A Surgically Implanted Elastic Band to Restore Paralyzed Ocular Rotations

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Five patients presenting ocular deviations of up to 70° and limitation of movement caused by a paralytic horizontal rectus muscle were treated with a surgical technique in which the affected eye was bound to the orbit by an elastic silicone band. The purpose was to obtain a fixation of the eye in an overcorrected position using general anesthesia (eg, in adduction if the patient had an exodeviation). After surgery, contraction of the antagonist to the paralytic muscle stretched the elastic band and moved the eye. Relaxation of the antagonist muscle allowed the silicone band to move back to the resting position. In some cases, an additional weakening procedure of that active muscle was necessary. Rotations of up to 35° into the field of action of the paralytic muscle were obtained within the first week after surgery, with a total amplitude of horizontal movements up to 55°. The best late results (6 or more months postoperatively) were 18° and 35°.

Although the regulation of the proper tension with which the elastic bands have to fix the eye is a complex matter that remains to be determined, this surgery could prove to be an alternative procedure to reestablish paralyzed rotations in cases where current techniques are not applicable.

After an oculomotor paralysis, the lost eye rotations may be spontaneously recovered. In some cases, however, an impairment remains due to the neuromotor lesion or due to contracture of the antagonistic muscle. When a complete paralysis persists, there is no possibility of recovering a full rotation in the direction of action of the affected muscle by classic recess-resect surgery. Transposition of the vertical recti to the horizontal plane (eg, to replace abduction) has the disadvantage in that original actions of the transposed muscles are weakened, vertical deviation may be introduced, readjustment of control of innervation to the new movement is doubtful, and results with this technique are frequently imperfect. Ocular rotations caused by a direct stimulation to the affected muscle is a theoretical approach. However, regulations of the motor signal and muscular reactivity to it are among the problems with this approach. We attempted a mechanical solution for repositioning lost forces, which seems to be technically easier and theoretically sound.

Any stable position of the eye corresponds to a balance of forces of which two basic components may be considered. The active forces are those represented by the muscular contraction and regulated by neural stimulation. The passive forces depend on the viscoelastic properties of the periocular tissues. When no innervational input is present (eg, under deep general anesthesia), the eye position in the orbit is purely related to those passive forces. If the eye is (passively) rotated and then released, it comes back quite close to the previous position of balance, with a so-called spring-back movement. Obviously this centripetal return rotation is the expression of the forces that were accumulated by the tissues during the former passive movement.

It is then possible to use the energy of an active muscle to promote a movement opposite to that of its original action. A real abduction may come from a relaxation of the medial rectus if the point where the balance of passive forces occurs, has been moved temporally. There are three requirements for this to occur:

- The balance of passive forces must be displaced to the side of action of the paralytic muscle (the position where this passive balance occurs will correspond to the limit of the rotation in the direction of action of the paralytic muscle, when a complete relaxation of its antagonist is achieved).
The passive forces so introduced must be kept from restricting the ocular rotation to the opposite side.

- The force must be adjusted in a way that when the patient is awake (tonic forces present) the deviation is zero in the primary position.

One solution may come from introducing such passive forces by means of elastic materials. This technique has been used with relatively good and immediate results, although such effects were lost after days or weeks. Elastic silicone "threads" were used in five patients with total paralysis of one or more extraocular muscles, four of whom had previous unsuccessful surgeries.

MATERIALS AND METHODS

Application of forces to the eye through use of an elastic band to replace the paralyzed muscle presents several technical problems. First, the internal walls of the orbit are weak (eg, nasal) and access to their posterior parts is difficult, making attachment of the band difficult. Second, a very short elastic band is not convenient because it strongly resists distension and limits the amplitude of required movements.

To resolve these problems, we decided to fix the elastic band to the orbital margins anterior to the center of ocular rotation. For horizontal rotations, the fixation above and below the horizontal plane avoided contact between the cornea and the elastic artifact (Fig 1) and balanced undesired (vertical and torsional) actions. The pressure of the artifact perpendicular to the ocular surface has to be minimal in order to avoid scleral erosion. A double traction will also divide such a pressure.

- A third difficulty with this technique is the regulation of the introduced force: it is not known precisely how a redistribution of forces under anesthesia influences the final oculomotor balance of the awake patient. Therefore, an empirical adjustment of the balance was attempted in a way that the eye stayed as far from the primary position as possible, without having important limitations of its passive movements. Basically a variation of 1.0 to 1.5 g/degree (ie, the normal relationship between forces and eye positions) is the ideal tension to be obtained.

The silicone "threads" used in our patients were tubes (with internal and external diameters of about 0.5 and 1 mm, respectively). They were sutured to the eye and to the periosteum with polyester fiber (Mersilene) 4-0 and 5-0. The operative technique is shown in Figure 2.

CASE REPORTS

Five patients with total paralysis of one or more extraocular muscles underwent elastic implant surgery. All of them made the option for the surgery based on this new technique, after being informed about its objectives and possible problems. Four of the patients had had previous unsuccessful surgeries, and four of them had poor vision in the paralyzed eye. All the patients that were previously operated on (1, 2, 3, and 5) presented some kind of restriction due to the cicatricial tissues of the initial surgery. The neutralization of the restriction was attempted, but was not well succeeded in cases 2 and 5.

Case 1: Initial surgery was unsuccessful in a 34-year-old man who had suffered a complete traumatic section of the left lateral rectus muscle and the left optic nerve. In his second operation, the cicatricial tissues were removed. One elastic thread of silicone was inserted between the insertion
### TABLE

Horizontal Measurements Preoperatively (P) and for Immediate (I) and Late (L) Results of Surgeries With Elastic Implants

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (Yrs)</th>
<th>Visual Acuity</th>
<th>Angle and Rotation</th>
<th>Correction</th>
<th>Amplitude</th>
<th>Artifact Rotation L-I Resistance Activity</th>
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<td></td>
<td></td>
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<td>P I L (°)</td>
<td>I-P L-P P I L</td>
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<td>35 15 28</td>
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<td></td>
<td>38 26</td>
<td>10 20 28</td>
<td>+20 -7</td>
</tr>
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</table>

* Values are in degrees of arc. Immediate results were those obtained during the first week after surgery. Late results are those obtained 6 or more months after surgery. Esotropias and/or positions in adduction are represented by positive values; exotropias and/or positions in abduction are represented by negative values.

† Previous esotropia.

### FIGURE 3: Horizontal gaze positions of patient 4. Before surgery, the left eye is almost completely fixed in adduction and there is esodeviation in primary position (about 40°). On the second postoperative day, correction is satisfactory between primary position and innversion. After 20 days and after one year the results are almost the same; there is a decrease of the abduction but adduction improves.

Case 2: A 52-year-old woman with paralysis of the third

### of the left medial rectus and the lower temporal orbital
erve underwent a second operation after unsuccessful

### initial surgery. A total tenectomy of the left lateral rectus

### muscle was performed along with a total myectomy of the

### left inferior oblique. The cicatricial tissues were removed.

### Passive adduction of the left eye could not be obtained,
However, two elastic threads of silicone were placed from the insertion of the left lateral rectus to the center of the superior and inferior orbital margins.

Case 3: A 15-year-old girl suffered traumatic paralysis of the left lateral rectus muscle. After the initial surgery the eye was fixed in slight abduction. She then had a second operation, in which the cicatricial tissues were removed. Passive adduction, however, remained restricted. A 10-mm recession of the left lateral rectus was performed. Silicone threads were fixed between the insertion of the left medial rectus and the superior and inferior orbital margins, at the temporal side (Fig 2).

Case 4: A 58-year-old man suffered paralysis of the left lateral rectus muscle after a cranial traumatism, but remained untreated for 8 years. He underwent a 5.5-mm recession of the left lateral rectus but abduction remained restricted. Silicone threads were fixed between the original insertion of the left medial rectus and the superior and inferior orbital margins, at the temporal side.

Case 5: A 55-year-old woman suffered a right third nerve paralysis which was not corrected by initial surgery. On her second operation, she underwent a recession of the right lateral rectus muscle, with reinsertion at 18 mm of the limbus and 5 mm below the equator. One silicone thread was placed between the inferior margin of the insertion of the right lateral rectus and the superior orbital margin, 3 mm to the nasal side of the midline. But not even passive adduction of the eye could be obtained.

In cases 2 and 5, limited results were predicted during the surgery since even passive rotation (as demonstrated by the traction test) could not bring the eye into an overcorrected position. But even in such cases, if the eye could be fixed with the elastic artifact under a low tension, the primary position results could be improved greatly.

No complications were noted. There were no complaints of pain or changes in vision. No inflammation occurred, except immediately following the surgeries; nor were there intraocular reactions. Follow-up (mean 4.5 years) ranged from 2.8 to 6.0 years.

RESULTS

The Table summarizes the preoperative and postoperative measurements of the five patients and Figure 3 illustrates the results of the patient in which no previous surgery was done (patient 4).

The alignment changes were quite large; for instance, a late correction of 43° in case 1 (no muscular surgery), an immediate correction of 42° in case 4 (added recession of 5.5 mm of the left medial rectus), and 58° in case 2. However, with the exception of one patient (case 1), angular correction decreased with time.

The amplitude of rotation presented variable results—the best improvement (55°, case 3), was found in the one case that was followed by a decrease in resistance of the artifact's effect. Case 4 presented a stable and good result compared with the ocular rotations before the operation. In three patients (2, 3, and 4), there was an improvement of rotations after the surgery.

DISCUSSION

Late and immediate results of elastic implant surgery in five patients with total paralysis of one or more extraocular muscles showed a decrease of the amplitude of the rotation due to the elastic artifact (mean, 9°) and an increase of the opposite rotation, with approximately the same value (mean, 10.2°). That is, the total amplitude of rotation can be taken as approximately constant with time (mean, around 27° to 28°). This suggests that alignment changes were due to the displacement of the point where the static balance occurred.

The small number and the heterogeneity of cases limit general conclusions and explain the great variability of the results. Based on our results, however, it seems that this technique should be considered as a new surgical approach for the correction of strabismus, mainly in patients with great angles of deviations or limitations of movements, and in whom other procedures were unsatisfactory. The regulation of the proper tension with which the elastic bands fix the eye, still however, needs to be determined.

REFERENCES