OCCURRENCE OF DISSOCIATED VERTICAL DEVIATION IN HORIZONTAL CONCOMITANT HETEROTROPIA: A HOSPITAL-BASED STUDY

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ABSTRACT

BACKGROUND
Dissociated Vertical Deviation (DVD) is a poorly understood supranuclear strabismic disorder in which there is slow upward and sometimes temporal movement of one eye with cortical suppression of vision in that eye when it is occluded. In DVD, one eye get dissociated from the fellow eye, so they don't follow Hering's and Sherrington's laws of innervation. DVD is also a marker of disruption of normal binocular function, which causes unbalanced input to vestibular system resulting in latent nystagmus with a cyclovertical component. To overcome this cyclovertical component, vertical vergence is invoked for which vision is aided in the fixing eye, but unfortunately it also produces DVD of the fellow eye. DVD is most commonly associated with infantile esotropia.

AIM
To determine whether age of onset of strabismus is related to the development of dissociated vertical deviation in patients with horizontal concomitant heterotropia (HCH).

To find out the occurrence of dissociated vertical deviation among patients with horizontal concomitant heterotropia and also to calculate how many of them is suffering from refractive error.

DESIGN
This is a cross-sectional, observational hospital-based study.

MATERIALS AND METHOD
This study was done in 100 children presenting with horizontal concomitant heterotropia randomly chosen in the age group 5 yrs.–19 yrs. attending outpatient department and squint clinic of Regional Institute of Ophthalmology, Kolkata. After taking proper history regarding time of onset of strabismus, age of onset of DVD, they underwent a full ophthalmic examination including visual acuity assessment, cycloplegic refraction, assessment and measurement of squint and DVD, and stereopsis.

RESULT
Mean age of horizontal concomitant heterotropes was 9.28 yrs. ± 3.94 yrs. of which 48% were male and 52% were female. Among horizontal concomitant heterotropes 24% were exotropes and 76% esotropes. The mean age of onset of strabismus in horizontal concomitant heterotropes leading to the development of DVD was 7.93 yrs. ± 9.95 yrs. Dissociated vertical deviation was present in 14% of horizontal concomitant heterotropia of which 78.57% were male and 21.43% were female. We found that 78.58% of DVD patients were having some type of refractive error.

CONCLUSION
This clinical study is a small endeavour on our part to suggest an earlier age of onset of strabismus is associated with higher chances of development of dissociated vertical deviation and we have also noticed a higher incidence of DVD in infantile esotropia.

KEYWORDS
Dissociated Vertical Deviation, Horizontal Concomitant Heterotropia, Infantile Esotropia.

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INTRODUCTION: We have conducted this study on patients suffering from horizontal concomitant heterotropia. Normally, our eyes are well-aligned so that the foveas are aimed on the same visual target, a condition termed as orthotropia,[1] any manifest deviation from this or an underlying tendency is known as strabismus.[2,3] Horizontal concomitant heterotropia is a subtype of strabismus where

there is deviation of one of the visual lines in horizontal axis either outward (Exotropia) or inward (Esotropia) and deviation of one eye accompanies the other eye in all its excursion.

Dissociated vertical deviation is most intriguing and least understood of all forms of strabismus. This anomaly is intermittent and is characterised by an upward excursion, excyclotorsion, and lateral movement. No movement is seen in the fixing eye when the deviated eye returns for refixation. Traditionally, the upward excursion is labelled as dissociated vertical deviation; the excyclotorsion is called as dissociated torsional deviation; and the lateral movement is termed as dissociated horizontal deviation. Generally, its unique clinical feature distinguishes it from other forms of vertical deviation, but diagnosis may get difficult when it is associated with other forms of strabismus. It was Schweigger[4] and Duane who first reported this entity, but Bielschowsky[5] was the first to provide comprehensive description and minute clinical analysis of DVD. In the beginning, there was much controversy regarding its name as the precise aetiopathology was not known. Different terminologies were coined to define it such as anatopia, alternating hypertropia, occlusional hypertropia, alternating sursumduction, but none was perfect. George Stevens in 1895[6] attributed the term 'alternating vertical strabismus' due to an error in declination of the fixing eye[7]. Now a days, the term dissociated vertical deviation is preferred as it carries no implication with regard to the aetiology of this condition because the ocular motor mechanism underlying DVD and its torsional and horizontal component is yet to be explained. It is one form of cyclovertical deviation characterised by spontaneous upward drifting of either eye when the patient is fatigued or daydreaming or fusion is artificially interrupted by covering one eye. After removing the cover, the eye will move downward and settle in primary position. Bielschowsky[5] reported an observation known as Bielschowsky phenomenon in patients suffering from DVD when a photometric neutral filter wedge is placed before the fixating eye while the other eye is occluded and elevated the eye behind the cover will make a gradual downward movement and may even move below the primary position as the visual input to the fixating eye is progressively decreased by the filter wedge. When the wedge is moved from positions of greater to lesser filter density, the eye behind the cover will elevate. The possible explanation to this phenomenon as proposed by him is that when visual input to the fixating eye is decreased by filter wedge of increasing density an abnormal innervation to the elevators is triggered while to maintain fixation by the fixating eye. A compensatory innervation to the depressors is elicited for which the non-fixating eye makes a downward movement to the primary position or even below it.

Usually, DVD does not have any visual symptom except for a cosmetic blemish. The patients do not complain of diplopia as there is poor fusion and suppression of the deviating eye. However, occasionally diplopia and confusion has been reported. The characteristic excursion of the eye maybe present as phoria (manifesting only under cover) or tropia (when it manifests spontaneously in conditions of fatigue, daydreaming, inattentiveness, or during poor health). The signs are more profound in an amblyopic, non-dominant, or non-fixing eye. As the elevated eye returns to normal position, it incycloducts. It is rarely seen in isolation and associated features include esotropia, intermittent divergent squint, and latent nystagmus. It is also found in association with inferior oblique overaction and head tilt. Occasionally, excycloduction of each eye under cover or spontaneously and latent nystagmus maybe the only manifestation of a dissociated deviation.

As already stated, there has been much controversy regarding its aetiology. Some authors have speculated that DVD is a manifestation of atavistic oculomotor reflexes that are present in birds and fish.[8,9,10,11] Crone[10] considered that DVD may represent a phylogenetic residuum of monocular vertical movements present in birds and inhibited in normal humans. Brodsky[8] suggested that DVD is a primitive dorsal light reflex in which asymmetrical visual input to the eyes evokes a vertical divergence movement.

There are also other theories such as abnormal binocular development causes unbalanced input to vestibular system resulting in latent nystagmus with a cyclovertical component. To overcome this cyclovertical component, vertical vergence is invoked known as 'nystagmus damping mechanism'. Thus, by this mechanism, vision is aided in the fixing eye, but unfortunately, it also produces an undesirable elevation and excyclotorsion of the fellow eye resulting in DVD of that eye.[5,11]

There is a neurophysiologic basis of DVD, which states that interstitial cells of Cajal (brainstem nucleus) regulating cyclovertical movement is under constant inhibitory input from binocular cells in occipital cortex[12]. Lesion around these cells results in nucleus disinhibition, which is clinically manifested as 'see-saw nystagmus.' This 'see-saw nystagmus' looks quite similar to DVD.

Dissociated vertical deviation is almost always bilateral, but asymmetrical cases may appear to be unilateral. Prolonged occlusion of the eye that appears not to have DVD, however, will almost always disclose a latent DVD. DVD violates Hering's law of yoke muscles because covering right eye makes right eye to drift up and covering the left eye makes left eye to drift up with no hypotropia of the fellow eye.

MATERIALS AND METHODS: A cross-sectional observational study was carried out in Outpatient Department and Squint Clinic of Regional Institute of Ophthalmology, Kolkata, during the period of February 2011 to February 2012. 100 children presenting with horizontal concomitant heterotropia have been randomly chosen in the age group 5 yrs. – 19 yrs. The following criteria were followed: -

Inclusion Criteria:

- A diagnosis of horizontal concomitant heterotropia.
- Age of at least 5 years required for obtaining reliable stereopsis measurements.

- No H/O prematurity, trauma, or neurological diseases.
- No ocular or orbital pathology.
- No previous cyclovertical surgery.

Exclusion Criteria:

- Patients with noncomitant heterotropia.
- Patients having superior oblique palsy.
- Patients with neurological diseases.
- Patients with systemic diseases like Down syndrome, Noonan syndrome, or Marfan syndrome.
- H/O cyclovertical muscle surgery.

They underwent a full ophthalmic examination including visual acuity assessment, cycloplegic refraction, assessment and measurement of squint and DVD, and stereopsis measurement by Titmus stereo test. We looked for any presence of head tilt and nystagmus. For measurement of squint, we used prism bar. For an accurate quantitative assessment of DVD, a modification of the prism and cover test was implemented. Patient was asked to look at a fixation target at 6 meter distance when one eye was occluded. Now, patient fixes with the unoccluded eye while eye behind the occluder will drift upward. The occluder is then quickly shifted to the fixating eye allowing the previously dissociated and elevated eye to take up fixation, which will then make a slow downward movement to the midline. The cover is then returned to the nonfixating eye. As the alternate cover test is continued, increasing amounts of base-down prisms are held under the occluder in front of the nonfixating eye until the downward fixation movement of that eye is neutralised. The procedure is then repeated with the fellow eye fixating. The power of the prism that neutralizes the downward fixation movement of the eye will give the magnitude of DVD.

STATISTICAL ANALYSIS: Data was presented as actual numbers and percentages, Epi Info and WinPepi softwares were used to find out statistical significance, $p<0.05$ was considered as significant.

RESULTS: In our study, all patients were suffering from horizontal concomitant heterotropia with a mean age of 9.28 yrs. ±3.94 yrs. of which 48% were male and 52% were female. Among horizontal concomitant heterotropes, 24% were exotropes and 76% esotropes. Among exotropes, 29.17% were male and 70.83% were female while among esotropes 53.94% male and 46.06% female. When we plotted this result in a 2 x 2 contingency table, we found that exotropia is significantly more among females ($p=0.03$, $X^2 = 4.49$, df = 1). Mean age of esotropes was 8.71 yrs. ± 3.6 yrs. while in exotropes it was 11.08 yrs. ± 4.49 yrs. Esotropes having an onset between birth and 6 months of age are referred to as congenital or essential infantile esotropia whereas those above that age group referred to as early acquired esotropia. In our study, 43.42% were infantile and 56.58% acquired esotropes.

The mean age of onset of strabismus in horizontal concomitant heterotropes leading to the development of DVD was 7.93 yrs. ± 9.95 yrs. while it was 30.61 yrs. ± 26.29 yrs. in horizontal concomitant heterotropes not leading to DVD. After calculation by t test, we found that the association between earlier age of onset of strabismus and development of DVD is statistically significant ($t=3.18$, $p=0.002$, df = 98). So, this meets our first objective, i.e. an earlier onset of strabismus is associated with greater chance of developing DVD.

We have found that dissociated vertical deviation was present in 14% of horizontal concomitant heterotropia of which 78.57% were male and 21.43% were female. So, percentage of horizontal concomitant heterotropes with DVD are more in males than females, which also is statistically significant [p (Yates corrected) = 0.03, $X^2 = 4.75$, df = 1]. We also noticed that 12 out of 14 DVD in our study were esotropes of which 9 were in infantile group that means 75% of the DVD patients were infantile esotropes. So, there is a high prevalence of DVD among infantile esotropes and a statistical calculation revealed this to be a significant association [p (Yates corrected) = 0.04, $X^2 = 4.36$, df = 1]. Yates correction was done as the value in acquired ET with DVD is less than 5. We also measured the amount of DVD. The mean amount among esotropes was $20.66^{\Delta} \pm 3.60^{\Delta}$ and among exotropes was $13.0^{\Delta} \pm 4.24^{\Delta}$.

We have also looked for the refractive status of DVD patients in horizontal concomitant heterotropes and found that 78.58% were having some type of refractive error and DVD both, but 21.42% were having only DVD without any refractive error. When we plotted this in 2 x 2 contingency table, it revealed that most of the DVD patients were having refractive error, which was statistically significant [p (Yates corrected) = 0.04, $X^2 = 4.06$, df = 1]. 50% of all DVD patients were hypermetropes, 21.43% myopes, 7.14% astigmatic, and the rest 21.43% normal.

Horizontal concomitant heterotropia	Male (%)	Female (%)	Total (%)
Exotropia	7 (29.17%)	17 (70.83%)	24 (100%)
Esotropia	41 (53.94%)	35 (46.06%)	76 (100%)
Total	**48**	**52**	**100**

Table 1: Distribution of Study Population According to Gender and Type of Horizontal Heterotropia (n=100)

$p=0.03$, $X^2 = 4.49$, df = 1.

70.83% of exotropes were female, so exotropia was found to be more prevalent in female and this association is statistically significant.

Horizontal Concomitant Heterotropia	Male	Female	Total (%)
DVD Present (%)	11 (78.57%)	3 (21.43%)	14 (100%)
DVD Absent (%)	37 (43.02%)	49 (56.98%)	86 (100%)
Total	**48**	**52**	**100**

Table 2: Distribution of Study Population According to Gender and DVD (n=100)

p (Yates corrected) = 0.03, X^2 = 4.75, df = 1.

78.57% DVD patients were male showing that DVD is more prevalent in male in my study and this association is statistically significant.

Esotropia	Infantile ET	Acquired ET	Total (%)
DVD Present	9 (75%)	3 (25%)	12 (100%)
DVD Absent	24 (37.5%)	40 (62.5%)	64 (100%)
Total	**33 (43.43%)**	**43 (56.57%)**	**76 (100%)**

Table 3: Distribution of Esotropes According to its Type and DVD (n=76)

p (Yates corrected) = 0.04, X^2 = 4.36, df = 1.

Percentage of DVD was more in infantile esotropes compared to acquired esotropes and this association was found to be statistically significant.

Horizontal Concomitant Heterotropia	Refractive Error Present	Refractive Error Absent	Total (%)
DVD Present	11 (78.58%)	3 (21.42%)	14 (100%)
DVD Absent	83 (96.51%)	3 (3.49%)	86 (100%)
Total	**94**	**6**	**100**

Table 4: Distribution of Horizontal Concomitant Heterotropes on Basis of Refractive Error and DVD

p (Yates corrected) = 0.04, X^2 = 4.06, df = 1.

78.57% DVD patients had some type of refractive error. This association was found to be highly statistically significant.

DISCUSSION: The initial description of what we now call dissociated vertical deviation is credited to Schweigger by Bielschowsky. Duane and Stevens were in agreement that "alternating vertical deviation" and "alternating hypertropia" terms used by Duane were caused by muscular imbalance between stronger elevators and weaker depressors.[13,14]

Dissociation refers to the situation where the innervation of one eye causes it to move involuntarily and independently of the other eye. Usually, both eyes work together as described by Hering's and Sherrington's laws of innervation.

David L. Guyton in his journal 'Dissociated Vertical Deviation: Aetiology, Mechanism, and Associated Phenomena' reported that in patients with an early onset defect of binocular function, the occlusion of one eye or even concentration on fixing with one eye produces unbalanced input to the vestibular system. This results in latent nystagmus with a cyclovertical component sometimes only seen with magnification. A normal oblique muscle produced cycloversion/vertical vergence then comes into play occurring in an exaggerated form in the absence of binocular vision probably as a learned response. This cycloversion/vertical vergence helps damp the cyclovertical nystagmus (A cyclovertical "nystagmus blockage" phenomenon), aiding vision in the fixing eye. But, this mechanism also produces unavoidable and undesirable elevation and extorsion of the fellow eye, which we call DVD.[15]

Anderson noted that dissociated vertical deviation patients having good vision were usually under 35 years of age and that surgery was usually unsatisfactory. He also noted large fusional amplitudes and a 35% incidence of torticollis with the head tilted toward the side of the fixing eye in patients with occlusion hypertropia. He concluded that dissociated vertical deviation is not well understood and said "probably there are centres or controlling spheres for uniocular and binocular vertical movements not necessarily well-defined structurally, but adequate in function, which can under certain conditions permit unilateral vertical movements with nystagmus after occlusion.[16]

In a study carried out by Eugene M. Helveston,[17] he found an incidence of 11.1% of DVD among 1000 patients with strabismus and nystagmus in which 100 patients were suffering from DVD among 807 horizontal concomitant heterotropes that leads to a prevalence of 12.39%. Another study by Kutluk S, et al[6] found 12.5% DVD among patients with sensory heterotropia. So, the results are more or less corroborating with each other and also with the result of our study where we have found it to be 14%. A study by Min EJ et al J Korean Ophthalmol[18] revealed that 47.6% of horizontal concomitant heterotropia were male and 52.4% female thus corroborating with our result. Eugene M. Helveston,[17] found 68.64% esotropes and 31.36% exotropes among 807 patients with horizontal heterotropes. In our study, 43.42% were infantile and 56.58% acquired esotropes. A study by Vicente Victor D Ocampo Jr. revealed that infantile esotropia accounts for 28%-54% of all esotropias[19]. We found in our study a high prevalence of DVD among infantile esotropes. This association of infantile ET and DVD has been calculated by different authors and they got much different results Lang (90%),[20] Parks (76%),[21] Helveston (70% to 90%),[17] and Calcutt and Murray (60%)[22] while Von Noorden found it to be 51%.[23] A possible reason for these differences in the reported prevalence of dissociated vertical deviations is that some authors restrict the diagnosis to the presence of a manifest dissociated deviation whereas others include cases with a latent

dissociated deviation, which can only be elicited by covering one eye. Verhoeff in his study 'occlusion hypertropia' in the year 1941 stressed the importance of occlusion in eliciting vertical anomaly. He studied 42 cases, age ranging from 3½ to 45 yrs. found 37 had strabismus, 27 esotropes, 9 amblyopes, and only 3 cases had manifest nystagmus. 5 of 42 patients had occlusion hypertropia as their only anomaly.[24]

In our study, we have also noticed that 78.58% were having some type of refractive error. Helveston[13] in his study found 70.27% of DVD patients were having refractive error of which 70% were hyperopes, 14% myopes, 11% astigmatic, and rest (5%) were normal.

There has been a continuous debate regarding the treatment of DVD. Umut Arslan et al concluded that in the treatment of infantile esotropia, early surgical intervention to obtain binocularity and prevent amblyopia is associated with a reduced incidence of the development of DVD. It is concluded that the incidence of the development DVD increases if surgery is not performed, if performed at a later age or if additional muscle surgery is needed during follow-up due to under correction.[25] Daniel E Neely et al concluded that DVD occurs in almost all patients with surgically-treated congenital esotropia, and its development is unrelated to the timing of surgical intervention during the first 24 months of life.[26] Cho YA et al had the clinical impression small amount of DVD in intermittent exotropia would be reduced or would disappear spontaneously after intermittent exotropia surgery.[27]

In our study, in all cases, we have first done horizontal muscle surgery for horizontal heterotropia, as we had all large DVD, so horizontal muscle surgery alone could not correct DVD, so for DVD correction, either superior rectus recession of almost 7 to 8 mm or inferior oblique recession was done in patients with DVD of 10.0 $^{\Delta}$ to 20 $^{\Delta}$. In patients with DVD more than 20 $^{\Delta}$, either superior rectus recession or inferior rectus resection was done. In patients with additional inferior oblique overaction, anterior displacement of inferior oblique was done along the previous surgery. For bilateral cases, we have done surgery in both the eyes, but for unilateral cases with amblyopia we have done only unilateral surgery. In all these cases, we have never made operative intervention on more than three ocular muscle.

According to Bielschowsky, the only means of reducing the onset of these deviations is by improving the fusional innervation-the stronger the fusional mechanism, the easier it is to keep dissociated vertical movements latent. This implies that early visual rehabilitation in such cases of sensory visual deprivation could prevent unmasking of primitive reflexes such as dorsal light reflex and in turn the DVDs.[22]

CONCLUSION: Patients with dissociated vertical deviation generally suffer from poor binocularity and depth perception and most of them have some sort of refractive error. In our study, we have found that dissociated vertical deviation has a prevalence of 14% among horizontal concomitant heterotropes and most commonly found among the infantile esotropes. We also noticed that an earlier onset of strabismus generally leads to development of DVD.

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