An electromyographic study of esotropia

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SUMMARY Under general anaesthesia the eye position of esotropia generally moved divergently. When retrobulbar anaesthesia was added bilaterally, the eye position moved further in the same direction. In the electromyogram under general anaesthesia the 4 horizontal recti were silent in controls. In many cases of esotropia, however, both medial recti showed a considerable amount of discharge under general anaesthesia. When retrobulbar anaesthesia was superimposed on one eye, the discharge from its medial rectus tapered off and, reciprocally, that of the opposite eye increased. These facts may suggest that proprioception plays a part in the development of esotropia.

Esodeviations are a condition occurring mostly in young children. If the deviations persist, the development of binocular visual function is considerably impaired. The aetiology of esodeviations is obscure except for cases with high hyperopia. One probable cause is an anomalous light-motor reflex,^{1,2} but this is inadequate to explain the development of constant esotropia. The present study attempted to find a relation between proprioception and the development of esotropia by measuring the eye position and electromyogram (EMG) under anaesthesia.

Materials and methods

Twenty-two cases of esotropia were selected as subjects. Only cases of uncomplicated comitant esotropia were used. Patients with neurological diseases, congenital anomalies, and hyperopia over 2 dioptres were excluded. Twenty of the 22 cases had no history of surgical treatment and 2 had undergone recession of the medial rectus. Four cases of exotropia and 4 other orthophoric cases were used as controls in the second experiment as described below.

In the first experiment the eye position was measured under general anaesthesia and after the addition of retrobulbar anaesthesia bilaterally. In the second experiment the EMG of the 4 horizontal recti was recorded under general anaesthesia and after the addition of retrobulbar anaesthesia unilaterally on the right eye only. This experiment was done in a shielded operation room.

The position of the eye was measured by the Hirschberg test in 5-degree steps. The general anaesthetic was nitrous oxide-oxygen-halothane (GOF) administered by the semiclosed method after conventional premedications and in combination with succinylcholine, and all measurements were made at the surgical plane. For retrobulbar anaesthesia about 2 ml of 4% procaine solution was injected by a conventional procedure. The EMG was recorded as usual with needle electrode containing 2 centre conductors as the pick-up. The electrode was inserted at the position of the muscle where the greatest discharge was recorded.

Results

POSITION OF EYE

The position of the eye under general anaesthesia and after the addition of bilateral retrobulbar anaesthesia was measured in 10 cases of esotropia. The results are summarised in Table 1. In 9 of the 10 cases the eye position moved divergently under general anaesthesia, while in the other (case 6) it moved convergently. As a result 4 of the 10 cases still showed esodeviation, 2 showed the straight eye position, and 4 showed exodeviation. These deviations, when present, were almost symmetrical, that is, both eyes showed eso- or exodeviation of about the same degree, except for 1 case (case 3) in which the medial rectus of the right eye had been recessed 2.5 years earlier.

In 7 of the 10 cases (cases 4 through 10) retrobulbar anaesthesia was added bilaterally under general anaesthesia. The eye position then moved further divergently until finally symmetrical exodeviation resulted in 6 of the 7 cases and the straight eye

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Table 1 Eye position of esotropia under general anaesthesia and after addition of bilateral retrobulbar anaesthesia

No.	Age	Sex	Diagnosis	Eye position	
				Under general anaesthesia	Plus bilateral retrobulbar anaesthesia
1	22	F	LET 15°	SX 5°	ND
2	5	F	RLET 30°	SE 10°	ND
3*	5	F	RET 20°	LE 5°	ND
4	62	F	RET 20°	SX 10°	SX 20°
5	15	F	LET 20°	O	SX 5°
6	5	F	LET 20°	SE 30°	SX 5°
7	11	F	RLET 20°	O	SX 30°
8	26	M	LET 40°	SE 20°	O
9	7	F	LET 20°	SX 5°	SX 40°
10	14	M	RLET 10°	SX 10°	SX 15°

Abbreviations: E: Esodeviation. X: Exodeviation. O: Orthophoria. L: Left. R: Right. RL: Alternative. S: Symmetrical. T: Tropia. ND: Not done.

*2.5 years after recession of the right medial rectus.

position in 1 (case 8); that is, none of the cases showed persistent esodeviation.

Fig. 1 shows an example of the change in the eye position under general anaesthesia and after the addition of retrobulbar anaesthesia in a 7-year-old girl (case 9). Before anaesthesia the left eye was esodeviated by about 20° (Fig. 1a). After general anaesthesia a slight exodeviation of about 5° resulted (Fig. 1b). When retrobulbar anaesthesia was added first to the left eye (Fig. 1c) and then to the right (Fig. 1d), each eye moved outward by about 20° until finally a symmetrical exodeviation of about 40° resulted.

ELECTROMYOGRAM OF THE 4 HORIZONTAL RECTI

When measured under general anaesthesia the EMG of the 4 horizontal recti was almost silent in the 4 normal controls and in the 4 cases of exotropia. Examples are shown in Fig. 2.

In esotropia the lateral recti were consistently silent under general anaesthesia. However, in 8 of the 11 cases examined both medial recti showed discharges like those seen in the usual EMG (Table 2). The amount of discharge from both muscles was about the same.

Cases positive for this kind of discharge included 1 in which the medial rectus of the left eye had been recessed 1 year earlier (Table 2, case 4). In this case also the amount of discharge was about the same for both medial recti.

In 7 of the 8 cases showing positive discharges from the bilateral medial recti retrobulbar anaes-

thesia was added to the right eye under general anaesthesia. The discharge from the right medial rectus began to taper off after 5 minutes, and a considerable decrease or silent EMG was attained after 10 to 20 minutes. At the same time the discharge from the associate medial rectus increased. This kind of reciprocity between the 2 medial recti was seen in all of the 7 cases examined. It was also apparent by inspection that the right eye moved in the direction of abduction in 5 minutes, followed by the adductive movement of the left eye several minutes later.

Fig. 3 shows an example of discharges from the medial recti under general anaesthesia and the reciprocal change which occurred between these discharges when retrobulbar anaesthesia was added on the right eye (Table 2, case 4).

Fig. 1 Esotropia of the left eye in a 7-year-old girl. a: Before anaesthesia. b: Under general anaesthesia. c and d: After addition of retrobulbar anaesthesia to the left and then to the right eye.

Fig. 2 EMGs of the 4 horizontal recti of a normal (left) and an exotropic (right) case under general anaesthesia. All muscles are nearly silent.

Another example is shown in Fig. 4 (Table 2, case 7). In this case abnormal discharges from the medial recti were only suspected in the recording under general anaesthesia, as shown on the left of the figure. However, when retrobulbar anaesthesia was added to the right eye, the right medial rectus

clearly became silent after 20 minutes, and a reciprocal increase in the discharge became obvious in the left medial rectus, as shown on the right of the figure.

Among the 11 cases shown in Table 2 the medial recti were silent under general anaesthesia in 3 cases. In 1 of these (Table 2, case 2), the EMG was recorded without anaesthesia except for the instillation of a surface anaesthetic. The result is shown in Fig. 5. The figure shows the EMG when the eyes took the position of 'symmetrical esodeviation', which was attained by moving the point of fixation. The EMGs of the 2 eyes show a symmetrical pattern. However, the discharges of the medial recti exceed those of the lateral recti by about 6 dB. Similar EMG patterns were obtained without anaesthesia in 3 other cases of esotropia which are not included in Table 2. The dominance of the medial recti in the EMG was in the range of 6 to 9 dB when measured at the symmetrically esodeviated position.

The EMGs of the 4 horizontal recti without anaesthesia were examined in 4 normal cases also. In all these cases dominance of the medial recti was observed at the straight eye position. This dominance was in the range of 3 to 6 dB. An example is shown in Fig. 6.

Discussion

It is unanimously accepted that the eye position generally moves divergently under general anaesthesia, and that the degree of this movement is greatest in esotropia.³⁻⁷ In the present study it was shown that in esotropic cases the eyes diverge con-

Table 2 The EMG of esotropia under general anaesthesia and after addition of unilateral retrobulbar anaesthesia

No.	Age	Sex	Diagnosis	Eye position	Under general anaesthesia		Reciprocity in MR-EMG by addition of retrobulbar anaesthesia to right eye
					Discharge from MR in EMG		
1	5	F	LET 20°	SE 10°	++		ND
2*	14	M	RLET 10°	SX 10°	—		ND
3	7	M	RET 10°	SE 5°	—		ND
4**	6	F	RET 5°	RE 5°	++	++	++
5	4	F	RLET 30°	SE 20°	++		+
6	7	F	RET 35°	SE 20°	+	++	++
7	23	M	RET 20°	SE 15°	±	++	++
8***	11	F	RLET 20°	O	—		—
9	4	F	RLET 20°	SE 15°	±	++	++
10	5	F	RLET 25°	SE 20°	+	++	++
11	3	M	LET 15°	SE 5°	++	++	++

Abbreviations: MR: Medial rectus. EMG: Electromyogram. E: Esodeviation. X: Exodeviation. O: Orthophoria. R: Right, L: Left. RL: Alternative. S: Symmetrical. T: Tropia. ND: Not done.

*The same case as case 10, Table 1. **One year after recession of the left medial rectus. ***The same case as case 7, Table 1.

Fig. 3 EMGs of the 4 horizontal recti of an esotropic case under general anaesthesia (left) and after addition of retrobulbar anaesthesia (right) to the right eye. Active discharges are seen from both medial recti under general anaesthesia. After addition of retrobulbar anaesthesia to the right eye the discharge from the right medial rectus decreased and, reciprocally, the discharge from the left medial rectus increased.

siderably further when retrobulbar anaesthesia is superimposed upon general anaesthesia.

Since electromyography was introduced to clinical ophthalmology by Björk,⁸ Kuboki,⁹ and Breinin and Moldaver,¹⁰ this examination has become an important tool in neurological investigations of extraocular muscles in man. Breinin found that in exotropia the horizontal recti show a silent EMG under thiopentone general anaesthesia.¹¹ This finding was later confirmed by Ohmi *et al.* using GOF

anaesthesia.⁷ The present investigation showed, however, that in many cases of esotropia the EMG under general anaesthesia recorded discharges which indicated firing of the medial recti. When retrobulbar anaesthesia is superimposed on one eye, the discharge from the ipsilateral medial rectus decreases considerably and may even disappear in 10 to 20 minutes. However, this decrease is accompanied by a reciprocal increase in the discharge from the contralateral medial rectus. This reciprocity can

Fig. 4 EMGs of the 4 horizontal recti of an esotropic case under general anaesthesia (left) and after addition of retrobulbar anaesthesia (right) to the right eye. Active discharges from both medial recti are only suspected under general anaesthesia, but when retrobulbar anaesthesia was superimposed on the right eye the right medial rectus clearly became silent, and the reciprocal increase of the discharge from the associate medial rectus became obvious.

Fig. 5 EMG without anaesthesia in a case of esotropia, when the eyes were guided to a symmetrically esodeviated position. The medial recti are seen to be dominant by about 6 dB.

most probably be explained by blockage of unilateral proprioception by the retrobulbar anaesthesia, which sends positive and negative feedback to the ipsi- and contralateral motor nerves, respectively. An important role of proprioception in ocular

movements has been suggested from various standpoints.¹²⁻¹⁹ Among them the electromyographic evidence for ocular muscle proprioception was first presented by Breinin.¹⁸

Our hypothesis regarding the role of propriocep-

Fig. 6 EMG without anaesthesia in a normal man at the straight eye position. Dominance of the medial recti by about 4 dB is obvious.

Fig. 7 Block diagram showing the role of proprioception in the development of esotropia. Pa: Proprioceptive afferent. III: Oculomotor nerve. V: Trigemini. Solid black circle: Inhibitory interneuron. For details see text.

tion in the development of esotropia is shown as a block diagram in Fig. 7. Some factors which cause esophoria, such as an anomalous light-motor reflex,^{1,2} may trigger excitation of an abnormal proprioceptive impulse from extraocular muscles, which is reflected to the ipsilateral medial rectus as a positive feedback and to the contralateral medial rectus as a negative feedback. The continuing discharge of this impulse results in esotropia. This impulse may persist under general anaesthesia by a principle similar to that described by Collins *et al.*,¹⁹ where the oculomotor nerve is released from the control of higher centres.

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