Vertical Fusional Vergence

The Key to Dissociated Vertical Deviation

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Objectives: To test the previous findings of Enright that disparity-induced vertical vergence is mediated primarily by the oblique muscles, and to relate this normal eye movement pattern to the eye movement pattern seen in subjects with dissociated vertical deviation.

Methods: Sixteen normal volunteers underwent 55 measurements of the cycloversion associated with prism-induced vertical vergence using an afterimage apparatus. A Vernier scale measured the direction and magnitude of the torsional shift that occurred with recovery of fusion on removal of a 3- or 4-prism diopter prism.

Results: Of the 55 trials, the directions of torsional shift were consistent with the oblique muscles being the primary mediators of vertical fusional vergence in 51 (93%) (P = .03 using a binomial distribution). The mean ± SD value of torsional shift was 1.15° ± 0.76° in the expected direction.

Conclusions: Vertical fusional vergences in this study were produced primarily by the oblique extraocular muscles. The eye movement patterns of these vertical vergences in normal subjects are qualitatively similar to those seen in recordings of patients with dissociated vertical deviation. Dissociated vertical deviation thus seems to be an exaggeration of a normally occurring eye movement pattern. The cyclovertical component of dissociated vertical deviation may help stabilize the fixing eye by damping vertical nystagmus, while the accompanying hypertropia is an incidental and undesirable side effect.


Dissociated vertical deviation (DVD) is an enigmatic motility disorder that has defied explanation since its original description more than a century ago.1 It may occur spontaneously or as a result of cover testing. It may occasionally be found as an isolated phenomenon, but it generally occurs in association with strabismus, with the most common association being congenital esotropia.2,3

The dissociated eye movement of DVD is normally elevation and extorsion of the covered eye, accompanied by intorsion of the fixing eye. It has been documented, however, that dissociated deviations can be primarily horizontal or torsional.4 The eye movements of DVD have previously been described as a form of vertical vergence.2,4 Enright6 reported the interesting, and unexpected, finding that vertical fusional vergence induced by vertical disparity in normal subjects is associated with binocular torsion. He placed a weak vertical prism in front of 1 eye and noted vertically divergent eye movements that were accompanied by a conjugate cycloversion. The direction of the cycloversion implied predominant action by the oblique muscles and not the vertical rectus muscles. He concluded that the bulk of the reflex vertical fusional vergence was due to the superior oblique muscle. The role of the inferior oblique muscle was considered passive and minor. van Rijn and Collewijn7 attempted to reproduce Enright’s findings using scleral search coil recordings. They confirmed his cycloversion findings in normal subjects accompanying disparity-induced vertical vergences, but refuted his hypothesis that only the superior oblique muscle was the primary mediator of vertical vergence. In their study, part of the cycloversion accompanying the disparity-induced vertical vergence was in the form of torsional nystagmus.

The primary purpose of this study was to confirm Enright’s finding that ver-
SUBJECTS AND METHODS

Sixteen volunteers, 8 men and 8 women, participated after giving informed consent. Their ages ranged from 17 to 53 years. All had a best-corrected visual acuity of at least 20/20 OU. None of the volunteers had manifest strabismus or any evidence of amblyopia.

An apparatus was constructed using an ordinary photographic flash unit that was attached to a standard rotatable optical mount (Figure 1). The mount could be rotated manually for 360°, and the outer edge had an engraved 360° Vernier scale that allowed measurement with a precision of 0.1°. The flash aperture was masked using black tape such that 2 horizontal slits were created parallel to one another. The 2 slits were separated by 4 mm. Below and parallel to the 2 slits, a thin line of phosphorescent paint was applied to the black tape.

A near reading card (Bausch & Lomb, Rochester, NY) was then taped to the front surface of the flash unit, with a slot cut in the card to expose the underlying parallel slits and phosphorescent line. Lettering (size 20/50) was immediately adjacent to the slits.

The entire apparatus was placed on an optical rail at a distance of 40 cm from a headrest–chin rest assembly. Two cam-type rings were mounted on either side of the headrest that, when rotated into place, served to stabilize the head and ensure that there were no significant head movements.

Each subject was instructed to fixate on the 20/50 size lettering while progressively stronger vertical prisms were placed either base up or base down in front of 1 eye, with the order of possibilities randomly selected. Initially, a 2–prism diopter (PD) prism was introduced, and this was slowly increased to 4 PD, if possible. Two subjects were only able to fuse a maximum of 3 PD vertically on one of the trials (Table).

Once either 3 or 4 PD of vertical disparity were fused, the subject was asked to look at a small white dot that was painted centrally between the 2 slits on the flash unit. The flash was then fired, and the prism was rapidly removed from the eye. Gaze was maintained on the white dot until the induced vertical diplopia resolved (normally between 5 and 10 seconds). The room lights were then turned off, and the subject rotated the entire flash unit until the phosphorescent reference line was parallel to the 2 parallel afterimages that had been created (Figure 2). The magnitude and direction of any torsional movement occurring, associated with the vertical fusional vergence to recover single binocular vision, were then read from the scale to the nearest 0.1°. Each subject performed 2 to 4 trials in this manner (Table).

To ensure reliability in determining the position of the afterimage relative to the reference line, each subject initially performed 2 trials without any prism in place. Subjects were instructed to look at the central white dot, and the flash was fired. The assembly was then rotated 30° from the horizontal position, and the lights were turned off. The subject was instructed to rotate the assembly back such that the phosphorescent reference line was again parallel to the afterimages. If a subject could not perform this task within 0.5° of the original horizontal position on each trial, the volunteer was not considered reliable. The 16 volunteers selected fulfilled these criteria; 1 volunteer was rejected.

RESULTS

Each subject participated in 2, 3, or 4 trials using the afterimage device, for a total of 55 trials (Table). In 51 (93%) of the 55 trials, the direction of the cycloversion that accompanied the vertical vergence required to recover fusion was consistent with the oblique muscles being the primary mediators of vertical fusional vergence. That is, in most cases, removal of a base-down prism from the right eye or a base-up prism from the left eye resulted in a counterclockwise torsional movement (levocycloversion) as fusion was regained. Similarly, removal of a base-up prism from the right eye or a base-down prism from the left eye resulted in a clockwise torsional movement (dextrocycloversion) as fusion was regained.

Any individual having at least one observation that was not consistent with oblique muscle mediation of vertical fusional vergence was classified as “inconsistent.” Any individual with all observations consistent with oblique muscle mediation was classified as “consistent.” The criteria for consistent were thus quite strict. The hypothesis of equally likely mediation of the vertical fusional vergence response by the oblique muscles or the vertical rectus muscles was tested by considering each subject’s consistency or inconsistency as an independent observation. A binomial distribution was used with $P = .50$ to describe the chance of observing certain numbers of subjects with consistent and inconsistent results.
Of the 16 subjects, 4 had inconsistent results. The probability of observing a proportion this small, if the true probability of an inconsistent result is .50, is .03. The observed results are thus inconsistent with a hypothesis of equally likely control by the oblique muscles or vertical rectus muscles, and consistent with predominant control of vertical vergence by the oblique muscles. Since observations within an individual subject are not independent, a mean value of torsional shift was calculated for each subject, and these values were averaged to obtain an overall mean. A positive value was assigned to torsional cycloversions in the expected direction of oblique muscle action and a negative value to those in the opposite direction. The mean ± SD value was 1.15° ± 0.76°, with an SEM of ±0.19°.

**COMMENT**

The findings in this study strongly support Enright’s position that the oblique muscles are the primary mediators of vertical fusional vergence. When a vertical disparity is created using a small prism, a vertical vergence is expected. If, for example, a base-up prism is placed before the right eye, the right eye should move down with respect to the left eye to regain fusion. When the prism is removed, the opposite relative movement should occur to recover single binocular vision. With each vertical fusional recovery, there was an associated torsional movement that was recorded using the afterimage apparatus. In separate pilot experiments with a monocular afterimage, we had already established that both eyes cycloduct in the same direction. In other words, the movement is a cycloversion. In the example previously cited, when the base-up prism was removed from the right eye, the right eye moved up and customarily extorted. The subject perceived this movement as a clockwise rotation of the afterimage. Upward movement of the right eye with extorsion can only be mediated by the oblique muscles, with the inferior oblique muscle contracting, and/or the superior oblique muscle relaxing. If a contracting superior rectus muscle had been responsible for the elevation, an intorsion of the right eye (counterclockwise movement of the afterimage) should have been measured with the afterimage apparatus.

The cycloversion occurring with vertical fusional vergence appears to be an important key to understanding DVD. van Rijn and coworkers showed with scleral search coil recordings that the cyclovertical movements in patients with DVD are remarkably similar to disparity-
induced vertical vergence in normal subjects. In 3 of their 5 patients with DVD, the time course of the vertical divergence and the direction of the cycloversion were comparable with those observed in disparity-induced vertical vergence in normal subjects. Although DVD may use the same eye movement pathways as vertical fusional vergence, but in an exaggerated manner, the etiology of DVD still remains to be explained. We believe that further clues to understanding DVD come from the strong association of DVD with latent nystagmus. In the setting of the cyclovertical latent nystagmus that frequently accompanies DVD, Guyton and colleagues\textsuperscript{9,10} have shown through the use of sensitive search coil recordings that the cycloversion or vertical vergence associated with DVD helps damp this cyclovertical nystagmus. This helps stabilize the fixing eye, but also results in an unavoidable and undesirable elevation of the fellow eye, which we recognize as DVD.

In summary, the present study demonstrates that the vertical vergence that results from a prism-induced vertical disparity in normal subjects is mediated primarily by the oblique muscles, supporting the previous finding of Enright.\textsuperscript{6} The vertical fusional vergence that occurs in normal subjects on the introduction of vertical disparity has been shown to have a time course comparable with the vertical vergence seen in subjects with DVD.\textsuperscript{8} We suggest that DVD is actually an exaggeration of this normal vertical vergence pattern, recruited to help compensate for nystagmus, particularly latent nystagmus, in patients with absent or imperfect binocular function.\textsuperscript{9,10} The notable prevalence of cyclovertical nystagmus that has been reported in conjunction with DVD, and that we have observed clinically, suggests that DVD serves to preferentially damp this form of nystagmus.

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\textbf{REFERENCES}


\textbf{From the Archives of the ARCHIVES}

A look at the past . . .

\textbf{WIDMARK has made a series of experiments with a grating spectroscope in order to determine the sensibility of the retina for ultraviolet rays. He finds the following. The normal human eye perceives only a small portion of the ultraviolet rays. The limit of the visible spectrum varies with different individuals, but usually lies within L-M. The rays are perceived directly, and not through fluorescence. Older persons recognize fewer of the ultraviolet rays than younger. This is especially noticeable in persons over sixty-five. The lens is the chief factor in preventing the visibility of the extreme rays, and after its removal the violet end of the visible spectrum is considerably elongated.}