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“... the belief that one’s view of reality is the only reality is the most dangerous of all delusions ...”-Watzlawick, 1976

BINOCULAR ALIGNMENT:
That is a term we really like. Isn’t just that what we strabologists and orthoptists are all about?. We are alignment specialists, like front end alignment workers on automobiles. We could have titled this editorial like the last two, “Binocular Vision” (BV) of which this item is part, but....

Other terms: “Ocular motility” is still a valid term but ocular “alignment” just isn’t the same because the first thing that occurs to the hearer is “alignment” to what? Ocular is singular and suggests you are talking about just one eye and its “alignment” but what would that mean, the alignment of a single eye? To what? To the orbit, to other adjacent structures, to the head?. None of the foregoing relations is what we are talking about. We are talking about alignment with the other eye. Therefore the proper term for that would be, without much dispute, “BINOCULAR alignment”. So that is why we like that term better and think it rather better than simply “ocular motility or alignment”

And while we were working with that further expansion of the use of the term “binocular” to make other terms more specific and less likely to be misunderstood, we found another place to insert it. In the necessarily first paper in this issue, featuring our most favorite BV feature, “3D”, and employing highly sophisticated electronic testing, on “vision therapy” we noted that what they were doing was working not on or with all types of “vision therapy”, most or many of which are devoted to the act of seeing primarily, monocularly, especially as espoused by optometry and some other eye care specialists, and most of which have appeared in the ophthalmology literature only to be heavily criticized and its users even castigated, especially those practices related primarily to vision per se. But Laria and Piñero were using forms of vision therapy relating only to or primarily to BINOCULAR vision, namely binocular vision characteristics, (see pages 136 - 145) specifically, “different types of vergence, accomodation,” and diplopia awareness. And these are approved methods of treatment which we in ophthalmology have used for many years, perhaps even considered exclusively “orthoptic” since surgery is only exceptionally utilized in treatment of such deficiencies, but was never labeled as “vision therapy” by ophthalmologists, only as included by practitioners of “vision therapy” in general.

This is not just a semantic problem but a professional one too, raised by the that first article. But they invite the critical eye of ophthalmologists since they used the otherwise unspecified term of “vision therapy”. So we found ourselves in a position to help us all out, by calling what they looked at “binocular vision therapy”, and that is what they did, study binocular alignment, new and different ways of measuring and studying binocularity which must be included in the more general term “binocular vision”.

So we did adopt it for the first time for use in this paper for those reasons.. Elsewhere.

In this issue
To continue with our emphasis on the importance of BV the next paper in this issue (see Table of Contents on the prior page) by Shokida
et al tackles with even more highly sophisticated technology, fMRI, INTERFERENCE with BV, (another new BV term) from their fortuitous research patient with loss of vision due to an acquired monocular cataract, which, enabled them as in their conclusion to determine that ..

“under a severe binocular vision asymmetry caused by unilateral diffusion (i.e., blur without contour perception, or light perception only) [one sees] an interference effect under binocular viewing that is not seen in the case of weaker asymmetry such as in functional amblyopia, or from the extreme case of total elimination of visual input from one eye, such as in occlusion or monocular blindness.”

We certainly appreciate these authors stressing the importance of binocular vision, which has been a theme of this journal since inception, only recently reinvigorated.

From here on this issue is all strabology!

See Table of Contents on prior page for details of authors and title and pages.

First, Ameri et al, Report good results in their hands from slanting the medial rectus muscle for exotropia with convergence insufficiency by resecting a little more of the length of lower muscle fibers than the upper ones.

Akar et al compare the results in their hands of two schemes for eye muscle surgery for accommodative esotropia with convergence excess: Y-splitting recession and retroequatorial myopexy. They opined after their experience with many patients ( # ) that results were the same.

Sekeroglu et al demonstrate and opine that we should pay more attention to amblyopia and binocular vision in the initial assessment of patients with Duane’s Syndrome.

Finally, Khawam et al give us another one of their detailed all encompassing reviews, this time on strabology surgery for what we used to call “consecutive” vertical deviations.

The net result of having all these excellent papers to publish is that there is no room in this issue for any news, abstracts or Hyde Park Editorial-Blog. Maybe next issue.

Happy holidays - per
Evaluation of Binocular Vision Therapy Efficacy by 3D Video-Oculography Measurement of Binocular Alignment and Motility

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ABSTRACT: Objective: To evaluate two cases of intermittent exotropia (IX(T)) treated by vision therapy the efficacy of the treatment by complementing the clinical examination with a 3-D video-oculography to register and to evidence the potential applicability of this technology for such purpose.

Methods: We report the binocular alignment changes occurring after vision therapy in a woman of 36 years with an IX(T) of 25 prism diopters (Δ) at far and 18 Δ at near and a child of 10 years with 8 Δ of IX(T) in primary position associated to 6 Δ of left eye hypotropia. Both patients presented good visual acuity with correction in both eyes. Instability of ocular deviation was evident by VOG analysis, revealing also the presence of vertical and torsional components. Binocular vision therapy was prescribed and performed including different types of vergence, accommodation, and consciousness of diplopia training.

Results: After therapy, excellent ranges of fusional vergence and a “to-the-nose” near point of convergence were obtained. The 3-D VOG examination (Sensoro Motoric Instruments, Teltow, Germany) confirmed the compensation of the deviation with a high level of stability of binocular alignment. Significant improvement could be observed after therapy in the vertical and torsional components that were found to become more stable. Patients were very satisfied with the outcome obtained by vision therapy.

Conclusion: 3D-VOG is a useful technique for providing an objective register of the compensation of the ocular deviation and the stability of the binocular alignment achieved after vision therapy in cases of IX(T), providing a detailed analysis of vertical and torsional improvements.

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INTRODUCTION

Vision therapy encompasses a broad group of techniques aimed at correcting and improving binocular, oculomotor, visual processing, and perceptual disorders (1). Several studies have evaluated the efficacy of these techniques for some specific clinical conditions but always using subjective measurements based on patient or examiner’s subjective perception (2-10) and/or quality-of-life questionnaires (11). However, no objective validation has been performed to this date of the efficacy of vision therapy. Only Alvarez et al (12) have demonstrated by means of magnetic resonance imaging that vision therapy was associated with clinical and cortical activity changes in cases of convergence insufficiency. Therefore, there is a need for studies validating the results of vision therapy but using objective methods.

The 3D-videoculography (3D-VOG) is a non-invasive method to evaluate and analyze objectively and with high precision the horizontal and vertical ocular movements as well as the torsional components (13). This technology allows the clinician to perform a 3-D register of the ocular movements (14-17) and to have an objective guidance for taking clinical decisions. The 3D-VOG has been found to have a great variety of clinical applications, such as the objective characterization of nystagmus (18), the precise analysis of effects of extraocular muscle paralysis or paresis in ocular dynamics (19), the objective analysis of saccadic eye movements (20), the evaluation of eye movement impairment in neurological diseases (21), and even the analysis of cyclotorsional changes in refractive surgery (22).

However, to this date, the 3D-VOG technology has not been used in the field of vision therapy as a tool for evaluating objectively the efficacy of exercises to restore the binocular functionality. In the current case report, we show the objective evaluation of two cases of intermittent exotropia IX(T) treated by vision therapy and evaluated with a 3D-VOG system pre and post-therapy in order to evidence the potential applicability of this technology in this field.

CASE 1

A woman of 36 years old attended to our clinic referring intermittent deviation of the left eye without diplopia, especially at the end of the day or when she is very tired. On examination, the patient presented an uncorrected distance visual acuity (UDVA) of 0.0 LogMAR in right eye (RE) and -0.10 LogMAR in left eye (LE). Manifest refraction was 0 in both eyes, whereas under cycloplegia it was of +0.50 sphere -0.50 x 10º cylinder in RE and +0.25 sphere in LE. Anterior segment analyzed by biomicroscopy, Goldmann intraocular pressure (IOP), and fundus analyzed by indirect ophthalmoscopy were found to be within the normality ranges.

The oculomotor study revealed the presence of an intermittent exotropia IX(T) of 25 prism dipters (Δ) at far distance (5 m) and 18 Δ of exophoria (X(P)) at near (40 cm) (cover test). The negative and positive fusional vergence amplitudes measured with a prism bar were acceptable and the near point of convergence was to the nose. Specifically, the negative fusional vergence (NFV) was 16/12 and 20/18 Δ (break/recovery) at far and near distances, respectively. Positive fusional...
vergence (PFV) was 25/20 and 40/35 Δ at far and near distances, respectively. A video-oculographic study was performed with the 3D video-oculography system 3D-VOG from Sensomotoric Instrument (SMI, Teltow, Germany) which is a noninvasive optical system with two infrared video cameras mounted in a non-invasive pair of goggles (VOG goggles). These cameras are adjusted to a mask that is placed on the head with two plastic rubs that allow the ocular movements at the different sight positions to be registered independently at the three axis of the space with each movement of the patient’s head. The spatial resolution of the 3D-VOG is 0.05°/0.05°/0.10° (horizontal/vertical/torsional) and the measurement range is ±2.5°/±20°/±18° (horizontal/vertical/torsional), with a measurement area for torsional eye movement measurement of ±20° around the primary gaze position. This video-oculographic study showed that there was a variable horizontal deviation component that increased spontaneously at distance during a period of time until reaching the values measured dissociating with the cover test (Figure 1A, next page). No significant changes were evidenced in the vertical and torsional components during the period of examination (Figure 1A).

A 2-month vision therapy programme was prescribed and performed including different type of exercises, such as Brock string, Hart charts, prism bar vergence training, consciousness of diplopia training, variable anaglyphs, accommodative facility training with flipper, or aperture rule. After therapy, the patient referred an absence of episodes of deviation that could be objectively confirmed with the video-oculographic examination (Figure 1B, next page). The patient was very satisfied with the outcome obtained.

CASE 2

A child of 10 years old attended to our clinic referring intermittent ocular deviation of the left eye without diplopia that had increased in the last year. On examination, the patient presented a corrected distance visual acuity (CDVA) of 0.0 LogMAR in both eyes, with -1.75 sphere and -0.50 x 120º cylinder in RE and -1.75 sphere and -1.00 x 40º cylinder in LE. The same refraction was obtained under cycloplegia. Anterior segment was analyzed by biomicroscopy, Goldmann intraocular pressure (IOP), and fundus analyzed by indirect ophthalmoscopy were found to be within the normality ranges.

The oculomotor study revealed the presence of 8 Δ of IX(T) in primary position associated to 6 Δ of RE hypertropia, and a X(P) and RE hyperphoria of the same magnitude at near. In addition, a grade 3 hyperfunction of the RE inferior oblique was observed, with excyclodeviation associated. Positive fusional vergence amplitudes were low (NFV: far 8/4, near 20/18; PFV: far 10/8, near 2/1) and the near point of convergence was of 8 cm.

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Figure 1 (Laria & Piñero): Graphic display of the results of the video-oculographic analysis performed before (A, Top) and after (B, Bottom) a vision therapy programme in the first case reported simulating distance vision. In each display, changes in horizontal, vertical and torsional components during the period of time of the examination.
CASE 2 (continued)

The video-oculographic study performed with the 3D-VOG system confirmed the presence of a variable horizontal and vertical deviation, with a very significant instability of the torsional component (Figure 2A, see next page, Top). Vision therapy was recommended as the magnitude of the deviation was in the limit of the indication of surgery. A complete programme of vision therapy including different types of exercises was followed during a 3-month period. As in the other case reported, the programme included exercises such as Brock string, Hart charts, prism bar vergence training, consciousness of diplopia training, variable anaglyphs, accommodative facility training with flipper, or aperture rule. The therapy finished with the compensation of the deviation (2Δ X(P) and 6Δ hyperphoria RE far and 8Δ X(P) and 3Δ hyperphoria RE near) which could be objectively monitored with the video-oculographic examination (Figure 2B, see next page, bottom graphic). The ranges of fusional vergence were excellent (NFV: far 10/6, near 40/35; PFV: far 40/35, near 45/40) and the near point of convergence was to the nose. The patient’s parents were very satisfied with the outcome obtained, especially from a cosmetic point of view. Only certain instability remained in the torsional component, but not inducing binocular destabilization.

DISCUSSION

There is scientific evidence available on the nonsurgical treatment of accommodative and nonstrabismic dysfunctions, although it has been shown to be consistent only for the treatment of convergence insufficiency (23,24). Besides the limitation in the number of controlled studies evaluating the efficacy of vision therapy for most of binocular disorders, another controversial issue is the reduced number of studies using objective tests for registering the improvements achieved, without the need of the intervention of the patient or examiner (25).

In the current case report, we show a potential applicability of video-oculography for assessing the improvement achieved with vision therapy. Specifically, we evaluated by video-oculography using the 3D-VOG system the stability of the horizontal, vertical and torsional components in two different cases of distance IX(T) before and after a complete vision therapy program.

The 3D-VOG system allows the clinician registering the ocular movements in x/y axes due to a customized calibration that should be always performed prior to the measurement for each patient. Furthermore, this system allows characterizing the torsional movements using the iris pattern as a reference. The video-oculographic test is non-invasive, only requiring the use of a mask that is adapted to the patient’s head. This mask does not interfere with the patient’s capability of movement (freedom of movement in a 20°-visual field) and provides an exact oculomotor register. The 3D-VOG system has been successfully used for characterizing strabismic disorders (19), but not for non-strabismic anomalies.

In the two cases reported, the video-oculographic examination was complementary to other tests commonly used for the binocular evaluation of a patient, such as the measurement of the fusional vergence amplitude or the characterization of eye movement (freedom of movement in a 20°-visual field) and provides an exact oculomotor register. The 3D-VOG system has been successfully used for characterizing strabismic disorders (19), but not for non-strabismic anomalies.
Figure 2 (Laria & Piñero): Graphic display of the results of the video-oculographic analysis performed before (A, Top) and after (B, Bottom) a vision therapy programme in the second case reported simulating distance vision. In each display, changes in horizontal, vertical and torsional components during the period of time of the examination.
binocular misalignment with the cover test, requiring the intervention of the examiner and/or patient’s criteria. As two cases of IX(T) were evaluated, the video-oculographic register was especially used to monitor the stability of the ocular alignment, a critical issue for the success of the treatment in such cases. This evaluation could have been done even while introducing some elements of dissociation. It should be considered that fusional vergence amplitude can be acceptable prior to vision therapy treatment in some cases of IX(T) (26) and therefore its measurement is less useful as a parameter for evaluating port-therapy improvement. This occurred in our first case in which pre-therapy PFV amplitude was large, not suggesting the presence of a limitation in the range of fusional vergence. In such cases, the analysis of the stability of the ocular alignment seems crucial and the VOG allows the clinician to obtain a register of this stability. In addition, the torsional component could be monitored with the VOG examination, which is a deviation component not infrequent in patients with IX(T) (27).

The management of IX(T) at far distance by means of vision therapy has been suggested as a potentially useful therapeutic option since many years ago (28). However, it is not successful in all cases that may require a surgical intervention as a first option or even the combination of surgery and vision therapy (29). Figueira & Hing (30) in a retrospective analysis of the progress of 150 treated IX(T) patients concluded that surgery with orthoptic/occlusion therapy was more effective in reducing exodeviation (prism diopters per millimeter of horizontal rectus surgery) compared with surgery only. It is still unclear which factors are crucial for an appropriate selection of a surgical or non-surgical treatment for IX(T), although the magnitude of deviation seems to be one of them.

Thorburn et al (31) performed a review of the peer-reviewed literature on IX(T) of the divergence excess type and found that there was a lack of evidence for best practice and a need for not only high-quality clinical studies but also a better understanding of current practice patterns among clinicians so as to inform future research. We report a case of successful treatment with vision therapy of a case of 25Δ of far IX(T) which was objectively evaluated by VOG. Randomized controlled studies on the treatment of IX(T) are necessary in the future to define consistent scientifically-based clinical criteria. In these studies, the inclusion of VOG as an additional examination test would be of great value for providing an objective validation of the outcomes obtained.

The second case report shows a significant improvement of the horizontal deviation in a case of IX(T) associated to significant levels of vertical and torsional components. To our knowledge, this is the first report showing an improvement in the vertical and torsional deviation in far IX(T) after a vision therapy programme. Van den Berg and colleagues (32) developed a model in the attempt of finding an explanation for the torsional components in X(T). They found the increased horizontal vergence effort resulted in excess cyclovergence (32). Shin et al (27) found that the amount of torsion was significantly correlated to the disease severity of IX(T). Indeed, these authors suggested that the assessment of ocular torsion could be considered as a supplementary tool for
evaluating fusion in patients with IX(T) (27). Regarding the rehabilitation of the vertical deviation, some previous experiences on the treatment of vertical deviations by vision therapy have been reported (33). The achievement of the compensation of the horizontal deviation may be crucial for the vertical and even torsional alignment. More research on this issue is needed because the peer-reviewed literature is scarce.

CONCLUSION

In conclusion, 3D-VOG is a useful technique for providing an objective register of the compensation of the ocular deviation and the stability of the alignment achieved after vision therapy in cases of IX(T). Furthermore, it provides a detailed analysis of the torsional component allowing analyzing its improvement after vision therapy in such cases. More studies evaluating the efficacy of vision therapy should be performed using the VOG technology in order to complement the outcomes obtained with the classical clinical tests. This technology may have a crucial role in the validation of vision therapy techniques for a great variety of binocular disorders.

REFERENCES

Binocular Vision Interference from Unequal Inputs in an Adult Patient with Monocular Dense Acquired Cataract

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ABSTRACT: The effect of the unequal visual inputs in uniocular cataracts is addressed through the hypothesis that a marked inequality of the visual inputs will have an interference effect that will degrade the binocular vision relative to that of the better eye. We tested this hypothesis of ‘reverse’ interference effect by both clinical and functional Magnetic Resonance Imaging (fMRI) assessments in an acute unilateral cataract patient. The patient was 63-year-old woman who rapidly developed a dense sub-capsular cataract following steroid radio-chemotherapy treatment for breast cancer.

Methods: Clinical: Ophthalmologic evaluation and distance visual acuity (both uniocular and binocular), contrast sensitivity, binocular function, ocular motility and cover test to evaluate the presence of strabismus, and a slit lamp assessment of cataract density were performed. Neuroimaging: Functional MRI was run in a 1.5T Philips Intera Master with a SENSE neurovascular coil of 8 channels. The experimental design included three conditions: a) Binocular: both eyes viewing; b) OS-mono: left eye viewing, right eye occluded by a black cover; c) OD-mono: right eye viewing, left eye occluded by a black cover.

Results: Clinical: The logMAR visual acuity was 0.9 OD, hand movement at one meter OS, and 0.7 for binocular viewing, i.e., the binocular acuity was worse than the better eye acuity alone. As hypothesized, adding a diffuser lens and a penlight glare on the cataract eye increased the interference signal from that eye, and thus further reduced the binocular acuity to 0.4. Binocular contrast sensitivity also was worse than the OD alone. Neuroimaging: The fMRI results were consistent with the clinical findings. The number of activated voxels in the visual cortex under binocular viewing was reduced by about 40% relative to that for the fellow eye alone.

Conclusion: Clinical and fMRI data were well-correlated and consistent with the prediction for the marked binocular asymmetry. The results imply that the mechanisms operating under a severe binocular vision asymmetry caused by unilateral diffusion (i.e., blur without contour perception, or light perception only) exhibit an interference effect under binocular viewing that is not seen in the case of weaker asymmetry such as in functional amblyopia, or from the extreme case of total elimination of visual input from one eye, such as in occlusion or monocular blindness.

The authors thank Arthur Jamplosky, M.D. for his helpful discussion. 
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INTRODUCTION

In this study, we ask what form of binocular interactions occur in late-onset acquired dense unicular cataract, and how these interactions are affected by modulating the intensity of the (diffuse) light signal reaching the retina of the cataract eye. Jampolsky (1,2) emphasizes that there is a fundamental difference between diffusion (‘contourless light’, ‘white noise’) and occlusion (‘no stimulus’) in clinical observations, and shows that there are sensory and motor consequences of these two different categories of stimuli. He emphasized that such a “unilateral overall blur (diffusion) creates unequal inputs of both macula and periphery results in active tonic motor divergence response, which [leads to] exotropia of the affected eye”.

This kind of interference does not occur, however, in the case of a complete occlusion of one eye, nor in the case of a moderate input difference model, which allows the higher-contrast signals in the weak eye to be suppressed by the better eye. The same paper points out that adult patients with a gradually developing uniocular diffusion such as cataract or retinal detachment typically develop exotropia (or, more rarely, dissociated vertical deviation, DVD, of the affected eye), which is understood as an adaptive response to avoid the visual interference from the cataract. Such uniocular diffusion patients typically report a lack of stereopsis, difficulty with walking and discomfort glare. (Note that the reduced luminance resulting from the dense cataract will be compensated to a substantial degree by both pupillary and retinal light adaptation, maximizing the visibility of the residual scattered light and thus enhancing its interference effects relative to the level expected without such mechanisms.)

The aim of the present study was to test the Jampolsky hypothesis that a marked binocular asymmetry, such as in a result of retinal image diffusion of an advanced cataract with no image vision, is very different from either a) a moderate asymmetry or b) full occlusion. For this purpose, we selected a patient with a dense sub-capsular cataract. Discomfort under binocular viewing and better vision when the affected eye was covered were reported. The patient’s clinical behavior was evaluated and then compared with occipital brain activation using uniocular and binocular viewing conditions during counterphase grating stimulation in the fMRI scanner. We should note that finding patients with dense cataract is no longer a trivial task, as they are usually operated at an earlier stage.

Thus, to evaluate the relative contributions of the contour degradation and the veiling luminance of the light scattered by the cataract, the uniocular and binocular performances of the patient were compared under two experimental paradigms: 1) natural viewing conditions (with refractive correction), and 2) corrected viewing with a light diffuser covering the affected eye to ensure complete elimination of any residual form or contour vision. (As the patient could see hand movements at 1 m, the cataract eye was not yet degraded to the level of light perception only), together with a source of increased illumination (isolated to the affected eye only) in order to maximize the intensity of diffuse light in that eye.
**FIGURE 1** (Shokida et al): There is a fundamental difference between diffusion of the retinal image (B – E), on the one hand, and a lack of a retinal image (F), which leads to different sensory and oculomotor consequences. Unequal inputs from both the macula and the periphery typically result in exotropia in the mature adult system, but esotropia in the immature developing infant visual system. **B – E:** Image diffusion occurs from many sources: hazy lens, cornea, vitreous, and a closed eyelid. **F:** Occlusive devices that prevent light from entering the eye through cornea or sclera (i.e., occlusion) cause a no-stimulus condition (similar to total blindness, NLP). (After Jampolsky, 1994 (2), with permission.)

**PATIENT AND METHODS**

**Clinical History:** The patient was a 63-year-old woman who had developed a dense subcapsular cataract OS, starting 3 months before the study, following 6 weeks of chemotherapy, radiotherapy and steroid treatment for breast cancer. She complained of susceptibility to glare, closure of OS in bright light, difficulty with walking and discomfort in binocular view, reporting that she saw better when she covered the affected eye. She had difficulties in going downstairs and lack of stereopsis.

Before the onset of the treatment her visual acuity was measured as 0.9 OD and 0.7 OS. The visual field performed with Octopus 1-2-3 automated perimeter was normal OD and OS showed some peripheral depression OS. The retina examination before the cancer treatment showed that the macula and the optic disc were normal in both eyes at that time. Visual acuity OS decreased abruptly within in a 3 month period to counting fingers at 2 meters, then to seeing movement only at 1 meter OS and 0.9 with Sph +1.5 OD.

**Ophthalmological Examination:** (see Figure 2, next page) The ophthalmological examination was done under three different viewing conditions in order to vary the degree of image-diffusion and contour degradation, and to also vary the strength of the diffusion signal from the retina to the brain.
FIGURE 2 (Shokida et al.): A, left. Slit-lamp view of the dense subcapsular cataract developed by our 63-year-old patient after treatment for breast cancer. B, right. Focal slit of illumination shows posterior subcapsular cataract. (A) Normal Viewing Condition

All tests were performed in a medical examination room with an illumination of 210 Lux with full correction OD (Sph +1.5), but no correction OS because acuity and retinoscopy were insufficient to determine the required correction.

The Worth 4-Dot Test, as well as the Computer Visual Field performed with Octopus 1-2-3 automated perimeter, were run both before the surgery and radiation, and 3 months later when the rapid cataract has been developed. The contrast sensitivity was evaluated with the LH Symbols low contrast acuity test. The Ishihara color test and a Slit Lamp examination were also conducted.
A. FIGURE 3 (Shokida et al): An illustration of the estimated degree of image degradation in the Normal Viewing Condition for the ophthalmological examination of the cataract eye, OS, based on the image of a chair. Dense cataract, such as in our patient, creates an overall blurred image when the macula and the periphery of one eye is affected.

B. FIGURE 4 (Shokida et al): An illustration of the Enhanced Unequal-Input Condition for the ophthalmological examination of the cataract eye, OS. To ensure the elimination of any contour- or form-vision (even blurred) and thus, to be able to simulate the ‘white-noise’ state, we added a condition with a Spielman diffuser in front of the cataract eye. In addition, to enhance the interfering signal from this eye under binocular viewing, we shone a penlight on the diffuser, restricting the beam to the affected eye only.

“Eyelid closure or other diffusion states produce diffusion such that there is an absence of contours (i.e., “white noise”).… Note that "contourless" is not necessarily the same as "formless," and contours are the name of the game in strabismus.” (2).

A hypothesis of a different pathway being stimulated under diffusion predicts an increase of the interference effect of the cataract eye on the binocular vision as a function of the strength of stimulation of this eye. To probe this prediction, we retested the visual acuity under conditions designed to enhance the interference effect of the cataract eye on its fellow normal eye (see Figure 4, above). Thus, first, to ensure complete uniocular diffusion (no contour, no form - even blurred) and to simulate the ‘white noise’ state, we placed a Spielmann diffuser in front of the affected eye. In addition, to enhance the interfering signal from the affected eye under binocular viewing, we shone a penlight on the diffuser, restricting the beam to this eye only.
C. Psychophysical Matching A psychophysical matching experiment was conducted to estimate how much light goes through the diffuser to the cataract eye under different lighting conditions. We varied the intensities of uniform light to the good eye (through a Spielman diffuser) and determine the level at which the luminance perception in the good eye matched that of the cataract eye.

Functional Magnetic Resonance Imaging (fMRI)

Visual cortex activity was studied with functional Magnetic Resonance Imaging (fMRI). The study was performed with a Philips Intera Master 1.5 Tesla (Best Netherlands) with a sense NeuroVascular coil of 8 channels. The patient was in supine position. An anatomical MRI sequence was carried out before the functional blood oxygen level dependent (BOLD) sequence to rule out any kind of anatomic abnormalities. 3D sagittal T1 scanning was used with 180 slices of 1.0 mm, with no gap (FOV 256 mm, matrix 256, TR 500 ms, TE 50 ms parallel to the midline. The full sequence lasted 3’49”.

A second anatomical scan for axial T2 scanning was used with 20 slices of 5/0.1.4 mm (FOV 230 mm, matrix 229, TR 4418 ms, TE 110 ms) parallel to the corpus callosum. This sequence lasted 1’24”. Axial slice orientation was used with 24 slices of 4.0 mm thickness and a gap of 1.0 mm (FOV 230 mm, matrix 64, TR 2900 ms, TE 50 ms). Each experimental sequence had 54 volumes with a total scan time of 2’57”.

First, the data was analyzed in a Philips Extended MR Workspace (software version 2.6.3.2) with the BOLD program. The number of activated voxels in the occipital cortex were assessed for each condition.

For further analysis, the Stanford Vision and Imaging Science and Technology (VISTA) analysis software was used for calculation of the fMRI time course and voxel-wise parametric maps. The statistical parametric maps were generated based on the estimated activation amplitudes from a standard general linear model (GLM) of the response time course in each voxel. These maps could be viewed in the 3D volume or projected onto 3D views of the inflated cortex or flatmaps of cortical regions of particular interest at a statistical criterion of $10^{-3}$.

Experimental fMRI Design

The visual stimuli were generated by a computer and projected via a mirror system in the scanner. Gratings of black vertical stripes on a white background with a spatial frequency of 1.5 c/deg flickered in counterphase in a visual field of 10 x 8 deg, and were alternated for 5 cycles of 15-20 s "on" vs 15-20 s "off" up to 3 minutes in a jittered block design in three different conditions: a) Binocular: both eyes viewing; b) OD-mono: right eye viewing, left eye covered by a an opaque occluder; c) OS-mono: left eye viewing, right eye covered by a an opaque occluder. The patient was brought out of the scanner between conditions to switch the viewing conditions. The baseline condition was a black screen.

In order to ensure the state of ‘contourless’, diffused vision we run the sequence of these three experimental conditions was under the enhanced unequal-input condition, with OS viewing through a Spielmann diffuser in order to ensure total uniocular diffuse-light interference; OD viewing with optical correction of Sph +1.5.

RESULTS

Ophthalmological Results: The
results from the uniocular and binocular measurement under each of the experimental conditions were as follows:

**Normal viewing condition:**

a. **Without refractive correction:**

OD: 0.2 (black cover over OS)  
OS: hand movement (black cover over OD)  
Binocular: 0.2 – 0.3  

Binocular contrast sensitivity with LH Symbols low contrast test was worse than for the OD alone.

b. **With refractive correction** (i.e., increased asymmetry):

OD (Sph +1.5): 0.9 (black cover on OS)  
OS: hand movement (black cover on OD)  
Binocular: 0.7  

Under these conditions of increased asymmetry (i.e., with refractive correction OD) the measured binocular acuity was significantly worse than the fellow eye acuity alone. The background illumination of the medical examination room was 210 lux.

**All of the following tests** were performed with refractive correction of Sph +1.5 OD:

The LH Symbols low contrast test was used for the evaluation of the contrast sensitivity. Importantly, the figures at 1 m were seen better with the right (fellow) eye than than binocularly with both eyes; the binocular contrast sensitivity was about two times lower than that of the good eye. The Worth 4-Dot test was consistent with the effective lack of vision in the left eye, i.e. only the right eye stimulus was reported. The Ishihara color test was normal in the right eye but was not seen with the affected eye. Slit Lamp examination showed a dense subcapsular cataract in the left eye, as shown in Figure 2 (see prior page).

(Previous the cancer surgery and radiation treatment, the Computer Visual Field performed with Octopus 1-2-3 automated perimeter was normal in the right eye, and showed only a peripheral depression in the left eye. No macular or peripheral scotoma was found, and fundus examination showed no age-related macular degeneration).

**B. Enhanced unequal-input condition** (with refractive correction OD)

A psychophysical matching experiment was performed in order to estimate how much light goes through the cataract to the retina, we varied the distance of the penlight in a dark room (zero lux background) with a diffuser over the fellow eye (while the cataract eye was occluded), until the resulting percept in this eye matched that in the cataract eye during preceding exposure with the penlight. The light reduction from the cataract was a factor of 7.5, i.e., the cataract was absorbing about 87% of the light.

Binocular vision: 0.7 (Diffuser plus shining a penlight, restricted to the left eye only)  
Binocular vision: 0.4 (Diffuser plus a double-intensity light)  

Remarkably, adding a Spielmann diffuser and a penlight glare on the cataract eye further reduced the binocular vision to 0.4.

**Summary of the ophthalmological result** (see Figure 5, next page)

Doubling the light intensity resulted in almost doubling of the interference effect of the bad (cataract) eye on the good (fellow) eye as reflected in the binocular vision acuity and contrast sensitivity.
Thus, we found the strongest subtractive interference reduction of the binocular vision with the diffuser and penlight glare in front of the cataractous OS.

Functional Magnetic Resonance Imaging Results

**FIGURE 5** (Shokida et al): Axial views of the posterior anatomical (Occipital lobe) MRI overlaid with the functional MRI activation (orange-yellow coloration) for the three viewing conditions, *(see text prior page)* Left image, left cataract eye, right image, normal right eye: A. **Fellow Eye**: Note that the strongest activation is evident in the uniocular OD condition B. **Binocular**: Note that the binocular activation is reduced relative to that of the fellow OD eye alone (A.). C. **Cataract Eye**: The cataract OS eye activation is reduced relative to both the fellow eye (A.) and the binocular conditions (B.).
The activation was specified in terms of the number of significantly activated occipital voxels. The number of significantly activated occipital voxels in each of the three experimental conditions: Binocular (OU): 122 voxels Right eye (OD): 200 voxels Left eye (OS): 55 voxels

Thus, as expected, the affected OS eye showed less activation. The reduction of OS activity relative to OD (200 – 55 = 145 voxels) was significant (t = 9.08, significant at p < 0.01). Importantly, placing a Spielmann diffuser in front of the affected eye in the binocular condition resulted in significant reduction of the occipital binocular activation in comparison to the good eye (200 – 122 = 78 voxels; t = 4.58, significant at p < 0.01).

To define the form of binocular interactions as reflected in the fMRI activation, we evaluated the results in terms of the following basic models:

\[ B = L+R: \text{ full summation} \]
\[ B = (L+R)/2: \text{ averaging} \]
\[ B < \text{Better eye}: \text{ interocular interference of a partial-subtraction type} \]
\[ B = (\text{Better Eye} - \text{Affected Eye}): \text{ interocular interference of a full-subtraction type} \]

**Note:** In these expressions ‘B’ stands for ‘Binocular’; ‘L’ and ‘R’ – for ‘Left Eye’ and ‘Right Eye’, respectively.

The above summary shows that the number of activated voxels in the visual cortex under binocular viewing was reduced by about 40% relative to that for the fellow eye alone (p < 0.01), consistent with the Partial-Subtractive Interocular Interference Model (i.e., B < Better Eye). The reduction for the cataract eye was even more significant.
FIGURE 6 (Shokida et al). Inflated whole-brain 3-D views of the functional MRI activation under the three viewing conditions, to indicate the full extent of the lateral occipital activation (within the white line circled ellipses). Yellow-orange coloration indicates significant activation. A. **Normal Fellow Eye**: Lateral views of the left and right hemispheres, showing the unioocular OD activation. Note, that there is an extended occipital activation, as well as activation distributed throughout higher brain areas, all the way up to the frontal lobe. B. **Binocular**: The activation under binocular viewing. Note that the binocular activation is reduced in comparison to the fellow (OD) eye alone (A.). C. **Cataract Eye**: Visual stimulation of only the cataract eye, OS, produced only very reduced activation restricted to the foveal confluence.
This interference effect was evident initially from the patient’s subjective complaints of discomfort when viewing binocularly as her binocular vision became worse than the better eye alone. To overcome the subtractive interference from the cataract eye and improve her vision, the patient used to habitually occlude that eye. Furthermore, the results from our objective ophthalmological and brain imaging measurements also were also consistent with the diffusion-based binocular interference hypothesis.

In contrast, studies in normal young adults show that vision with two eyes is more sensitive than with one eye because of summation or gain in binocular vision (3,4). Even in strabismic amblyopia with low vision, loss of contrast sensitivity and abnormal binocular vision, Baker et al. (5) reported that binocular summation of contrast remains intact.

Moreover, binocular gain is known to decline with age or in the presence of large interocular differences, where the better eye acuity is not truly representative of binocular performance. Schneck et al. (6) evaluated contrast sensitivity in elderly population and found that binocular performance is not well represented by unocular measures for the better eye, and that binocular loss occurs much more frequently than binocular gain in subjects with high contrast acuity. Thus, the worse eye often negatively affects the binocular function and reduces it relatively to that for the better eye alone.

**“Diffusion” and Strabismus**

As reviewed in the Introduction, Jampolsky (1,2) reported that there are fundamentally different sensory-motor consequences of unocular retinal image diffusion versus unocular occlusion. Patients with gradual acquisition of unilateral cataract often develop large exotropia, in contrast to a sudden total loss of vision, which does not lead to strabismus. (It was also found that patients with a partial vision field loss, such as those with maculopathy and glaucoma, typically do not develop exotropia, because of preserved peripheral or central fusion.)

Thus, we need to ask why our patient had not developed exodeviation or any form of strabismus. This might be attributable to the rapid development of the cataract over three months, providing insufficient time for the sustained divergence mechanism to come into play. This rapid onset is consistent with the above requirement of ‘gradual’ development of the marked interocular asymmetry, as one eye’s vision reduced to the level of light perception only.

**Hypothesizing the Underlying Interference Mechanisms**

It has been postulated that there is an important, qualitative difference between “form deprivation” such as in “contourless light” (diffusion or "white noise" stimulus) “It should also be noted that "contourless" is not necessarily the same as "formless," and contours are the name of the game in strabismus” (1,2,7).

The unique and powerfully destructive nature of diffuse, contourless light stimulation was given a distinguishing term “white noise” (2) to account for the qualitative difference between “form deprivation”, such as in “contourless light”, vs in “occlusion” (or dark-rearing, i.e., with no stimulus at all). Moreover, Linksz (8) had proposed that there should be some ‘atavistic’ pathway in the visual system that controls the relative eye position in the absence of binocular fusion, and that it is this pathway that determines the strabismic angle. Thus, the critical difference under diffusion may come from a difference in the neural pathways engaged.
One of the present authors (LTL) has hypothesized that this ‘mysterious’ pathway may be indeed the recently discovered, although very ancient, pathway mediated by the intrinsically photosensitive retinal ganglion cells (ipRGC), which mainly ‘skips’ the high-resolution form-pathway through the striate cortex V1, and instead connects directly to networks of deep brain structures. This novel hypothesis leads to the predictions that (i) the diffuse-light signal from the dense cataract eye that is lacking any form or contour information have little impact on striate cortex but instead, activates predominantly subcortical pathways, and that (ii) if there is an interaction between the ipRGC specific pathways and the visual cortex, that interaction will be increased as a function of increasing the strength of the stimulation (i.e., of intensity of the diffuse-light signal from the affected eye).

To test these predictions, we designed the Enhanced Unequal-Input experimental condition. Thus, we ensured complete elimination of any contour- or form-vision by placing a Spielmann diffuser in front of the cataract eye. To increase the strength the hypothesized interfering of the “contourless” signal under binocular viewing, we increased its intensity by shining a penlight on the diffuser, restricting the beam to this eye only. These experimental manipulations further reduced the binocular visual acuity from 0.7 to 0.4 (a dramatic reduction, in spite that the monocular acuity of the fellow eye was 0.9). Comparative analyses of the fMRI activation across the three conditions (binocular viewing, OD-mono, OS-mono) revealed a form of (partial) subtractive interference effect (instead of binocular summation) under binocular viewing. These results are consistent both with the ophthalmological findings and the patient’s subjective complaint of poorer vision under binocular viewing.

We envision that the above-suggested hypothesis of the role of the intrinsically photosensitive ganglion cells, ipRGC, has further implications for the studies on binocular vision. It implies that, at a general level, clinical cases of marked interocular asymmetry can be conceptualized as a model for studying both the binocular interaction and the interactions between these different pathways (the ancient subcortical no-contour pathways vs. the form-vision pathway through the striate/primary visual cortex in area V1).

CONCLUSIONS

To conclude, in this rare case of a dense cataract with intraocular diffusion resulted in a subtractive-interference form of binocular interactions that was manifested both clinically and in the fMRI responses. This deficit of binocular visual function was consistent with the Jampolsky/Linksz model of the interocular interference effect of a uniocular diffuse-light or ‘contourless’ image under binocular viewing conditions.

Further studies are needed to gain insight in the specific brain mechanisms underlying the subtractive-interference effect that was observed, and to test the novel ipRGC hypothesis suggested above. We plan further analyses of the functional responses across the visual cortex, and their differences among different viewing conditions, such the relative activation V1, V2, V3, etc. Also, we plan to take advantage of advanced high-resolution fMRI analyses for studying subcortical structures, recently developed in the Tyler and Likova Labs. Moreover, running comparative investigations immediately after strabismus
operations and after an extended recovery period will allow us to go from activations to causality, thus providing a qualitative leap in the depth of interpretations and obtaining knowledge critical for building informed clinical prognosis and treatment.

REFERENCES


Slanted Medial Rectus Resection for Treatment of Exotropia with Convergence Insufficiency Strabismus: A Report of Results in 15 Cases

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ABSTRACT: **Purpose:** To evaluate the surgical and functional results of slanted medial rectus(MR) resection for treatment intermittent exotropia of the convergence insufficiency type. **Methods:** Fifteen patients with near vision asthenopia and intermittent exotropia of the convergence insufficiency type were included in this prospective study. The upper edge of the MR was resected more than the lower edge. Slanted bilateral or unilateral medial rectus resection was performed. The mean length of follow-up was 14.9 months (range, 9–21 months). **Results:** Slanted medial rectus resection(s) caused a significant postoperative reduction in the mean distance exodeviation from 11.40±7.13 to 4.53±4.99 PD (P<0.0001), as well as a change in the mean near exodeviation from 23.93±8.69 PD to 10.73±5.91 PD (P<0.0001). Although mean near-distance difference reduced from 12.53±2.09 to 6.2±1.820 PD (P<0.0001). In final examination,11 patients(73.3%) showed surgical success rate and recurrent exotropia occurred in 4 cases. On the other hand, 13 cases (86.6%) had experienced significant relief from their symptoms. **Conclusion:** Slanted medial rectus resection is useful in decreasing the symptoms of intermittent exotropia of the convergence insufficiency type. However, it can result in undercorrection in larger deviations.

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INTRODUCTION

Intermittent exotropia X(T) of the convergence insufficiency type consists of an exodeviation that is greater at near than distance by at least 10 prism diopters (PD) or more and is associated with mild to severe symptoms of asthenopia, reading problems, and intermittent diplopia (1,2). Although nonsurgical treatment may relieve the symptoms, in some refractory cases muscle surgery is necessary. Recommended surgery for these patients include bilateral lateral rectus (LR) recession with or without slant procedure (3,4), bilateral medial rectus(MR) resection with or without slant procedure (5-7), and LR recession with MR resection (8).

However, one prospective study found an unsatisfactory result of slanted medial rectus resection in X(T) in terms of reducing exodeviation and collapsing near-distance differences (7). These unsatisfactory results prompted us for doing a new study. We proposed that surgery might improve the subjective symptoms even without significant surgical success. Therefore, we undertook this surgical technique to evaluate long-term surgical results and functional improvement in patients with X(T) and convergence insufficiency.

METHODS

This prospective interventional case series was performed in Farabi Eye Hospital between August 2010 and July 2012. We included 15 consecutive adult patients with X(T) greater at near than at distance by 10 PD or more, which was confirmed by repeated examinations. All patients had a history of prolonged difficulties with near work. All cases had undergone periods of unsuccessful nonsurgical therapy including orthoptic treatment. Patients with amblyopia, paralytic or consecutive XT, previous ocular or extraocular muscle surgery, an abnormal neurologic status and postoperative follow-up of less than 9 months were excluded. Informed consent was obtained from the all patients before operation. We also explained to patients, the probability of postoperative overcorrection and diplopia.

The patients underwent full ophthalmologic and orthoptic evaluation, including cycloplegic refraction (with cyclopentolate 1%). The distance (6 m) and near (33 cm) deviations were measured by the prism and alternate cover test when the patients fixated on accommodative targets. Deviometry was performed when the patients were wearing their best optical correction. The presbyopic patients were corrected for near vision. Prism adaptation test was performed in the office for all patients to ascertain that the maximal deviation was measured. Near point convergence (NPC) was measured for all patients. Binocular testing for stereopsis was performed for all subjects by the Titmus Stereotest at near.

Our surgical plan was unilateral or bilateral slanted MR resection according to patient’s deviometry. All operations were
done by one surgeon (AKJ). The MR muscle resection was performed through a medial limbal peritomy in all cases. Generally, the extent of the resection was based on the surgical dosage schedule of Parks (9). The upper edge of the MR was resected according to the distance exodeviation and the lower edge of the MR was resected according to near exodeviation after two separate sutures were woven through the muscle's thickness and then locked at the muscle edges. Following resection, the MR was reattached at its original insertion (see Figure, right).

Postoperative follow-up intervals were determined according to the patients status, but patients were usually examined 1 day, 1 week, 3 months and every 6 months after the operation. The examination included the angle of deviation at distance and near and the difference between them, NPC measurement, as well as binocularity and extraocular muscle motility. In patients that manifested a consecutive esotropia with diplopia at distance and/or near, alternate patching was performed. When a patient maintained single binocular vision, alternate patching was discontinued. Criteria for successful outcome were a postoperative residual deviation at near or distance of ≤10 PD and a difference between the near and the distance angle of exodeviation less than 10 PD.

Also, subjective improvement and patients satisfaction from operation was evaluated through a questionnaire. The patients were asked to fill the questionnaire about the experience time for the beginning of

Figure (Akbari et al): Slanted MR resection: After two separate sutures are woven diagonally through the muscle's thickness and then locked at the muscle edges (upper figure), the lower muscle horn length was resected more than the upper horn. The muscle was then reattached to its original insertion (lower figure).
blurred vision and asthenopia during reading. If symptoms occurred within less than 30 minutes after reading, it was categorized in score 1. If it began between 30 minutes and 60 minutes the patients were categorized in score 2 and score 3 was for those having symptoms after one hour of reading. The SPSS program (version 16.0) was used for all statistical calculations. Statistical analysis was performed with either the paired t test or the Wilcoxon matched pairs signed ranks test (nonparametric test), as appropriate. We used paired t test for comparison; mean near angle of deviation preoperatively and postoperatively, mean distance angle of deviation preoperatively and postoperatively, and mean near-distance esodeviation difference pre- and postoperatively.

RESULTS

Two of 17 patients operated with slanted medial rectus resection, were excluded because they did not complete their follow-up examinations. The patients ranged in age from 15 to 42 years (mean, 26.3 years), and the mean length of follow-up was 14.9 months (range, 9–21 months). The database of the study for preoperative evaluation and the last follow-up visit, are shown in Table, next page.

This study showed a significant postoperative reduction in the mean distance esodeviation, from 11.40±7.13 PD (range, 2 to 40 PD) to 4.53±4.99 PD (range, 4 to 25 PD; P<0.0001). Near-distance deviation differences also collapsed significantly from a preoperative mean of 12.53±2.09 (range, 10 to 16 PD) to postoperative mean of 6.20±1.82PD (range, 4 to 10 PD) (P<0.0001).

On first day after surgery, eight of the 15 patients (53%) had esodeviation at distance ranging from 4 to 12 PD. For these patients we advised alternate patching (3 hours per day). Diplopia was resolved in six cases with esodeviation less than 10 PD surgery within two weeks. Two patients (cases 13 and 14) had esodeviation more than 10 PD in distance on the first day after the operation and they had to patch for one month to relieve diplopia. We did not use prism therapy for controlling diplopia in our patients.

At the final follow-up examination, 11 patients (73.3%) had a residual esodeviation at distance and at near less than 10 PD, and the difference between the distance and near deviation was within 10 PD, which was defined as surgical success. Although, 4 cases (cases 6, 7, 10, 11) did not meet the surgical success criteria and they showed recurrent exotropia, but in 3 of them, near-distance differences collapsed to <10 PD (cases 6, 10, 11). Of 4 patients who were not included in the surgical success group, 3 patients refused re-operation and only case 10 underwent additional surgery. Slant recession of one (left) lateral rectus was done as a second surgery (5 mm for upper pole and 8 mm for lower pole). Follow-up examination
TABLE: RESULTS: Preoperative and Postoperative Data for 15 Subject Patients with Convergence Excess Exotropia Strabismus who Underwent Slanted Medial Rectus Eye Muscle Strabismus Surgery.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age/sex</th>
<th>Preoperative results</th>
<th>Postoperative results</th>
<th>Subjective Score (pre op.→post op.)</th>
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<tr>
<td></td>
<td></td>
<td>X(T) pattern D/N(PD)</td>
<td>Difference, N-D(PD)</td>
<td>Stereopsis (S/Arc) NPC (mm)UP/LP</td>
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<td>42/F</td>
<td>14/30</td>
<td>16</td>
<td>80</td>
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<td>35/F</td>
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<td>25/F</td>
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<td>18/M</td>
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D/N, distance/near; ET, constant exotropia; N-D, near minus distance; ortho, orthotropia; X(T), intermittent exotropia; PD=prism diopeter; UP=upper pole; LP=lower pole; pre op.=pre operation; post op.=post operation.
(4 months after second surgery) revealed orthotropia at distance and 4 PD exotropia at near. Stereopsis at near was improved postoperatively rather than preoperatively in 10 (66%) patients (P=0.003). Also, our evaluation showed improvement in postoperative NPC finding in 14 cases (93%). NPC reduced from a preoperative mean 17.25±7.2 centimeter to postoperative mean of 9.40±2.8 centimeter and this difference was statistically significant (p=0.002).

At final examination, 13 cases (86.6%) had experienced significant relief from their symptoms and these patients no longer complained of headaches, eye strain and difficulties with reading or diplopia at distance. Case numbers 7 and 12 complained from headache and eye strain in reading that got serious 3 months post surgery.

**DISCUSSION**

Slanting recessions or biased resections of the superior and inferior poles of the horizontal rectus muscles asymmetrically have been reported to be useful for treating A- and V-pattern strabismus (10-12). For example, for a V pattern esotropia, authors recessed and slanted the inferior pole of the medial rectus muscles back farther than the superior pole and applied similar reasoning for A-pattern esotropia and for A- or V-pattern exotropia.

Other researchers extrapolated from slanting method to treat convergence excess esotropia(13) or convergence insufficiency X(T)(4,7,14-16). Thus, for X(T) of the convergence insufficiency type, the lower edge was resected more than the upper edge. Kushner (12), in a review, mentioned that slanting method could not contribute substantially to the outcome of strabismus surgery because sarcomere remodeling should even out the differential edge tension and largely negate the effect of the slanting procedure. Therefore, the efficacy of several surgical approaches in X(T) of the convergence insufficiency type remains controversial.

Several authors performed medial rectus resection. After bilateral medial rectus resection, all patients showed a dramatic relief of asthenopic symptoms in one study (3). MR resection(s) with adjustable suture combined with intentional postoperative aggressive overcorrection was useful with success rate of 76% in another study (5).

Snir et al (4) also demonstrated that slanted recession of the lateral rectus was an effective procedure in patients with convergence insufficiency type of X(T) for reducing both distance and near exodeviation and at collapsing near-distance differences.

According to the literature, the results of slanted MR resection in patients with convergence insufficiency type exotropia, have been evaluated previously in at least three studies (7,14,15). In the first two studies with the distance angle of exotropia of 2-10 PD(14,15) all six patients showed postoperative alignment within 10 PD in all field gazes without diplopia. However, in another study (7), no patient met the criteria of
surgical success and all had recurrent exotropia. In that study, the range of preoperative exodeviation at distance was 15–40 PD and at the last follow up, the mean exodeviation at distance was 16.3PD (range, 10–25 PD) and at near, 24.6PD (range, 14–35 PD) without clinically successful improvement.

Our study included patients whose preoperative distance deviations ranged from small to large angle (2 PD to 25 PD), which was different from previous studies. At the final follow-up examination, four cases did not meet surgical success criteria. These cases had a preoperative distance deviation of 10 PD or more. All six patients with preoperative distance deviation of less than 10 PD, reached to successful results. The mentioned result was in accordance with the observations by Choi (7). These results suggest that the amount of slanting for patients with preoperative distance deviation of 10 PD or more may be too small to correct exodeviation successfully and there still remains a possibility for an increased slanting to make any significant difference.

There are several reports for postoperative diplopia in convergence insufficiency exotropia. Concordant with previous studies for slant medial rectus resection (7,14,15), our study also demonstrated that postoperative esotropia or diplopia was short-lived (less than 6 weeks). Postoperative improvement of stereopsis happened in 66% of patients. Of 15 patients who had been evaluated, 8 patients had stereacuities within 80 second of arc. All of these cases (except case number 7) were included in the surgical success group. Three patients (cases 6,10,11) who were not included in the surgical success group had stereacuities of 100,140 and 400 seconds of arc, respectively. Therefore, preoperative stereopsis might be a prognosticated factor in the success rate of surgery.

At the final examination, 13 patients (86.6%) had experienced significant relief from their symptoms and subjective score improved. Even patients with modest under-correction showed dramatic relief of symptoms, because most of residual exodeviations were well controlled. Between 4 patients who were not included in the surgical success group, only in one (case 7) symptomatic relief and prolonged period of comfortable reading time, did not happen. Apparently in our study, it seems that the subjective results were better than the objective results.

There are some limitations in our study. First, only fifteen patients could obtain our inclusion criteria and it is clear with increasing in number of patients, we can get more documentary results. Second, the longer follow-up time, may have an effect on final result.

In conclusion, the present study indicates that, in patients with X(T) and convergence insufficiency when nonsurgical treatment fails, the use of slanted resection of MR muscle is an effective procedure. Slanted
resection of MR muscle can improve exotropia in far and near and reduces near-distance difference without the risk of long-term diplopia.

REFERENCES


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From Professor Dr. N. Resat Belger Beyoglu Education and Research Eye Hospital, Istanbul, Turkey and Agri State Hospital, Agri, Turkey (Dr. Sabanci)

ABSTRACT: **Purpose:** To compare the results of a medial rectus (MR) Y-split recession with those of a MR retroequatorial myopexy for the treatment of partially accommodative esotropia with convergence excess.

**Methods:** In this retrospective study, patients who underwent bilateral MR Y-split recession or bilateral MR retroequatorial myopexy for partially accommodative esotropia with convergence excess (accommodative convergence: accommodation ratios >5 prism diopters:diopters) between March 2006 and January 2011 were included.

**Results:** Sixty-one patients underwent bilateral MR Y-split recession, and 60 patients underwent retroequatorial myopexy of the bilateral MR muscles. Satisfactory binocular alignment (≤ 10 pd esotropia) was achieved in 77% of the patients who underwent MR Y-split recession by the final examination and 78% of patients who underwent a MR retroequatorial myopexy. There was no statistically significant difference in near or distance deviation or the near-distance disparity at the postoperative 1 month or final examination. The proportions of patients who had a successful alignment at the final examination did not differ between the two groups. No patients had any complications.

**Conclusion:** We determined that both the MR Y-split recession and MR retroequatorial myopexy achieved satisfactory results for the treatment of partially accommodative esotropia with convergence excess though both techniques had some disadvantages.

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INTRODUCTION

Esotropia is partially accommodative when accommodative factors contribute to but do not account for the entire deviation (1). For the treatment of patients with esotropia associated with convergence excess, the results with conventional surgery, namely unilateral or bilateral medial rectus (MR) recessions, have been mixed, while the use the retroequatorial myopexy alone or in conjunction with conventional surgical techniques is accepted as an alternative (2-11).

Hoeranter and colleagues reported that the MR Y-split recession operation was sufficient to stabilize the variable strabismus angle, while avoiding the known side effects of Cüppers retroequatorial myopexy operation and would be a powerful alternative for the treatment of such cases (12-14).

In this study, we conducted a retrospective comparison between the Y-split recession of MR muscles and the retroequatorial myopexy of MR muscles for the treatment of partially accommodative esotropia with convergence excess. Our aim was to compare the postoperative outcomes, success results and probable complications of both procedures.

METHODS

After obtaining approval from the Ethics Committee and the Institutional Review Board at the Professor Dr N Reşat Belger Beyoğlu Education and Research Eye Hospital, Istanbul, a retrospective medical record review was conducted to identify all patients operated on with a diagnosis of partially accommodative esotropia with convergence excess. The patients who underwent Y-split recession of the bilateral MR muscles and those who had undergone bilateral MR retroequatorial myopexy between March 2006 and January 2011 were identified. The cases in both groups with the same distribution of age (range: 3 to 14 years), preoperative refractive errors (range: +2.0,+6.0), visual acuity (range: 0.5-1.0), preoperative near esotropia (range: 25-45 pd) and distance esotropia (range: 10-25 pd), and preoperative near esotropia exceeding the distance esotropia by at least 10 pd that existed despite full correction of a hypermetropic refractive error; high accommodative convergence: accommodation (AC:A) ratios >5 prism diopters:diopters (pd/d) were included in this study. Patients who had no previous extraocular muscle surgery; and follow-up lasting at least 1 year after surgery were included. The exclusion criteria were as follows: the presence of fully accommodative esotropia, nonaccommodative esotropia or infantile esotropia; the presence of amblyopia (2 Snellen lines difference of visual acuity between eyes) at the time of surgery; the presence of neurologic, developmental or ocular structural disorders; or a history of previous nonstrabismus eye surgery. Patients undergoing simultaneous oblique muscle surgery for an A or V pattern or vertical transposition of the horizontal recti were also excluded. The study and the data collection conformed to all local laws and were compliant with the principles of the Declaration of Helsinki. Informed consent was obtained from each participant; for children younger than 18 years of age, consent was obtained from one or both of the parents.

Retrospective data collection was performed over a period comprising surgery and a postoperative follow up of at least 12 months. The main measures recorded were preoperative and postoperative (in the first month and at the final examination) near and
distance deviations, near-distance disparity, stereopsis and fusion and complications. The last examination was performed at a mean postoperative follow-up time of 31±3.1 months (12-48 months) for Y-Split recession cases and a mean postoperative follow-up time of 31±4.1 months (12-49 months) for the retroequatorial myopexy operations.

All patients received complete ophthalmic and orthoptic examinations, pre- and postoperatively. Ocular motility was analyzed using unilateral cover and alternating cover tests and was measured using the prism cover test while the patient wore full cycloplegic correction and viewed an accommodative target requiring near and distance fixation. The stimulus AC:A ratio was calculated using the gradient method. Values >5 pd/d were considered to be high AC:A ratios (15,16). Binocular sensory testing was performed using the patient’s optimum hyperopic correction during the postoperative examination. Stereopsis and fusion were measured via prism offset, if necessary. Sensorial foveal fusion was measured using the Worth four-dot test at 6 m and 33 cm. Stereoacuity was measured using the Titmus stereoacuity test, the Randot preschool stereoacuity test, the Lang tests and/or the TNO test at 33 cm. Preoperative A- and B-scan echography (Ocuscan; Alcon, Fort W 71 orth, TX) were performed in patients who undergoing Y-split recession to determine the axial length of the globes.

The Y-split recession technique is always combined with an additional recession (12-14). Both rectus muscles were split at a length of 15 mm, and the two parts were reinserted on the globe surface with two non-absorbable sutures. First, the muscle was split bluntly for a length of 15 mm. To obtain the correct new insertion points for the two muscle halves, we employed the following procedure: a first orientation point, labeled “A” in Fig 1A, was located in the middle of the natural insertion of the muscle. A second point, labeled “B”, was located 6 mm straight behind A. With the compasses centered at A, the distance “ra” was marked on the globe with methylene blue. The same procedure was repeated at B, with the distance “rb”. The intersection point of the two methylene blue lines (“C”) marked the new insertion point of the first muscle half (Fig 1A).

![Figure 1](image_url)

Figure 1. (Akar et al): Surgical techniques:

A. Medial rectus Y-Split recession; The muscle was split at a length of 15 mm, and was reinserted at position C. Position A is the middle of the original muscle insertion and position B is 6 mm behind in a radial direction. The intersection of distance ra, measured from point A, and distance rb, measured from point B, indicates the new insertion point C. The same procedure is applied to the second muscle part.

B. Medial rectus retroequatorial myopexy; The muscle was sutured at 12–13 mm from the original insertion.

A detailed description of the surgical technique has been presented previously by
Hoerantner et al (12-14). The following values were typically used for a globe length of 21.2 mm: \( rb = 8.4 \pm 0.02 \times \text{Strabismus Angle (mm)} \), where Strabismus Angle is the maximum strabismus angle. The resulting muscle recession is given by \( \text{Recession} = 22.0 - 0.052 \times \text{Strabismus Angle (mm)} \), and the control distance is given by \( \text{Control Distance} = 10.2 + 0.032 \times \text{Strabismus Angle (mm)} \) (12-14).

A retroequatorial myopexy was performed based on the modified method of Cüppers described by de Decker, and the recommended guidelines based on the degree of esotropia were followed (9,17). Both MR muscles were sutured at 12–13 mm from the insertion, see Figure 1.B. (9,17), prior page.

Postoperatively, orthotropia or esotropia of less than 10 pd at near and distance fixations with available optical correction was considered a satisfactory outcome.

The preop’ data and postoperative results of the two groups (MR Y-split recession and MR retroequatorial myopexy) were compared. The data were analyzed using SPSS for Windows, version 16 (SPSS Inc., Chicago, IL). The descriptive statistics, frequencies and percentages of categorical variables and the means and standard deviations of numeric variables were calculated. A Shapiro-Wilk test was used to evaluate the normality of the distributions. An independent samples t-test was used for normally distributed variables, and a Wilcoxon signed-rank test was used for non-normally distributed variables. Pearson’s \( \chi^2 \) test was used to compare the proportion of categorical variables. Values of \( p<0.05 \) were considered statistically significant.

RESULTS

One hundred twenty one patients (52 females and 69 males) with an age range of 3 to 14 years who met all the entry criteria were included in the study. Sixty-one of 121 patients underwent bilateral MR Y-split recession, and 60 patients underwent bilateral MR retroequatorial myopexy.

The Y-split technique was always combined with an additional MR recession of a mean \( 2.8 \pm 0.5 \text{ mm} \) (range 2.1-3.5 mm). In this technique, we used parameters of \( ra = 9.0 \pm 0.7 \text{ mm} \) (range 7.4–12.9 mm) and \( rb = 8.5 \pm 0.6 \text{ mm} \) (range 6.6–11.5 mm). The mean axial length of the patients was 21.1 mm.

Pre- and postoperative patient data was shown in see Table 1, next page. In the MR Y-split recession group, there was a statistically significant difference between the preoperative and first postoperative month near and distance deviations and near-distance disparities (\( p<0.001 \) for each comparison). There were no statistically significant differences between the first postoperative month and the final examination near and distance deviations and near-distance disparities (\( p=0.68, p=0.24, p=0.44 \), respectively). In the MR retroequatorial myopexy group, there was a statistically significant difference between the preoperative and first postoperative month near and distance deviations and near-distance disparities (\( p<0.001 \) for each comparison). There were no statistically significant differences between the first postoperative month and the final examination near and distance deviations and near-distance
Table 1: **RESULTS:** preoperative and postoperative data of 121 patients treated with either retroequatorial myopexy or the Y-split recession

<table>
<thead>
<tr>
<th></th>
<th>Bilateral MR Y-split recession</th>
<th>Bilateral MR retroequatorial myopexy</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of patients (n)</td>
<td>61</td>
<td>60</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>5.4±0.2 (2-14)</td>
<td>5.8±0.4 (3-14)</td>
</tr>
<tr>
<td>Gender F/M</td>
<td>26/35</td>
<td>26/34</td>
</tr>
<tr>
<td>Visual acuity (SL)</td>
<td>0.7±0.2 (0.5-1.0)</td>
<td>0.8±0.2 (0.6-1.0)</td>
</tr>
<tr>
<td>SE of refraction (d)</td>
<td>+4.3±0.5 (+2.0, +6.0)</td>
<td>+4.4±0.7 (+2.0, +6.0)</td>
</tr>
<tr>
<td>AC/A ratio (pd/d)</td>
<td>7.8±1.7 (5.5-9.0)</td>
<td>7.9±0.9 (6-9)</td>
</tr>
</tbody>
</table>

**Preoperative**

- Mean near deviation (pd) 38.0±5.9 (25-45) 36.4±6.1 (25-45)
- Mean distance deviation (pd) 20.5±4.5 (10-25) 19.6±4.9 (10-25)
- Mean near-distance disparity (pd) 17.5±3.1 (10-20) 16.9±2.1 (10-20)

**Postoperative first month**

- Mean near deviation (pd) 8.4±2.7 (0-15) 7.6±2.2 (0-15)
- Mean distance deviation (pd) 5.2±4.8 (0-15) 5.3±1.1 (0-15)
- Mean near-distance disparity (pd) 3.2±0.1 (0-10) 2.3±1.5 (0-6)

**Final examination**

- Mean near deviation (pd) 9.2±2.7 (0-15) 7.7±2.4 (0-15)
- Mean distance deviation (pd) 5.4±2.1 (0-15) 5.6±2.5 (0-15)
- Mean near-distance disparity (pd) 3.8±1.1 (4-8) 2.1±1.2 (0-6)

**Follow-up period (mo)**

<table>
<thead>
<tr>
<th></th>
<th>Bilateral MR Y-split recession</th>
<th>Bilateral MR retroequatorial myopexy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up period (mo)</td>
<td>31 ±3.1 (12-48)</td>
<td>31 ±4.1 (12-49)</td>
</tr>
</tbody>
</table>

MR; medial rectus, yr; year, F/M; female/male, SL; Snellen line, SE; spherical equivalent, d; diopeter, AC/A; accommodative convergence: accommodation, pd; prism diopeter, mo; month

disparities (p=0.38, p=0.44, p=0.53, respectively).

The preoperative patient data and postoperative results between the two procedures were compared (**Table 1, above**). There was no statistically significant difference in the number of patients, age, gender, visual acuity, refraction of spherical error, AC/A ratios, preoperative near and distance deviations, near-distance disparities, or follow-up period between the MR Y-split recession and retroequatorial myopexy groups (p>0.05 for each comparison). There was no statistically significant difference in near and distance deviations or near-distance disparities at 1 month postoperative between the MR Y-split group and the MR retroequatorial myopexy group (p=0.48, P=0.31, p=0.98). There was no statistically significant difference in near and distance deviations or near-distance disparities at the final examination between these two groups (p=0.09, p=0.18, p=0.67) (**Table 1**).
Table 2: RESULTS: Final postoperative results in 121 patients who underwent MR Y-recession or the MR retroequatorial myopexy (at the final examination)

<table>
<thead>
<tr>
<th></th>
<th>Bilateral MR Y-split recession</th>
<th>Bilateral MR retroequatorial myopexy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful Alignment (n%)</td>
<td>47 (77)</td>
<td>47 (78)</td>
</tr>
<tr>
<td>Residual ET n (%)</td>
<td>14 (23)**</td>
<td>13 (22)*****</td>
</tr>
<tr>
<td>Secondary XT (n %)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total n (%)</td>
<td>61 (100)</td>
<td>60 (100)</td>
</tr>
</tbody>
</table>

MR; medial rectus  *Postoperatively, orthotropia or esotropia of less than 10 pd at near and distance fixations with available optical satisfactory outcome. **These patients had undercorrection at near fixation (mean 12.7 pd, range 10 to 15 pd esotropia) and distance fixation mean 10.8 pd, range 10 to 15 pd esotropia). ***These patients had undercorrection at near fixation (mean 13.2 pd, range 10 to 15 pd esotropia) and distance fixation (mean 11.2 pd, range 10 to 15 pd esotropia).

The comparison of the postoperative results at the final examination in patients who underwent MR Y-split recession or the retroequatorial myopexy of MR are summarized in Table 2. There was no statistically significant difference in the proportions of patients who had successful binocular alignment or undercorrection at the final examination between the MR Y-split recession group and the MR retroequatorial myopexy group (p = 0.91, p = 0.78). No patients were overcorrected.

Postoperatively, fifty patients (82%) in MR Y-split recession group and 47 (78%) patients in MR retroequatorial myopexy group were able to cooperate with sensory tests for stereoaucity, and Worth four-dot test. Nineteen (38%) of 50 patients in the MR Y-split recession group and sixteen (34%) of 47 patients in the MR retroequatorial myopexy group had fusional ability and stereopsis better than 200 seconds of arc.

None of the 121 patients showed any complications, including retinal detachment, scleral perforation, significant globe retraction, or significant reduction of globe movement, and no reoperation was required.

DISCUSSION

Conventional muscle surgery techniques have been used with mixed success to treat esotropia associated with a high AC/A ratio (1-6). Surgeries that are based on the level of deviation measured at distance fixation often result in unacceptably high degrees of undercorrection (2). Many different approaches have been described, all of which attempt to improve on the frequent surgical undercorrections for near fixation that occur with bilateral MR recessions while avoiding distance exotropia (3-6,18,19). MR recessions reduce near-distance disparity in accommodative/partially accommodative esotropia with convergence excess by around 2/3. (3,18,19). Vivian and colleagues summarized the controversies of this scenario, describing the problematic disparities in target outcomes, follow up periods, and lack of high quality evidence in the current literature (20).
of corrected and uncorrected near deviations to augment bilateral MR recessions in 40 patients, 98% of whom achieved motor alignment of orthotropia ±10 pd (5). West and colleagues (6) reported the outcomes of surgery on the corrected near angle in 25 patients with near distance disparity (mean, 21 pd) They achieved an 80% success rate in motor alignment (orthotropia±10 pd distance and near) (6). Some authors used prism adaptation for the near angle in patients with near distance disparity (>10 pd) (21,22). Kutsch and colleagues found that almost 90% had motor or sensory fusion with prisms (prism response), whereas 31% were prism builders (21). Wygnanski-Jaffe and colleagues reported that excellent postoperative outcomes (orthotropia ±8 pd and Worth 4-dot near fusion) were more frequent for the prism builders (100%) than in the nonresponders (55%) (22).

The effectiveness of a retroequatorial myopexy with or without MR muscle recession in the treatment of convergence excess esotropia remains under debate (1,2,4,7-10,16). Some authors reported that 71–86% of patients with convergence excess were capable of maintaining satisfactory near ocular alignment with bilateral retroequatorial myopexy of the MR muscles at an average of 2–4.8 years of follow-up (7-10). Other authors used pulley fixation in patients with accommodative or partially accommodative esotropia associated with a near distance disparity greater than 10 pd (23,24). Bilateral MR recession was performed either for their prism-adapted, corrected distance angle or their uncorrected distance angle, whereas those with no esotropia at distance underwent pulley suture fixation alone (23,24). An 80% mean reduction of near-distance disparity was observed by Mitchell and Kowal (24). This is similar to the results reported by Clark and colleagues (23).

The principal reason for adding pulley fixation suture in this group of patients is to reduce the distance-near incomitance (convergence excess)(23,24). Scleral retroequatorial myopexy sutures have been advocated for this purpose (2,7,9-11,17,25). Although scleral retroequatorial myopexy sutures reduce the distance-near incomitance when used by themselves, they do not necessarily provide additional effect when combined with MR muscle recessions(2,7,26). The MR muscle pulley fixation was a useful additional surgical step for addressing marked convergence excess associated with accommodative and partially accommodative esotropia (24).

We determined that the use of both techniques (MR Y-split recession and the MR retroequatorial myopexy) decreased the near and distance deviation and near-distance disparity in patients who had partially accommodative esotropia with convergence excess and that these outcomes were stable during the entire follow-up period. In our study, satisfactory binocular alignment (orthotropia or esotropia of less than 10 pd at near and distance fixations) was achieved in 77% of patients who underwent MR Y-split recession and 78% of patients who underwent an MR retroequatorial myopexy by the final examination. The success rate of patients treated with MR Y-split recession for partially accommodative esotropia has not been previously reported. Residual esotropia (range 10 to15 pd) occurred in 23% of the patients who underwent MR Y-split recession and 22% of patients who underwent the MR retroequatorial myopexy, but no patients demonstrated overcorrection. We did not
perform any secondary surgery for these cases.

In our study, the 0% overcorrection rate for each of the two surgeries (MR Y-split recession and the MR retroequatorial myopexy), compares favorably with the persisting ≥5 pd overcorrection rate (11%-20%) seen in near angle surgery and prism-adapted near angle surgery (7%-10%) (6,21,22). None of the patients in our series had scleral perforation after retroequatorial myopexy surgery. Alio and Faci published a prospective study of 187 eyes undergoing medial rectus retroequatorial myopexy surgery (26). They found a 15.5% incidence of chorioretinal scarring related to the retroequatorial myopexy sutures (26). De Decker reported an incidence of perforation of three in 1000 retroequatorial myopexy operations (9). Lyons and colleagues (27) suggested that the retroequatorial myopexy operation is a safe procedure in their hands since the 7% prevalence of chorioretinal scarring compares favorably with previously published figures of 8-12% for standard recessions (28,29). The retroequatorial myopexy procedure is technically difficult for the muscles are sutured posteriorly. However, experienced surgeons can minimize the risk of complications by using a careful surgical technique. MR Y-split recession had some disadvantages such as the relative number of surgical steps, the need for ultrasound and complex formulas to compute the actual split muscle placement, and the amount of intraoperative additional time compared to a standard recession.

We determined that both MR Y-split recession and the MR retroequatorial myopexy achieved satisfactory results for the treatment of partially accommodative esotropia with convergence excess though both techniques had some disadvantages. Despite achieving similar outcomes with both techniques, we prefer the retroequatorial myopexy procedure for the treatment of partially accommodative esotropia with convergence excess. For the MR Y-split recession operation, studies including more data and a longer follow-up period are necessary to clarify postoperative outcomes, and complications.

REFERENCES


Functional Amblyopia and Deficient Binocular Vision as Initial Clinical Features in Duane’s Syndrome

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from Department of Ophthalmology, Hacettepe University Faculty of Medicine, Ankara, Turkey

ABSTRACT: Background and Purpose: To investigate and report the clinical characteristics at initial presentation in patients who had Duane’s Syndrome (DS), especially binocular vision and functional amblyopia.

Methods: The medical files of patients with DS were reviewed. The main outcome measures of the study were the initial clinical characteristics including amblyopia and associated risk factors including deficiencies of binocular vision.

Results: The review identified 99 patients with DS. The median age of patients was 6 years (4-21). The frequency of amblyopia at initial presentation was 23%. Forty-five (45/62, 72.6%) patients had measurable stereopsis and 58 patients (58/67, 86.8%) had binocular vision fusion.

Conclusions: Amblyopia and altered binocular function are important among the clinical features of Duane’s Syndrome which should be highlighted at initial examination.

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The study was conducted in Hacettepe University Faculty of Medicine, Department of Ophthalmology, Ankara, Turkey.

The authors have no financial interest

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INTRODUCTION

Duane’s Syndrome (DS) is a congenital disorder of ocular motility which is frequently characterized by limitation of abduction, globe retraction in attempted adduction, often esotropia in primary position and abnormal head position which is acquired to provide binocular field which are all well defined in the literature (1,2). Ocular misalignment, presence of abnormal head position and anisometropia are described as causative factors for amblyopia in DS patients (2-5).

The main objective of the present study was to describe the initial clinical characteristics of patients with DS particularly with respect to the presence of amblyopia and its related risk factors.

MATERIALS AND METHODS

The retrospective study was conducted in Pediatric Ophthalmology and Strabismus Section. The study was carried out in full accord with the principles laid out in the Declaration of Helsinki and the approval of the institutional ethics committee was obtained. Patients who were diagnosed as having DS at initial examination were included in the study. The exclusion criteria included the presence of previous strabismus surgery. The surgery and its outcomes were kept beyond the purposes of the study and were not incorporated in the statistical analysis.

The medical files of the patients with DS were retrospectively reviewed and gender, the type of DS, best corrected visual acuity, presence of amblyopia, type of deviation, refractive errors, the amount of horizontal near, distance and vertical deviations, presence of abnormal head position and binocular status were all recorded.

Visual acuity was evaluated by using LEA chart or Snellen chart if possible. Ocular misalignment was measured by prism cover test or Krimsky test, in prism dipters.(pd). The presence of abnormal head position was noted. Presence and level of near stereopsis was evaluated by Titmus testing and distance fusion was assessed by Worth -4- Dot testing.

Statistical analyses were performed using SPSS software for Windows version 15.0 (Statistical Package for the Social Sciences, SPSS, Inc., Chicago, IL). Comparison between groups was performed by using chi-square test with Yates’ correction and likelihood ratio test for categorical variables. Median and range were given as descriptive statistics for quantitative data. Categorical data was summarized using frequency and percentages. Results were accepted as statistically significant when p was <0.05.

RESULTS

The medical record review identified 99 DS patients (51 males and 48 females) with a median age of 6 years (4-21). Initial clinical characteristics of the patients were summarized in Table 1, see next page. None of the patients had associated structural ocular abnormalities.

The frequency of amblyopia was 23% (17 patients) at initial presentation. The median best corrected visual acuity was 6/6 (6/60-6/6). The median best corrected visual acuity of the amblyopic eye was 6/19 (6/600-6/9.5) Left eye was more commonly affected from DS when compared to right eye (66.7% vs 26.3%). Of the 99 patients, 38 (53.5%) had hyperopia, 11 (15.5%) had myopia and 26 (36.6%) had astigmatism. Five patients (7.1%) had anisometropia.
### Table 1. RESULTS: Clinical Characteristics and associated findings in 99 patients with the three different types of Duane’s Syndrome.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Duane Syndrome</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unilateral</td>
<td>Type 1</td>
<td>Type 2</td>
<td>Type 3</td>
<td>Bilateral</td>
</tr>
<tr>
<td>No. of patients (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>35 (46.1)</td>
<td>2 (66.7)</td>
<td>9 (69.2)</td>
<td>5 (71.4)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>41 (53.9)</td>
<td>1 (33.3)</td>
<td>4 (30.8)</td>
<td>2 (28.6)</td>
<td></td>
</tr>
<tr>
<td>Deviations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET*</td>
<td>31 (40.8)</td>
<td>0 (0)</td>
<td>1 (7.7)</td>
<td>2 (28.6)</td>
<td></td>
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<tr>
<td>XT</td>
<td>6 (7.9)</td>
<td>3 (100)</td>
<td>10 (76.9)</td>
<td>1 (14.3)</td>
<td></td>
</tr>
<tr>
<td>No deviation</td>
<td>39 (51.3)</td>
<td>0 (0)</td>
<td>2 (15.4)</td>
<td>4 (57.1)</td>
<td></td>
</tr>
<tr>
<td>Amblyopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>15 (19.7)</td>
<td>0 (0)</td>
<td>2 (15.4)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>51 (80.3)</td>
<td>3 (100)</td>
<td>11 (84.6)</td>
<td>7 (100)</td>
<td></td>
</tr>
<tr>
<td>Anisometropia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>3 (3.9)</td>
<td>0 (0)</td>
<td>1 (7.7)</td>
<td>1 (14.3)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>73 (96.1)</td>
<td>3 (100)</td>
<td>12 (92.3)</td>
<td>6 (85.7)</td>
<td></td>
</tr>
<tr>
<td>Uphoot or downshoot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>7 (9.2)</td>
<td>0 (0)</td>
<td>3 (23.1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>69 (90.8)</td>
<td>3 (100)</td>
<td>10 (76.9)</td>
<td>7 (100)</td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head Position</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>44 (57.9)</td>
<td>3 (100)</td>
<td>6 (46.2)</td>
<td>3 (42.9)</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>32 (42.1)</td>
<td>0 (0)</td>
<td>7 (53.8)</td>
<td>4 (57.1)</td>
<td></td>
</tr>
</tbody>
</table>

*ET: Esotropia  
XT: Exotropia had anisometropia.

The median horizontal near deviation was 8pd (0-50), the median horizontal distance deviation was 8pd (0-50) and the median vertical deviation was 0pd (0-20).

At initial presentation among patients whose binocularity could be assessed; 45/62 (72.6%) had measurable stereopsis and 58/67 (86.8%) had fusion.

There was neither associated systemic abnormalities nor family history in any of the patients. There was no significant relation between presence of amblyopia and anisometropia (p=0.439) or ocular alignment in primary position (p=0.517).

**DISCUSSION**

Duane’s Syndrome is a congenital eye movement disorder, recently classified as a subgroup of congenital cranial dysinnervation
disorder which accounts for approximately 5% of all patients with strabismus (3). A variety of clinical features and surgeries have been reported for treatment of DS as large case series or case reports (6-8).

Amblyopia is a potential contributor for all types of strabismus. In the present study we aimed to investigate the initial clinical characteristics of patients with DS, especially the presence of amblyopia mainly at initial presentation.

Mohan et al., reviewed the clinical records of 331 patients with DS and determined the frequency of amblyopia as between 12-50% in unilateral forms and 50% in bilateral forms (5). The mean age of patients of their group was higher compared to those of the present study. They compared the clinical features of unilateral and bilateral DS and found in their large series that orthophoria was present in 40% of unilateral type 1, 27% of unilateral type 3 and in 22% of bilateral DS which was 51.3%, 15.4% and 57.1% respectively in the present study. Furthermore the frequency of amblyopia was 14%, 14% and 13% in their study vs 19.7%, 15.4% and 0% respectively in the present study. The frequency of amblyopia in the present study does not fall within the range defined in the literature. The difference of patient demographics and the difference of frequency of manifest deviations may highlight the mentioned inconsistency.

Zanin et al., compared the clinical characteristics of unilateral and bilateral forms of DS and reported that the mean best corrected visual acuity was significantly lower in bilateral compared to unilateral form and the main causes of anisocoria were the presence of strabismus and anisometropia (2). They also found that there was no significant
difference of incidence of ametropia between the unilateral and bilateral forms of DS.

Khan and Oystreck reviewed the medical records of 270 patients within whom 37 (14%) had bilateral DS and found that 78% of these patients had strabismus and 16% had amblyopia (4). In the present study bilaterality for DS was present in 7 (7.1%) of subjects. This number was different compared to some others which were previously reported in the literature (3-5,8).

The clinical features of patients who had unilateral and bilateral forms of DS were not compared because of unequal number of patients within two groups.

In the present study, the predominance of the left eye was found in a manner consistent with the literature (9,10). However, there was a predominance of men in the present study contrary to the previous studies.

Tomac et al evaluated the data on the relation of sensory features to clinical findings of patients with DS (11). They reported that 24% of patients had no measurable stereoacuity, 83% had near and 79% had distance fusion. In the present study, 72.6% of patients had stereopsis whereas 86.8% had fusion. The numbers may differ because of the diversity of clinical and demographic characteristics of the selected study populations. However, this finding may contribute to the fact that patients with DS may have altered high level binocular function.

Reduced cortical binocular interaction may also be a potential cause of reduced stereoacuity (12,13). These findings are also likely to be of relevance to the development of amblyopia. as well.
This study needs to be viewed in light of the following limitations; retrospective setting and single referral center dependent results. The clinical characteristics of the present study may not elucidate the general features of DS and may remain open to debate. The restriction of ocular movements were not included into the statistical analysis because the surgeries and the results of forced duction tests were kept beyond the study purposes.

However, our main purpose was to describe the initial clinical features of DS. In conclusion, amblyopia may be a concurrent ophthalmological finding in patients with DS which should be established from the initial visit in regard of its undeniable effect on clinical prognosis. Furthermore, there is a clear evidence of altered binocular function which was also previously reported in the literature in details. Even though the presence of amblyopia may be one of the inevitable and expected clinical component of DS and no significant relation was demonstrated between amblyopia and anisometropia or ocular misalignment in the present study, it should be kept in mind that amblyopia is frequent in DS.

REFERENCES

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Declaration of interest: None to declare.
Management of Strabismus Vertical Deviations, A- and V-Patterns and Cyclotropia Occurring after Horizontal Rectus Muscle Surgery with or without Oblique Muscle Surgery

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ABSTRACT: **Purpose:** To show conditions where a vertical deviation, an A- or a V-pattern or cyclotropia can appear after surgery on the horizontal rectus muscles, with or without oblique muscle surgery. Our purpose is also to show conditions when a vertical deviation can be anticipated before horizontal rectus muscle surgery and realignment of the ocular deviation. Finally, our purpose is to stress some surgical precautions one should take to avoid such complications.

**Case Reports:** We report two cases who showed significant vertical deviations due to complications that followed surgical weakening procedures of the inferior oblique muscles.

**Conclusions:**
1. Postoperative vertical deviations, A/V-patterns and cyclotropia can occur, can be anticipated and can be avoided in pure horizontal rectus muscle surgeries.

2. Vertical deviations are common following complicated oblique muscles surgery if the surgeon blindly sweeps the muscle hook into the area. They can be avoided if the weakening technique allows direct visualization of the inferior oblique muscle.

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The occurrence of a vertical deviation, an A or a V-pattern or a cyclotropia following even uncomplicated surgical correction of a comitant horizontal strabismus is a serious complication that often requires a second surgical procedure.

Several reasons have been given for these complications:

I: Vertical deviation developing in the primary position of gaze following horizontal alignment of a large angle exotropia (XT) with or without oblique muscles surgery.

In most exodeviations and especially in large angle ones, all oblique muscles often appear overacting for three reasons:

1) Overaction/contracture of the superior oblique (SO) and inferior oblique (IO) muscles: when an eye assumes an abducted posture, both the SO and IO muscles become slack. Eventually, these muscles “take up the slack”, become contracted, and overaction of the obliques is observed (1).

2) Contracture of the lateral rectus (LR) muscle: In large angle XT, contracture of the LR muscle occurs. If the eye attempts to adduct, upshoot and downshoot of the eye may be observed due to a leash effect, the globe flipping ventrally or dorsally showing an apparent pseudo-overaction of both IO and SO muscles. This is the so-called “Tight LR Syndrome” (1) described by Jampolsky with the following characteristics: a) Deficient adduction. b) Overshoot of both oblique muscles as bouncing off a wall delineated by the adduction restriction line. The overshoot of the obliques in either direction is a “knife-edge” effect, composed of two components: oblique muscle overaction and LR muscle sliding over the globe in a bridle effect.

3) Capo et al (2) proposed an additional explanation for the apparent overaction of the oblique muscles based purely on the mechanical limits of ocular rotations. In a study of ocular movements around the extreme perimeter of gaze for 360 degrees, recorded with a video camera in normal subjects and in 3 patients with XT and in evaluating ocular torsion by fundus examination, they found no abnormal ocular torsion and documented that the limits of ocular rotation are circular and elliptical rather than square or rectangular. So, when testing for oblique overaction or underaction in patients with XT, the abducting eye “runs into the wall” and experiences difficulty moving up or down, while the adducting eye is still free to move vertically (see Figures 1 and 2, next page).

This gives the appearance of both IO and SO overaction. This pseudo-overaction of the oblique muscles should be more evident in patients with large angle XT, but it can also be appreciated in cases of moderate XT. This proposed mechanism for pseudo-overaction of the oblique muscles in XT suggests that we should expect pseudo-underaction of the oblique muscles in esotropia (ET) (see Figure 3, next page). These circular or elliptical limits of ocular rotations represent a mechanical explanation for the pseudo-overaction of the obliques commonly present in XT and pseudo-underaction of the obliques occasionally seen in ET.

In these exodeviation cases, the vertical deviation may exist only in side gazes and be absent in the primary position (3). When the oblique muscles go into actual contracture, the SO shows usually the predominant contracture, along with ipsilateral inferior rectus (IR) muscle underaction, presumably due to the contracted contralateral SO muscle and a type of “inhibitional palsy” of the IR muscle. Occasionally there may be underaction of the superior rectus (SR) muscle due to more contracted contralateral IO muscle and a type of “inhibitional palsy” of the SR. In the former (IR underaction), we observe hypertropia (HT) in abduction due to IR underaction and often to contracture of the antagonist superior rectus (SR) and hypotropia (HoT) in adduction due to a marked SO overaction (see Figure 4, next page). In the latter, (SR underaction), we observe HoT in
Figures 1, 2, 3 (Khawam et al): From Capo et al (2): Each Figure is two normal pairs of eyes in different gaze positions, A, left pair; B, right pair... as viewed by you the observer, right eye to the left, left eye to the right of each pair of eyes.

Figure 1 (Khawam et al) [From Capo et al (2)]: Orthophoria: A, left hand pair: In primary position. Eyes move equally well vertically. B, right hand pair: Side gaze to left. Eyes "run equally and simultaneously into the adjacent orbital wall in right and left gazes."

Figure 2 (Khawam et al): Exotropia. A) Looking up in left gaze. Adducting RE continues to move vertically freely in upgaze. Abduction LE "runs into" the orbital wall (mechanical limitation with pseudo OA of the RIO). B) Looking down in left gaze. Adducting RE continues to move vertically freely in downgaze. Abduction LE "runs into" the orbital wall (mechanical limitation with pseudo OA or the RIO)

Figure 3 (Khawam et al): Esotropia. A) Looking upward in left gaze. Adducting RE "runs into" the orbital wall (mechanical limitation with pseudo UA or the RIO). Abducting LE continues to move vertically freely in upgaze. B) Looking downward in left gaze. Adducting RE "runs into" the orbital wall (mechanical limitation with pseudo UA of the RSO.) Abducting LE continues to move freely in downgaze.

Left exotropia with underaction of the left inferior rectus. Hypertropia in Abduction due to IR underaction. Hypotropia in adduction due to predominant superior oblique. No vertical deviation in primary position.
abduction due to SR underaction with contracture of the antagonist IR and either HT or HOT in adduction due respectively to a predominantly overacting IO or predominantly overacting SO muscle. In either instance, there may be no vertical deviation in the primary position associated with the exodeviation (see Figures 5, 6, 7, right) although the cover test may erroneously show HT or HoT if the fixing eye is fixating and the exotropic eye is in an abducted position.

For large angle XT that requires something more than conventional recession/resection procedures, several surgical techniques are employed to augment the effect of horizontal recession/resection procedures. The most common are recessions of the conjunctiva and tenon’s capsule overlying the recessed muscle, muscle recession and resection amounts beyond conventional “safe” limits, traction sutures tied over the lids, recession combined with marginal myotomy… all involve the risk of postoperative underaction of rotation.

Raab (4) advocated for deviations of XT exceeding 50 prism dipters and severe amblyopia or in a large angle XT following retinal detachment surgery with a compromised sclera or for the necessity of leaving the implant and encircling element undisturbed, a unilateral four-muscle surgery as a useful alternative procedure to operations based on more than the usual maximum amounts of recession and resection that could lead to deficient and restricted rotations. He treated these patients with conventional maximum amounts of horizontal rectus recession/resection combined with temporal conjunctival recession and weakening of both obliques on the amblyopic eye. He attributed the enhanced effect to the release of additional sites of contracture that occur in the oblique muscles acting as enhanced auxiliary abductors. The principal disadvantage he encountered has been a postoperative HT of the operated eye that could be due to the preponderant effect of SO weakening on vertical muscle imbalance. He stated this cosmetic disadvantage can be largely offset by routine infraplacement of both horizontal rectus muscles during the recession/resection procedure.
Jampolsky (3) called attention to the HT occurring following Raab procedure (4) as resulting either from surgical weakening of both agonist-antagonist obliques per se, or from the surgical horizontal realignment itself.

A): Following surgical weakening of both agonist-antagonist obliques, a vertical imbalance-usually a HT- is noticed because of gross inequality existing between the SO and the IO muscles imbalance of the vertical forces in unilateral XT, with a more marked SO overaction. On the other hand, and more rarely, if the IO overaction predominates, surgical weakening of both IO/SO muscles, will result in a net effect of induced HoT. In the circumstance of approximate equality of both obliques overaction, weakening of the obliques per se does not result in any vertical deviation.

B): On the other hand, a vertical imbalance may occur in the primary position gaze following simple horizontal realignment (without oblique muscle surgery). One may therefore anticipate the vertical deviation following horizontal realignment alone for the unilateral XT, by careful preoperative examination of the eye rotations, whereas the vertical deviation found by cover test is not necessarily the one that may be found following surgical horizontal realignment because the nonfixing exotropic eye can be elevated (being under the influence of an underacting IR muscle) or less commonly depressed (being under the influence of an underacting SR muscle).

Commonly when the usually fixing eye fixates from adduction to abduction, the nonfixing exotropic eye usually will be noted to be elevated in its abducted position because it is in the field of the underacting IR muscle. When it is in the adducted position, it may be either hypotropic because of the preponderant SO overaction, or hypertropic because of the preponderant IO overaction, or may show no vertical deviation because of equality of agonist-antagonist oblique overaction.

1- In the usual circumstance, there may be gross inequality between the SO and IO muscles imbalance of the vertical forces in unilateral XT, with SO preponderance. Rotations depict HoT as the exotropic eye passes through the primary position, although cover test may show no vertical or even HT (see Figure 8, below). Here, a postoperative HoT may be anticipated consequent to horizontal surgical realignment.

2- On the other hand and more rarely, the IO overaction may predominate, producing a HT as the eye is observed in the straight ahead position, although cover test may not depict any vertical. In this condition, a HT is depicted as the exotropic eye is realigned to the straight ahead position. (Figure 9, below)
3- There are exceptions wherein the net vertical forces in the exotropic eye are balanced because of approximate equality of both agonist-antagonist obliques overaction. Careful observation of rotations shows no vertical deviation in the primary position although cover test- with the fixing eye fixating- may show HT or HoT in the primary position. Here we may predict no vertical deviation will appear following horizontal realignment.

If one does a cover test for the basic deviation (sound eye always fixing), one will measure the XT and a HT because the affected eye was in an outward and upward position, or more rarely, will measure the XT and a HoT because the affected eye was in outward and downward position. Therefore, a better diagnostic-prognostic method is to have the fixing eye in such a position that the amblyopic eye is in the straight ahead position though not fixing. The vertical that it now exhibits in this new rotational straight-ahead position is the vertical that may be expected to be encountered when the horizontal deviation is surgically eliminated.

In case HT or HoT is anticipated - either by the obliques surgery or by the horizontal realignment - one should compensate for the expected induced vertical deviation by surgically transposing both the horizontal muscles respectively in a downward or upward direction during the recession/resection procedure for correction of the exotropia.

II: Vertical deviations are not uncommonly seen after surgery upon the lateral LR muscle. That is mainly due to the intimate connection between the LR muscle and the IO muscle. We propose four mechanisms:

1. Damage to the IO muscle. During freeing of the LR intermuscular septal membrane and check ligaments and during the freeing of the filaments and adhesions of the LR/IO muscles, one can cut into the IO, ending up in bleeding and subsequent scarring that creates vertical deviation (HT or HoT).

2. During recession of the LR muscle, if we do not free thoroughly the adhesions between the LR and IO muscles, the IO is dragged posteriorly, put on a stretch and it becomes overacting resulting in an incomitant hypertropia.

3. While resecting the LR muscle, if we do not thoroughly free its adhesions with the IO muscle, the IO is pulled anteriorly and an IO which had been behind the equator of the eye and an elevator, is now anterior to the equator of the eye and a depressor, resulting in an incomitant HoT.

4. During hooking of the LR muscle, the muscle hook, especially if deeply introduced and passed from the inferior quadrant with no direct visualization of the IO, frequently encounters the anterior fibers of the IO muscle that are pulled forward towards the insertion of the LR muscle. In our experience, that is a common complication not infrequently encountered following LR surgical procedures.

   The normal IO functions of excyclotorsion, elevation and abduction exist when the oblique fibers are positioned 17 mm behind the limbus. Once the IO fibers are displaced, such as in inclusion of the IO at the surgical attachment of the LR muscle, the function of the IO naturally becomes altered: HT or HOT are reported. Cyclotropia (incyclo- or excyclotropia) can also ensue.

III: Unintended upward/downward displacement of either horizontal rectus muscle.

Unintended upward displacement of either horizontal rectus muscle elevates the anterior aspect of the eye and downward displacement lowers it, resulting respectively in HT or HoT. Metz (5) found 0.5 mm of vertical transposition produces one prism diopter of vertical deviation. He and other authors (6-8) found for larger amount of coexisting vertical deviation, the effect of transposition was about 1 pd of vertical
correction per mm of offset surgery. Considering that normal vertical fusional amplitudes are only 2 to 3 diopters, very small vertical errors can seriously interfere with fusion after surgery. If, during a recession procedure on a horizontal muscle, an unintended vertical displacement of the new insertion takes place, the surgeon will surprisingly find a new post-operative vertical deviation, often associated with an A or V pattern.

IV: Marginal myotomy or “z-lengthening” procedure.

Among the techniques used to lengthen a muscle, the marginal myotomy of Blascovics and Kreiker (9) is the most effective. Unlike recession (10) which reduces the action of a muscle by decreasing its rotational force on the globe, a marginal myotomy weakens a muscle by reducing the number of contractile elements without changing its arc of contact with the globe. We use this procedure on already recessed muscles for mild or moderate residual deviations. Von Blascovics and Kreiker (9) estimated the amount of reduction of the deviation by this procedure to be 5 to 8 degrees. In our experience, the correction is equivalent to 3 to 4 mm recession. The disadvantage of this procedure is its irreversibility and re-operations following marginal myotomies should be avoided. The advantage is a fast, easy procedure unnecessitating disinsertion of the operated muscle.

It was found clinically and as a consequence of experiments on a model (11), that a) when the incision proximal to the insertion is done in the upper 2/3 of the muscle, the eye deviated downward and b) when the proximal incision is made in the lower 2/3, the eye deviated upward. So, depending on how the marginal myotomies are made proximal to the muscle insertion, it is possible to see an improvement or worsening of a vertical deviation or to induce a new one. If myotomies in both eyes are accomplished in a symmetric manner (cutting in each of the muscles similarly the upper or the lower 2/3), no vertical deviations ensue.

If the myotomies at the muscles of either eye are done in an asymmetric way (upper 2/3 in one eye and lower 2/3 in the fellow eye), a vertical deviation is induced, worsened or alleviated if previously present.

So, despite the fact that the insertion of the myotomized rectus muscle remained undisturbed, a secondary vertical deviation, attributed to the marginal myotomy, can appear if the marginal myotomies are placed in an asymmetric way.

V: Surgical tilting or obliquity of the new insertion.

During horizontal rectus muscle recession, failure to recess the muscle exactly perpendicular to the original insertion or to the limbus for muscles with an insertion line not parallel to limbus, can produce several types of complications (12):

A. The obliquity or tilting of the new insertion ends-up with a significant error of recession, namely loss of recession effect as well as upward or downward transposition of the insertion resulting respectively in HT or HoT (Figure 10).

Figure 10 (Khawam et al)[from Romano (12)]: a) Loss of recession effect. b) Vertical transposition effect.

B. This unintentional vertical transposition can also produce an A or V pattern since, according to Knapp’s rule (13), vertical transposition of the insertion of the horizontal rectus muscles alters their scleral attachments relative to the rotation center of the globe, thus increasing the arc of
contact of the transposed muscle in one vertical gaze and decreasing it in the opposite vertical gaze position. Since the pull power of the muscle is related to the stretch put on it by the arc of contact, the horizontal pull power is enhanced and diminished in the opposite vertical gaze positions. Hence, the horizontal rectus muscles become more effective abductors or adductors in the vertical gaze position opposite to the direction in which their insertions are moved. Stated differently, the transpositioned horizontal rectus muscles become less effective horizontal rotators in the same vertical gaze position at the direction in which they are moved.

C. Incyclotropia/Excyclotropia:

When recession of the horizontal rectus muscles is strictly perpendicular to its original insertion or to the limbus, the muscle remains on the “crest” or the “great arc” of the globe (14) and its axis of rotation still coincides with the “z” axis of the globe, therefore its action remains pure horizontal (abduction for the LR and adduction for the medial rectus (MR)). In case of severe restrictions, retraction of the globe occurs due to a “leash effect” provided its antagonist muscle is not palsied (Figure 11, below).

Figure 11 (Khawam et al)[from Jampolsky (14)]:Recession strictly perpendicular to insertion. The muscle remains on the "Crest" of the globe. Axis of rotation is still coincident with the Z axis.

However, when the recession is tilted or obliquely done relative to the muscle insertion or to the limbus, the muscle falls off the “crest” of the globe (14), and on attempted rotation, it intorts or extorts the globe because the “muscle plane” of the recessed muscle does not coincide any more with the x and y axes and its “axis of rotation” does no more coincide with the “z” axis, therefore the recessed horizontal muscle acquires an additional vertical and torsional action (Figure 12, below).

Figure 12 (Khawam et al)[from Jampolsky (14)]:Recession off the "Crest". A)(LEFT) Above the "Crest" = Intorsion and Upshoot. B(RIGHT)) Below the "Crest" = Extorsion and Downshoot.

In order to avoid surgical tilting or obliquity of the new insertion, Romano (12) designed an instrument to facilitate accurate and precise recession of eye muscles at right angles from the original insertion, thereby avoiding such technical errors. The instrument consists of two conventional Castroviego calipers which have been joined at a right angle. The conjoined fixed point of each is fashioned as to have a single common fixed point. The instrument permits to measure accurately at right angles of extra ocular muscle recessions as well as it facilitates accurate supra- and infraplacement of muscles. Consequently, lack of accuracy and precision in eye muscle surgery such as unintended vertical transposition of horizontal muscles can produce hypo or hypertropia, A or V pattern anisotropia or cyclotropia. The combination of vertical deviation and cyclotropia can create a severe obstacle to fusion and/or induce an abnormal head posture.

VI: Superior rectus overaction/contracture syndrome (SR Sy).

SR Sy was first described by Jampolsky in...
In long-standing cases of unilateral superior oblique palsy (SOP) where he noted that SR Sy could occur as a secondary effect. Later on, (16) he noted that this syndrome can occur in many other strabismus entities completely unrelated to SOP. He also stated it can be primary or even idiopathic simulating inferior oblique palsy (IOP), IR fibrosis or double elevator palsy (DEP) of the fellow eye. He also stated that the SR Sy can also follow even uncomplicated horizontal muscle surgery, with or without oblique surgery. The most important characteristics of an isolated SR surgery as described by Jampolsky (17) are:

1. Bielschowsky head tilt test showed a marked increase in hyperdeviation to the ipsilateral shoulder.
2. Hyperdeviation in all upgaze and downgaze fields.
3. Ipsilateral gaze maximum hyperdeviation.
4. Rotation deficiency down and out.
5. Mechanical restriction of the SR muscle.
6. Yoke SO overaction due to fixation duress in downgaze of the abducted affected eye.
7. Distance deviation approximates near deviation.
8. Overaction characteristics in upgaze: they consist in more deviation in upgaze, minimal to no deviation in downgaze, a negative or equivocal forced duction test (FDT) in passively moving the eye in down and out gaze and normal rotational movement of the eye in downgaze.
9. Restriction characteristics in downgaze where the deviation is most marked in the field of gaze opposite the field of action of the SR muscle, minimal to no deviation in the field of action of the involved SR muscle, severe restrictions with passively moving the eye in down and out gaze and deficient downward movement of the eye by version and by duction.

In the absence of dissociated vertical deviation (DVD) or SOP, a HT occurring after horizontal muscle surgery in the primary position and in all upgazes and downgazes with an increasing Bielschowsky head tilt difference to the ipsilateral shoulder is most likely due to an SR Sy whether it shows one or more of the other Jampolsky-described characteristics. We reported 25 such cases, many of which followed uncomplicated horizontal muscle surgery (18). In three cases, the SR Sy simulated DEP where the weakness of the IO and SR muscles of the fellow eye are due to an inhibitional palsy of these muscles due to an overacting/contracted contralateral SR muscle.

The appearance of a vertical deviation due to the SR Sy following horizontal rectus muscle surgery (with or without obliques surgery), is not rare and cannot be anticipated nor avoided.

VII: Horizontal muscle surgery for ET and XT along with weakening surgery on overacting oblique muscles for a V or an A pattern, unassociated with vertical deviation in the primary position.

In symmetrical primary overaction of the IO muscles with a V pattern or symmetrical primary overaction of the SO muscles with an A pattern, the esodeviation or exodeviation is most often unassociated with vertical deviation.

If during weakening procedures on the oblique muscles one of them is missed, inaccurately weakened or split by the muscle hook leaving behind a belly, the unilateral asymmetrical residual overaction of one oblique may result in an acquired significant vertical deviation in the primary position (HT or HoT).

CASE REPORTS

1) This case report illustrates such a complication:

B.S, a 4 y/o little boy was seen by one of us (EK) in 2011. The eye examination showed an exodeviation of 10 pd with a large V-pattern due
to a marked bilateral overaction of the IO muscles (both eyes shooting up in horizontal side gaze before reaching the inner canthus). He was lost to follow up and was seen 9 months later after he sustained strabismus surgery consisting of bilateral myectomy of the IO muscles. Patient showed 20 pd of left HT increasing in right gaze. Version showed a normal right IO muscle but a still markedly overacting left IO muscle. He also showed a head tilt to the right with a significant V-pattern with marked XT in only up gaze. A surgical exploration of the left IO muscle showed a large whitish inelastic IO belly that we generously denervated/myectomized. Postoperatively, the vertical deviation disappeared along with the habit head tilt and the V-pattern.

On the other hand, if a significant restriction to elevation occurs unilaterally or bilaterally but asymmetrically subsequent to bilateral myectomy of the IO muscles, a HoT can develop.

2). The following case report illustrated such a complication:

F.M, 21-year-old, had by one of us (EK) at the age of 7 years bilateral MR recession and bilateral denervation myectomy of the IO muscles for an infantile ET and a V-pattern to the deviation due to marked bilateral IO overaction. The results were most satisfactory for several years. The patient was then lost to follow up. About one year ago, I saw this patient who, to my dissatisfaction, showed 20 pd of right HoT increasing in levoversion: on rotations, byduction and version, patient showed severe deficiency of elevation of the right eye, with an inability to elevate that eye above the midline. Rotational movements of the left eye were normal.

The vertical deviation in that case is due to an adherence syndrome, a term first used by Johnson (19), to describe a congenital denser union between the insertion of the IO and LR muscles and between the SO tendon and the SR muscle causing pseudoparalysis of the LR or SR muscle.

Parks (20) used also the term of adherence syndrome to describe the pathologic findings that constitute a syndrome infrequently encountered late in the postoperative follow up of some weakening procedure of primary overacting IO muscles. Preoperatively, these patients had bilateral overaction of the IO muscles with no vertical strabismus in the primary position. As the postoperative months progressed, these patients were developing a vertical strabismus that continued to increase in a gradual and relentless manner. The hypotropic eye manifests restricted elevation more marked in abduction than in adduction. The hypotropic eye manifesting the restricted elevation was invariably the eye in which the disinsertion or myectomy was performed (21). None happened following an IO recession procedure. Surgical re-exploration of the hypotropic eye (20) revealed the weakened IO muscle was not attached to the sclera. Instead, the proximal end of the IO muscle was attached into the fatty tenon's and there was considerable proliferation of the fibrofatty tissue in the inferior temporal area extending up and attaching to the insertion and the capsule of the IR muscle. Traction test revealed resistance to passive elevation. Surgical management of the HoT was disappointing since despite severance of the fibrofatty tissue from its scleral and IR muscle capsule attachment, despite excision of the fibrofatty tissue and reattachment of the free end of the IO muscle to the sclera, the HoT in the primary position and the restricted elevation of the involved eye persisted. He believed secondary muscle surgery on the involved eye's IR, SR and even on the normal eye's vertical rectus muscles are required to overcome the HoT in the primary position. In this case report, the large angle HoT with markedly deficient elevation of the right eye was due to an adherence syndrome following denervation/myectomy of the IO muscle, although adherence syndrome, in our hands, is very rare following IO muscle surgery. In performing myectomies of the IO muscle in the inferior
temporal quadrant between the IR and LR muscles and under direct visualization of the IO muscle - as our preferred weakening procedure on that muscle for the past 40 years - we have encountered this complication in only three instances.

The above two case reports illustrate the 2 most frequent complications a surgeon can witness in IO muscle weakening procedures:

1) Inadvertently dividing only a portion of the IO, leaving a part of it unoperated and capable of continuing the same preoperative overaction.

2) Producing an adherence syndrome with HoT and significant restriction of elevation. These complications can be avoided if the surgeon restrains from blindly sweeping the muscle hook in the inferior temporal area of the eye and if a technique is used that allows direct visualization of the IO muscle. Moreover, we carefully engage the IR and the LR muscles with two separate muscle hooks in order to avoid a third complication known to occur in IO weakening procedures: cutting the LR or the IR muscle.

VIII:: Finally we should mention that:

1. Large degrees of vertical deviation occur postoperatively if surgery has been performed erroneously on a vertical rather on a horizontal muscle.

2. During prism cover test, the physician must rule out artifacts induced by oblique positioning of the prism (22). The amount of this artificial hyperdeviation is related to the power of the used prism.

REFERENCES


