final BCVA, and fewer CAM sessions).

The major cause of binocular amblyopia was refractive error. Therefore, we classified the patients with initial BCVA $\leq$ 0.5 into 3 refractive error groups: the astigmatism group (> 2.0D, range 2.0D to 6.0D, 61 cases), hyperopic group (> 3.0D, range 3.0D to 9.0D, 17 cases), and myopic group (> 4.0D, range 4.0D to 12.0D, 12 cases). The mean initial BCVA [oculus dexter (OD)/ oculus sinister (OS)] in these groups was 0.41/ 0.38, 0.39/ 0.39, and 0.34/ 0.33, respectively. The final BCVA (OD/OS) was 0.94/ 0.93, 0.97/ 0.95, and 0.86/ 0.88. The number of CAM sessions was 5.92/7.26, 6.17/6.56 and 9.73/10.45. Using repeated measures ANOVA, the myopic group was shown significantly poorer visual outcomes, including final VA and CAM sessions, than the other 2 groups ($p < 0.05$) (Table 2). At the same time, the hyperopic group was shown relatively

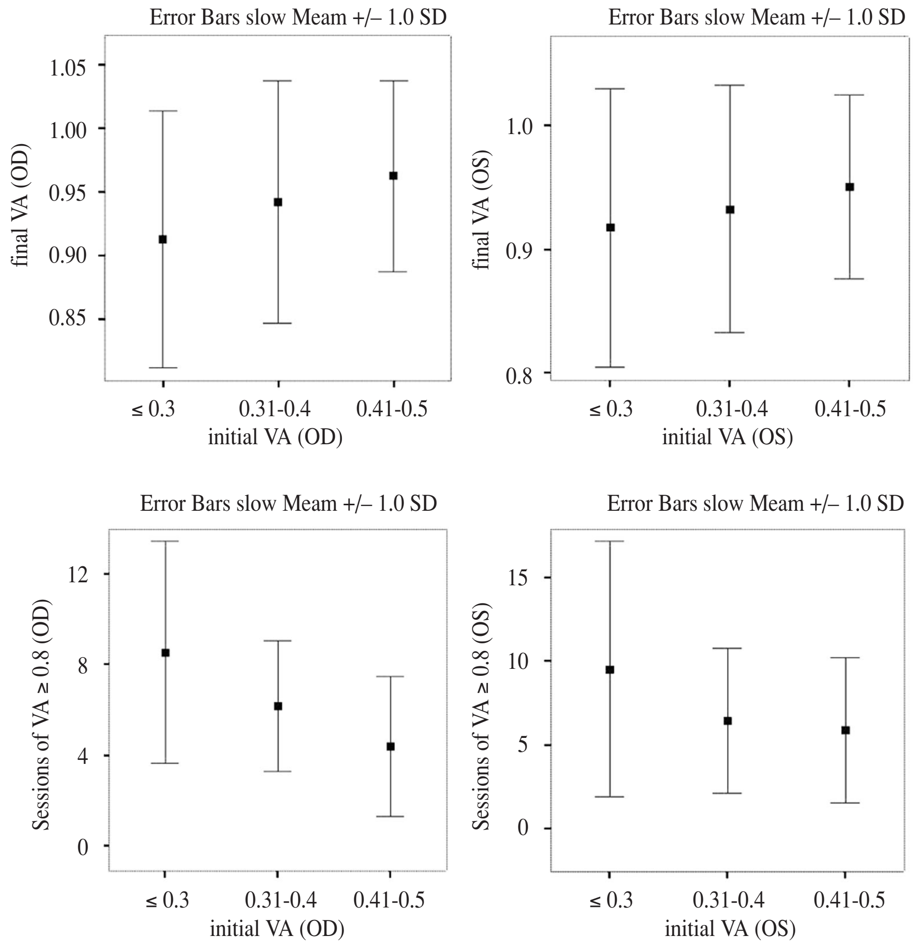

Fig. 1 Those with better initial BCVA had better final BCVA (top figures). Those with better initial BCVA needed fewer CAM sessions (bottom figures). OD: oculus dexter; OS: oculus sinister.

Table 1. Initial BCVA and Visual Outcome

		Initial BCVA (OD)	Initial BCVA (OS)
Final VA	r	0.188	0.101
	p value	0.075	0.342
Sessions ≧ 0.8	r	−0.431	−0.262
	p value	< 0.01	0.013

Abbreviations: BCVA: best-corrected visual acuity; R: Pearson correlation coefficient; OD: oculus dexter; OS: oculus sinister.

better visual outcomes. Seventeen children were classified as having combined strabismus and refractive error. Compared with the pure refractive error cases, we did not find any significant difference in visual outcome after CAM treatment with this type of bilateral amblyopia.

We classified the children into 3 age groups: ≤ 4 years old, 5 years old and ≥ 6 years old. The mean initial BCVA (OD/OS) in these groups was 0.38/ 0.38, 0.40/ 0.39, and 0.40/ 0.38, respectively. The final BCVA (OD/OS) was 0.95/ 0.93, 0.94/ 0.94, and 0.92/ 0.93. The number of CAM sessions needed to achieve a BCVA (OD/OS) better than 0.8 was 7.13/9.56, 6.07/6.57, and 5.65/5.85. Using repeated - measures ANOVA, there was no significant association between age and the effect of CAM treatment. However, we found that older patients had fewer CAM sessions (Table 3). There was no significant association between sex or strabismus and visual outcome after CAM treatment using repeated -mea-

Table 2. Visual Outcomes for Children with Astigmatism, Hyperopia and Myopia after CAM Treatment

	Etiology (mean ± SD)				
Variables	Astigmatism	Hyperopia	Myopia		
	n = 61	n = 17	n = 12	*p* value	Post hoc
Initial BCVA (OD)	0.42 ± 0.08	0.39 ± 0.09	0.33 ± 0.1	< 0.01	
Final BCVA (OD)	0.95 ± 0.09	0.98 ± 0.06	0.88 ± 0.11	0.001	A&M ($p = 0.017$)
BCVA ≧ 0.8 CAM sessions (OD)	5.75 ± 3.18	5.47 ± 3.96	10.92 ± 5.89	< 0.01	A&M ($p < 0.001$); H&M ($p = 0.001$)
Initial BCVA (OS)	0.39 ± 0.08	0.4 ± 0.1	0.33 ± 0.09	< 0.01	
Final BCVA (OS)	0.94 ± 0.1	0.95 ± 0.09	0.89 ± 0.12	0.021	A&M ($p = 0.024$); H&M ($p = 0.042$)
BCVA ≧ 0.8 CAM sessions (OS)	6.84 ± 5.9	6.06 ± 2.7	12.8 ± 7.86	0.012	A&M ($p = 0.016$); H&M ($p = 0.022$)

Abbreviations: BCVA: best-corrected visual acuity; n: number; A&M: comparison of the astigmatism group and myopia group; H&M: comparison of the hyperopia group and myopia group; OD: oculus dexter; OS: oculus sinister.
The data showed a statistically significant difference by repeated -measures ANOVA; Post hoc comparisons were applied with Bonferroni procedure.

Table 3. Visual Outcomes according to Age

	Age (mean ± SD)				
Variables	≦ 4	5	≧ 6		
	n = 32	n = 42	n = 26	*p* value	*p* value for linear trend
Initial VA (OD)	0.39 ± 0.1	0.4 ± 0.08	0.41 ± 0.08		
Final VA (OD)	0.96 ± 0.08	0.95 ± 0.1	0.94 ± 0.09	0.83	0.73
VA ≧ 0.8 CAM sessions (OD)	7.29 ± 5.35	6.15 ± 3.33	5.67 ± 3.67	0.34	0.17
Initial VA (OS)	0.38 ± 0.09	0.39 ± 0.09	0.39 ± 0.07		
Final VA (OS)	0.93 ± 0.1	0.93 ± 0.1	0.95 ± 0.08	0.91	0.87
VA ≧ 0.8 CAM sessions (OS)	9.68 ± 8.71	6.59 ± 4.12	5.9 ± 3.55	*0.029	*0.016

Abbreviations: BCVA: best-corrected visual acuity; n: number; OD: oculus dexter; OS: oculus sinister; *: the data showed statistically significant difference by repeated -measures ANOVA.

sures ANOVA.

DISCUSSION

Amblyopia is a reversible cause of visual impairment that may significantly affect a person's future quality of life. The prevalence of amblyopia in children has been established at between 1% and 4%.(11-14) It does not matter whether amblyopia is the monocular or bilateral type, the most important treatment is delicate near-work training.

In monocular amblyopia, the methods of treatment include atropine, occlusion, and the CAM stimulator. In 2003, the Pediatric Eye Disease Investigator Group reported that the success rates for atropine and occlusion were 74% and 79%.(15) Willshaw et al. revealed that the success rate for CAM was 91%, and that these improvements were frequently obtained within 4 weeks and appeared to be well-maintained.(10,16) Therefore, in our study, we kept a regular follow-up of at least 3 months during the period of CAM treatment, and most patients noted visual acuity improvement in 7 weeks. However, the effect of CAM on monocular amblyopia was controversial, because the children enrolled in CAM treatment received occlusion therapy at the same time.(17) In bilateral amblyopia, excluding the effects of occlusion, we found the CAM treatment success rate to be 95.2%. Klimek et al. reported bilateral amblyopia in children with high hyperopia.[18] Thirty-six children with ≧ 4.5D spherical equivalent were enrolled and 86% of them had a final visual acuity of 0.5 or better over a mean 3 years, 4 months after wearing corrected glasses only, which is almost identical to the results in a smaller study by Schoenleber.[19] At the same time, only 48% achieved a BCVA of 0.8 or better binocularly.[18] There were 11 children with bilateral high hyperopia (≧ +4.5D) in our study, and 10 of them (90.9%) achieved a BCVA better than 0.8 over a mean 6.15 weeks. In our study, there were 30 children who wore glasses for more than 1 month before CAM training, and there was no difference in the BCVA of two lines in the period before they word eyeglasses and the beginning of CAM training. Therefore, the CAM vision stimulator may hasten visual improvement in binocular amblyopia when wearing optimal glasses.

Previous studies of monocular amblyopia have found the prevalence of strabismus amblyopia is 22-62%, anisometropic amblyopia 17-50%, and combined causes 24-32%.[5,20,21] In 2002, the Pediatric Eye Disease Investigator Group reported VA would be best in patients with anisometropia, worst in patients with strabismus, and intermediate in patients with both anisometropia and strabismus in monocular amblyopia. They suggested that strabismus might produce cortical deficit in the amblyopic eye due to abnormal binocular interactions.[21] Our review found that the major cause of bilateral amblyopia was refractive error, and that the prevalence of combined refractive error with strabismus was 17%. However, there was no correlation between the combined strabismus type and the final VA. We suppose the reason for the different results was that, in the combined type, strabismus was not the dominant cause of bilateral amblyopia.

Furthermore, we classified refractive errors into 3 groups: astigmatism, hyperopia, and myopia. The prevalence, in order, was 61%, 17%, and 12%. However, using repeated -measures ANOVA, the myopic group showed significantly poorer final BCVA (OD/OS: $p = 0.001/<0.01$) and needed more CAM sessions to achieve a BCVA ≥ 0.8 (OD/OS: $p = 0.021/0.012$) than the other groups. The hyperopic group showed relatively better visual outcomes. We suppose the cause of the worse visual outcomes in the myopic group is subtle abnormalities in the retina or retinal pigment epithelium, which result in immature and delayed visual development, though there was no anterior segment or fundus pathology in these children.

Similar to previous studies,[5,22] we found the better the initial BCVA, the better the visual outcome, using Pearson's correlation.

Patient compliance is a critical determinant of treatment outcome, and age is a significant determinant of compliance.[23] At the same time, the final BCVA and number of CAM sessions ($p = 0.03$) were better in children older than 6 years than in children younger than 4 years. Perhaps the older children could better understand how to do the CAM training, and had better compliance than the younger children. Therefore they achieved better visual outcomes.

The limitations of our study were its retrospective nature and small sample size. In most children, CAM treatment with optimal glasses for bilateral amblyopia results in satisfactory improvement (mean final BCVA: 0.93) in 3 months. There was no significant association between different sexes, different ages, or strabismus. However, we found that the risk factors resulting in worse visual outcomes included highly myopic children, an age of less than 4 years, and poor initial BCVA.

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CAM 弱視訓練儀對不同病因所致之雙眼弱視的治療效果

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背 景：評估 CAM 弱視訓練儀對雙眼弱視之治療成效。

方 法：回溯性研究。100 個雙眼弱視並大於 3 歲、小於 7 歲的兒童，戴上最佳矯正後的眼鏡，施以每周一次 CAM 弱視訓練，並於每次訓練完成後，測量其視力。而評估項目包括初始矯正後視力、訓練後矯正視力及矯正後視力可達 0.8 以上所需訓練的次數。

結 果：雙眼弱視的主要原因爲雙眼屈光異常。將屈光異常的原因分爲遠視、近視及散光。發現高度近視的兒童所需治療次數明顯多於其他兩組，且治療後最佳矯正視力較差。另外，年齡越大及初始視力越佳的兒童，治療效果越好。

結 論：相較於之前的研究可知，對於雙眼弱視而言，CAM 弱視訓練可以加速視力的進步，因而可作爲治療的選擇。同時對於高度近視及年齡較小的孩子，應給予較長期的訓練方可達到治療效果。

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關鍵詞：CAM 弱視訓練儀，雙眼弱視

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