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原 著

Long Term Potentiation of Binocular Function in the Postoperative Period of Infantile Esotropia

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Abstract

This investigation was explained to improve the effect of orthoptic treatment of infantile esotropia by long term potentiation. In the successful group, 67% achieved a stereo acuity of 60 seconds or better. Partial improvement was seen in 20% and no improvement in 13%.

There were 3 types of cure processes in the successful group. The first type maintained a good binocular function before the operative stage. The second type achieved a good binocular function in a relatively early postoperative stage, while the third type had delayed development of binocular function over a period of several years. The former cases had sufficient intensive orthoptic treatment during admission, and the latter showed a gradual improvement of stereo acuity accompanied by good eye position.

Introduction

The prognosis for infantile esotropia has generally been considered to be poor even with the performance of strabismus surgery in very early life[1)2)3)4)5)]. Most reports, have indicated that alignment of the eyes after surgery was very rough (±5-10△), and achievement of normal binocular function and the maintaining of a straight eye position under fusional mechanism seemed to be difficult. Postoperative orthoptic management was rarely carried out. In this clinical study on infantile esotropia, surgery was not done at a very early stage, but intensive orthoptic management was done for a certain period of time to develop the binocular function. The period of observation ranged from five years till 12 years after surgery. In this report, the process of recovery of binocular function over a long period will be discussed.

Materials and Methods

Thirty cases of infantile esotropia (17 males and 13 females) were selected from 73 cases according to the following criteria; (1) Onset occurred before one year of age. This was confirmed by photographs of baby. (2) The deviation was more than 40△ both near and far and the esotropia was constant. (3)

Refraction anomalies were slight or nonexistent. (4) Underaction of the lateral recti muscle and overaction of inferior oblique muscle was demonstrated by the nine cardinal gaze test. (5) Complete following up was done by a chief orthoptist and an ophthalmologist for five years or more after the last surgery. (6) All cases were hospitalized for two to four weeks. The patients ranged in age from one to 13 years old (average 5.5) at the last admission.

Binocular function was analyzed by using the Titmus stereo tests, Bagolini's striated glasses (SG), the synoptophore test and the Worth four dots test. Deviation was determined by Krimsky's method and the alternate prism cover test.

The degree of cure was determined according to the standardization of the cure state of strabismus decided upon by the Japanese Association of Strabismus and Amblyopia. In this system, the degree of cure is classified into three levels; a Titmus score between 60 -40 seconds (circle 7/9-9/9) indicates a good cure, 140-80 seconds (circle 4/9-6/9) is fair and 200 seconds (circle 3/9) or more is poor. Follow up examinations were performed at six months, one, two, three, four, five and more than five years after surgery. In the preoperative stage, treatment of amblyopia and ARC (Abnormal retinal correspondence) was carried out for several months. Intensive orthoptics, such as antisuppression, kinetic biretinal stimulation, proprioceptive reorientation, bifoveal stimulation and fusion training were given for about a week during the preoperative stage.

After surgery, stabilization of alignment was attempted by using progressive power eye glasses, membrane prisms, 0.06% echothiophate iodide and physiological diplopia training. These methods of treatment were used when they were needed. Regarding the surgical procedure, recession of the medial rectus and resection of the lateral rectus was done in 25 cases, resection of the lateral rectus only was done in four cases, and recession of the medial rectus only was performed in one case. Recession of the inferior oblique muscle was done in 11 cases. Two or more surgeries were performed in 18 out of the 30 cases to correct residual deviation. The selection of muscles to be operated upon was decided by their degree of overaction or underaction. The standard dosis of muscle transposition was 1 mm for 4△ deviation but hypertonic deviation influenced by emotional and refractive status was not included. Final adjustment of the eye position in reoperation which was performed under a local anesthesia was done by adjusting sutures during surgery to completely remove any residual angle. Surgical invasion of the muscle proprioception structure was avoided because strabismus surgery damaged the proprioceptive endings[6)7)8)9)] and loss of proprioception might disturb the development of binocular function in young children[10)]. To prevent this, all surgery was done by same ophthalmologist.

Results

As a result of long term follow up, good binocular function was achieved in 20/30 cases (67%), partial improvement in 6/30 cases (20%) and no improvement in 4/30 cases (13%). The development of binocular function during the long term follow up is explained below:

1) Cases with achievement of good binocular function

The follow up period for these cases ranged from five to 12 years after final surgery (Table 1). Twenty out of the 30 cases belonged to this group. All of these cases showed a normal fusional amplitude by synoptophore,

Table 1 Postoperative changes in the Titmus score (circle number) and deviation (△)

Follow up period (year)		0.5	1	2	3	4	5	5.12
Complete cure	Titmus score	4.7±3.4	5.1±3.3	5.6±2.8	6.6±2.5	6.9±2.1	7.8±1.2	8.2±0.9
	Deviation							
20 cases	Horizontal (△)	3.6±3.6	3.6±3.2	3.9±3.2	2.3±2.5	3.0±3.0	3.4±2.4	2.3±2.4
(67%)	Vertical (△)	1.9±2.5	1.9±2.8	2.4±3.3	2.3±2.9	2.5±2.9	2.0±2.9	1.5±2.0
Partial improvement	Titmus score	1.0±1.5	1.0±1.4	2.2±1.8	2.4±1.5	3.7±2.1	4.0±2.2	5.2±0.8
	Deviation							
6 cases	Horizontal (△)	14.6±12.1	10.2±12.3	8.7±9.9	8.3±2.9	6.7±6.9	6.3±5.6	5.2±6.4
(20%)	Vertical (△)	0.0±0.0	0.7±1.6	0.5±1.2	1.8±2.1	1.0±1.5	1.7±2.1	2.3±1.7
No improvement	Titmus score	2.0±3.4	1.7±1.5	1.5±1.9	2.0±1.4	2.0±1.7	2.3±1.5	2.3±1.5
	Deviation							
4 cases	Horizontal (△)	6.0±7.1	4.0±5.7	2.5±3.0	3.0±3.8*	4.3±5.7	1.8±2.1*	9.0±5.0*
(13%)	Vertical (△)	2.0±4.0	2.3±2.6	4.0±2.9	1.3±2.5	3.5±4.1	4.3±3.5	5.3±7.5

* : include secondary XT

and in their final status, 95% showed fusion in casual viewing of striated glass. The Titmus score six months after the surgery was 4.7 ± 3.4 but slight improvement occurred two or three years later and subsequent improvement continued up to five years or more after surgery with a final average score of seven (60 seconds).

However, three types of developmental process were recognized (Figure 1). In Type 1, achievement of binocular function took place within six months and it was found in seven out of the 20 cases (35%), who ranged in age from four to 13 years old (average 7.1). Intensive orthoptics was done during the hospitalized period.

In Type 2, gradual improvement of the Titmus score was achieved in eight out of the 20 cases (40%, Type 2). In Type 3, the Titmus score was still low at the end of five years but delayed improvement was recognized in five out of the 20 cases (25%). The most prominent case achieved a Titmus score of 60 seconds after 12 years.

From a different analytical point of view, Figure 2 shows that increasing numbers of patients achieved a Titmus score of 60 seconds or better at the end of two years (27%), four years (43%) and more than five years (67%). This evidence suggests that long term

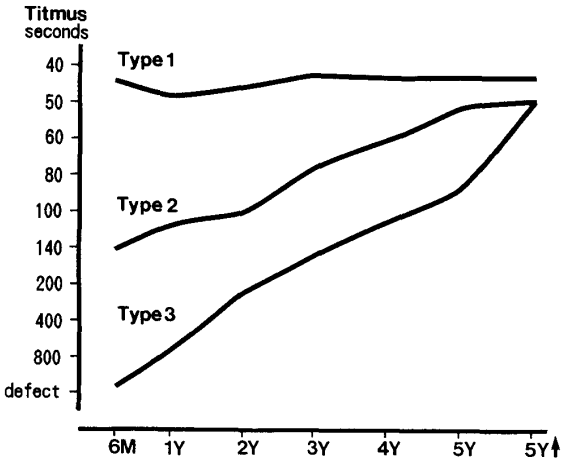

Fig. 1 Three types of developmental processes of the Titmus score in cases that achieved good binocular function.

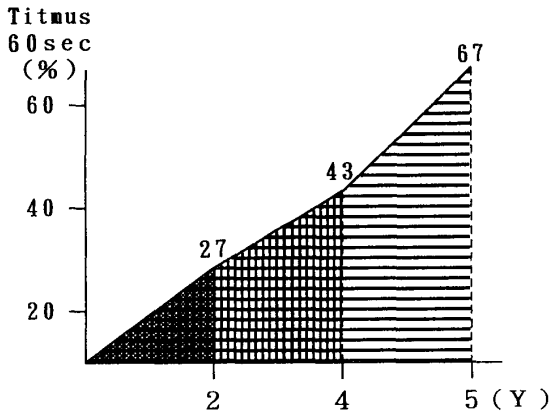

Fig. 2 Increasing numbers of patients who achieved a Titmus score of 60 seconds.

potentiation of stereopsis exists during the treatment of infantile esotropia.

2) Cases with partial improvement

Six out of the 30 cases showed partial improvement within five to eight years after final surgery. Table 1 shows the process of improvement of the Titmus score in these six cases. Slow improvement to the middle grade or no improvement after six months were observed. In this group, fusion determined by synoptophore was found in 40%, striated glass fusion was 50%, and ARC was the intractable factor.

3) Cases with a poor result

Four out of the 30 cases had a poor prognosis based on the Titmus score. The period of observation ranged from five till eight years after final surgery. Table 1 shows the changes in deviation and the Titmus score. Intractable amblyopia was the major cause of interruption of development of binocular function. In this group, fusion by synoptophore and striated glasses was 25% for both. Alignment of the eyes was unstable and secondary exotropia appeared after five years

4) Comparative analysis of pathological factors in the three groups (Tables 1, 2 and 3)

Cases with a good result (Group 1) had no manifest deviation, no amblyopia and no ARC after treatment. In some cases, these factors were dissolved. The average horizontal deviation was 3.5△ at six months postoperatively and it was reduced to 1.4△ of esophoria at the final visit. The average vertical deviation was 1.8△ at six months postoperatively and 1.9△ at the final visit. No cases exhibited a manifest strabismus.

In the cases with partial improvement (Group 2), residual amblyopia existed in 2/6 cases (33%) and ARC was noted in 4/6 cases (67%). The residual manifest deviation was found in 2/6 cases.

In the cases with a poor result (Group 3), intractable strabismic amblyopia existed in 2/4 cases (50%) and ARC was noted in 1/4 case (25%). These cases showed a sign of microtropia. The residual manifest deviation was found in all cases including two cases of the secondary exotropia. The ages at first surgery was 4.0 ± 2.2 years in the group with complete cure, 4.2 ± 1.3 years in the group with partial improvement and 2.8 ± 1.7 years in the cases with a poor result (Table 3).

How about orthoptic management in the cases with complete cure? In the preoperative stage, treatment of suppression, amblyopia and ARC was the first choice. There procedures were also continued before surgery after admission. In the postoperative stage, binocular function under casual viewing, correction of the residual angle with eye glasses, and prism and physiological diplopia training were used. Cases with a complete cure achieved good performance under this training within a few weeks. In the other

Table 2 Cure status and pathological factors in three group of infantile esotropia.

Cure status	Complete cure 20/30 (67%)	Partial improvement 6/30 (20%)	Poor result 4/30 (13%)
Refraction	−0.25D～+1.50D	+0.25D～+1.00D	+0.25D～+1.75D
Amblyopia	(−)	2/6	2/4
NRC-ARC	(−)	2/6	(−)
ARC	(−)	2/6	1/4

Table 3 Ages of surgery in different cure status.

Cure status	Complete cure 20/30 (67%)	Partial improvement 6/30 (20%)	Poor result 4/30 (13%)
First surgery (in age)	1 ~ 9 (4.0±2.2)	2 ~ 5 (4.2±1.3)	1 ~ 5 (2.8±1.7)

groups, however, cooperation in the orthoptic training was unsatisfactory.

Discussion

This investigation was designed to improve the effect of treatment on infantile esotropia by long term management. As a result, an unexpectedly high percentage of patients, i.e., 67%, achieved Titmus stereo acuity of better than 60 seconds. In this investigation, only 23% had achieved a Titmus score of 60 seconds when a follow up examination was done one year after final surgery. At three years after final surgery, 40% had achieved this score and at five years, 53% of the patients were successful. The final data showing achievement by 67%, indicates that a long term potentiation effect clearly developed in the Titmus score during the long follow up period.

What were the major factors that led to improvement of the prognosis? The first important factor before surgery was a gain in alternate fixation.

Since the mean age at the time of surgery was 3.8 years old, examinations of deviation, muscle action and binocular function were possible. For surgical planning, these data were very important and useful. The number of operations ranged from one to four (average 1.5). In some cases, surgical orthoptics under local anesthesia was carried out to eliminate a minimum deviation including a vertical deviation. Consequently, deviation was limited to less than 3△.

The postoperative orthoptic management was also very important and involved the following: 1) To develop binocular function, physiological diplopia play was recommended to design casual viewing. 2) Manipulation of chopsticks to pick up small pieces of food was also recommended. 3) Since almost all cases had a recession of the medial rectus muscle, fusional and accommodative convergence training was carried out. 4) To prevent recurrence, 0.06% echothiophate iodide eye drops, progressive power eye glasses and prisms were used. 5) If esotropia recurred, injection of botulinum toxin had a good effect[11].

According to Yazawa[12], 54% of patients with infantile esotropia achieved good binocular function if the surgical correction eliminated manifest deviation in a long follow up period.

In previous studies, many authors have claimed that surgery must be performed before the age of two years to obtain a functionally useful result. However, a cure is not always complete and many consist of several grades of subnormal or abnormal binocular cooperation. It has also been believed that the binocular cells in the striate cortex are permanently lost in infant monkeys after artificial strabismus. These cells also disappear in monkeys with eye lid suture or experimentally induced anisometropia.

In opposition to the deprivation theory, a theory of growth of dendrites as a result of increased use of the nervous system has been

proposed and demonstrated by many authors (Rutledge[13], Diamond[14], Gall[15], Lynch[16], Uylings[17], Bliss[18]).

In particular, Diamond *et al.*[14] discovered a plasticity in the 904-day-old rat cerebral cortex. The thickness of the occipital cortex was greater in rats placed in an enriched environment than in those placed in a non-enriched cage. They also reported that the dendritic length of the occipital cortex was longer in rats placed in an enriched cage than those in a non-enriched cage. For the former, they used a larger cage ($70 \times 70 \times 46$ cm) in which the rats had access to numerous replaceable objects which were changed biweekly.

Regarding the human strabismus, if the deviation is corrected completely, an enriched environment with toys, food and chopsticks and ball games involves depth perception will help the development of the visual cortex and binocular function.

The preliminary report of this study was published in Japanese in Acta Societatis Ophthalmologicae Japonicae[19].

References

1) Parks MM (1968) Symposium : Infantile esotropia, Summary and conclusions. *American Orthoptic Journal*, **18**, 19—22.

2) Taylor DM (1974) Is congenital esotropia functionally curable? *Journal of Pediatric Ophthalmology*, **11(1)**, 3—35.

3) Foster RS, Paul TO, Jampolsky A (1976) Management of infantile esotropia. *American Journal Ophthalmology*, **82(2)**, 291—299.

4) Ing MR (1983) Early surgical alignment for congenital esotropia. *Ophthalmology*, **90**, 132—135.

5) von Noorden GK (1988) A reassessment of infantile esotropia, XLIV Edward Jackson memorial lecture. *American Journal of Ophthalmology*, **105**, 1—10.

6) Steinbach MJ, Smith DR (1981) Spatial localization after strabismus surgery : *Evidence for inflow. Science*, **213**, 1407—1409.

7) Steinbach MJ, Kirshner EL, Arstikaitis MJ (1987) Recession vs marginal myotomy surgery for strabismus : Effect on spatial localization. *Investigative Ophthalmology and Vision Science*, **28**, 1870—1872.

8) Enomoto H, Ohmi S, Tsutsui J, Fukai S, Arita S (1986) Proprioception of eye movement induced by forced duction in strabismus. *Rinsho Ganka*, **40(7)**, 757—760.

9) Enomoto H, Tsutsui J, Kimura H, Fukai S, Hayakawa T (1989) Spatial localization of the eyeball in passive eye movement in strabismus. *Folia Ophthalmolegica Japonica*, **40(9)**, 1970—1974.

10) Trotter Y, Fregnac Y, Buisseret P (1987) The period of susceptibility of visual cortical binocularity to unilateral proprioceptive deafferentation of extraocular muscles. *Journal of Neurophysiology*, **58**, 795—815.

11) Fukai S, Arai N, Hayakawa T, Kimura H (1993) Studies on the Botulinum therapy for esotropia improvement of retinal correspondence. *Journal of Japanese ophthalmological society*, **97(6)**, 757—762.

12) Yazawa K, Akiyama M, Kanno K, Kawamura M (1976) Long term prognosis of operated esotropia. *Japan Review Clinical Ophthalmology*, **70**, 1197—1206.

13) Rutledge LT, Wright C, Duncan J (1974) Morphological changes in pyramidal cells of mammalian

neocortex associated with increased use. *Experimental Neurology*, **44**, 209—228.
14) Diamond MC, Johnson RE, Ingham CA (1975) Morphological changes in the young, adult and aging rat cerebral cortex, hippocampus and diencephalon. *Behavioral Biology*, **14**, 163—174.
15) Gall C, Lynch G (1978) Rapid axon sprouting in the neonatal rat hippocampus. *Brain Research*, **153**, 357—362.
16) Lynch G, Schubert P (1980) The use of in vitro brain slices for multidisciplinary studies of synaptic function. *Ann Review Neuroscience*, **3**, 1—22.
17) Uylings HBM, Kuypers K, Veltman WAM (1978) Environmental influences on the neocortex in later life. *Progress in Brain Research*, **48**, 261—274.
18) Bliss TVP, Gardner-Medwin AR (1973) Long-lasting potentiation of synaptic transmission in the dentate area of the unanaesthetized rabbit following stimulation of the perforant path. *Journal of Physiology*, **232**, 357—374.
19) Hayakawa T, Fukai S, Tsutsui J (1990) Delayed development of binocular function in the long postoperative period of infantile esotropia. *Journal of Japanese ophthalmological society*, **94**(**9**), 820—828.

乳児内斜視の長期増強効果

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要　旨

本報は乳児内斜視の両眼視機能の治癒過程を詳細に検討した初めての報告であり，両眼視機能の遷延治癒を明らかにした．

乳児内斜視30例の長期観察における両眼視機能の獲得（60 seconds）は良好例67%，改善例20%，不良例13%であった．

両眼視獲得には3つのタイプがある．

type 1は，術前より良好な両眼視があるものは5年後，良好な両眼視機能を保持していた．

type 2は，術後よりまもなく良好な両眼視機能を示したものである．

type 3は，数年間経過後に両眼視を獲得し遷延治癒を示した．

術後より良好な両眼視を示したタイプは積極的な視能訓練を施行したもので，訓練刺激により両眼視機能のシナップスの発達が示唆された．