Esotropia Greater at Distance

Children vs Adults

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Importance: Esotropia greater at distance than at near can be related to abducens palsy or to divergence insufficiency. Mild abduction weakness can be difficult to detect, blurring the distinction between these 2 conditions.

Objectives: To examine the clinical and eye movement findings that distinguish abducens palsy from divergence insufficiency and to account for these findings based on current knowledge of vergence neurophysiology and saccadic adaptation.

Design: Retrospective medical record review.

Setting: A pediatric referral center.

Participants: The medical records of 32 patients with esotropia greater at distance seen during a 17-year period from August 1989 to July 2006 were reviewed.

Main Outcome Measures: Details regarding age, medical history, oculomotor and neurological examinations, and result of any neuroimaging studies were recorded. Eye movements were recorded in 2 subjects using binocular video-oculography.

Results: Fifteen children and 17 adults were identified; 93.3% of the children had an underlying central nervous system disorder that coincided with the onset of their esodeviation, and 23.5% of the adult patients had an underlying central nervous system disorder. Eye movement recordings in 2 pediatric patients revealed lateral incomitance suggestive of abducens palsy not detected by clinical examination.

Conclusions and Relevance: The acute onset of an esodeviation greater at distance in a child is frequently associated with an underlying central nervous system disorder. Several features suggest that the children, unlike the adults, likely had a subtle abducens paresis rather than divergence insufficiency. This was confirmed by formal eye movement studies in 2 children in whom lateral incomitance was not detected clinically. The same pattern of strabismus in an otherwise healthy adult is more likely due to age-related reduction in accommodation, increased ratio of accommodative vergence to accommodation, and relative divergence insufficiency.


The term divergence insufficiency (DI) refers to a comitant esotropia that is greater at distance than at near with normal ductions. Affected individuals are neurologically normal and present with the insidious onset of horizontal diplopia at distance. In previous studies, adults collectively accounted for 83 of the 90 reported patients.1-8 Given the age predilection and typical lack of clinical or neuroimaging evidence of an associated neurological disorder, this disorder has been attributed to the progressive loss of fusional divergence amplitudes.9 However, the notion that DI results from age-related loss of fusional divergence is not supported by quantitative data obtained with binocular recording of eye movements. Yang and colleagues10 reported that divergence amplitudes and peak velocity overlapped in older adults vs young adults but duration was prolonged.

Abducens palsy is one of the most frequent causes of an esotropia that is greater at distance than at near. Complete paralysis of one or both abducens nerves is characterized by a large esodeviation in primary gaze and clinically obvious limitation of abduction, with lateral incomitance in unilateral or asymmetric cases. Incomplete or partial abducens paralysis is characterized by a smaller esodeviation in primary gaze with variable limitation of abduction and smaller amounts of incomitance in lateral gazes. Mild abduction weakness can be difficult to detect, blur-
ring the distinction between abducens palsy and DI. To help distinguish these 2 conditions, Lim and colleagues' quantified lateral rectus function in adults with DI using electro-oculography. First, they demonstrated comitant esodeviation in lateral gazes using a Hess screen test. Second, they showed that peak saccadic velocity was normal at eccentricities of 10°.

Divergence paralysis is another term used to describe the acute or subacute onset of an esotropia greater at distance than at near in patients with normal ductions. Subjects with divergence paralysis, unlike those with DI, have a neurologic disorder associated with increased intracranial pressure. Eye movement recordings using electro-oculography in a subset of these patients showed reduced saccadic velocities, suggesting possible mild bilateral abducens palsies.11

The purpose of this study was to determine whether the clinical features and mechanism underlying esotropia greater at distance than at near differs in children vs adults. To address this question, we compared the clinical findings in children vs adults, recorded the eye movements of 2 affected children, and integrated these findings with current knowledge of vergence physiology.

**Table 1. Clinical Characteristics of Pediatric Subjects**

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Medical History</th>
<th>Distance</th>
<th>Deviation, PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/3</td>
<td>Arachnoid cyst, cystoperitoneal shunt</td>
<td>35 ET</td>
<td>15 ET</td>
</tr>
<tr>
<td>2/F/4</td>
<td>Varicella meningitis</td>
<td>25 ET</td>
<td>8 ET</td>
</tr>
<tr>
<td>3/M/5</td>
<td>NF-1, chiasmal hypothalamic glioma</td>
<td>30 ET</td>
<td>14 ET</td>
</tr>
<tr>
<td>4/M/6</td>
<td>Transverse and sigmoid sinus thrombosis</td>
<td>28 ET</td>
<td>16 ET</td>
</tr>
<tr>
<td>5/F/7</td>
<td>NF-1, hydrocephalus</td>
<td>8 ET</td>
<td>0</td>
</tr>
<tr>
<td>6/M/8</td>
<td>Spina bifida, Arnold-Chiari malformation</td>
<td>20 ET</td>
<td>0</td>
</tr>
<tr>
<td>7/F/9</td>
<td>Medulloblastoma</td>
<td>25 ET</td>
<td>6 ET</td>
</tr>
<tr>
<td>8/F/10</td>
<td>Guillain-Barré syndrome</td>
<td>18 ET</td>
<td>0</td>
</tr>
<tr>
<td>9/M/12</td>
<td>Spina bifida, hydrocephalus</td>
<td>14 ET</td>
<td>0</td>
</tr>
<tr>
<td>10/M/13</td>
<td>Meningitis</td>
<td>16 ET</td>
<td>10 ET</td>
</tr>
<tr>
<td>11/F/13</td>
<td>Pilocytic astrocytoma posterior fossa</td>
<td>18 ET</td>
<td>8 ET</td>
</tr>
<tr>
<td>12/M/15</td>
<td>Viral meningitis</td>
<td>8 ET</td>
<td>1 ET</td>
</tr>
<tr>
<td>13/F/17</td>
<td>Guillain-Barré syndrome</td>
<td>20 ET</td>
<td>8 ET</td>
</tr>
<tr>
<td>14/M/18</td>
<td>Basal/sphenoid encephalocele</td>
<td>30 ET</td>
<td>20 ET</td>
</tr>
<tr>
<td>15/M/19</td>
<td>Sotos syndrome</td>
<td>12 ET</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: E'; esophoria at near; ET, esotropia; E(T'), intermittent esotropia at near; NF-1, neurofibromatosis type 1; PD, prism diopters.

**RESULTS**

Thirty-two patients (15 children and 17 adults) were included in the study. The mean age of the children was 11 years (range, 3-19 years) and of the adults was 50 years (range, 33-85 years). The baseline characteristics of the 2 groups and within each group reflect the age-related and clinical heterogeneity of these populations (**Table 1** and **Table 2**).

Fourteen (93.3%) of the children had the acute or subacute onset of esotropia that coincided temporally with the onset of a newly acquired or previously known central nervous system disorder. The systemic and neurologic manifestations of the underlying central nervous system disorder, rather than the acquired esotropia, were the primary concerns that prompted medical evaluation in most children. Three of the children were initially evaluated by an ophthalmologist (A.H.W.) for the acute onset of horizontal diplopia; 2 of these children had meningitis and 1 had a medulloblastoma of the posterior fossa. Each of the 15 children had an underlying central nervous system disorder that could be associated with increased intracranial pressure. Five children had a mass lesion (tumor, arachnoid cyst, and encephalocele), 3 had meningitis, 2 had spina bifida, 2 had Guillain-Barré syndrome, 1 had a transverse sinus thrombosis, and 1 had Sotos syndrome.

In comparison, each of the 17 adults was initially evaluated by an ophthalmologist because of the insidious onset of horizontal diplopia. Systemic evaluation included neurologic examination of all patients and neuroimag-
ing (computed tomography and/or magnetic resonance imaging) in 9 of the 17 patients (53%). Four of the 17 adults (23.5%) had an identified central nervous system disorder. One had syringomyelia of the cervical cord, 1 had a choroid plexus papilloma, and 2 had evidence of stroke (basal ganglia or cerebellum). Forty-seven percent of the adult patients were younger than 40 years. Six of the 8 young adults had a history of latent hyperopia, spasm of accommodative vergence, previous head trauma, or exposure to drugs that could reduce accommodation.

The mean (SD) esodeviation was 20 (8.2) prism diopters (range, 8-35 prism diopters) at distance and 7 (6.9) prism diopters (range, 0-20 prism diopters) at near in the pediatric group. The mean (SD) esodeviation was 14 (5.1) prism diopters (range, 6-25 prism diopters) at distance and 1 (1.7) prism diopters (range, 0-4 prism diopters) at near in the adult group. The distributions of distance and near esodeviations were significantly different between children and adults (P = .02 for distance; P = .005 for near) (Figure 1 and Figure 2).

Ocular rotations assessed clinically were found to be normal in children and adults. None of the adult patients showed incomitance in lateral gazes. Quantitative determination of lateral incomitance in the children was problematic because of limited cooperation, especially in the context of acute illness.

Eye movement recordings were performed within several days of the onset of diplopia in patient 4 with transverse sinus thrombosis. Although abduction was normal by clinical assessment, the recording revealed limited abduction in left gaze with lateral incomitance. Gaze holding was stable in primary gaze and at eccentricities of 15° up, down, right, and left. Smooth pursuit gain (eye velocity/target velocity) of right and left eyes to a target drifted sinusoidally along the horizontal at a peak velocity of 10° per second was 1.04 (phase, 4.4°; sinusoidal cycles = 4). Mean (SD) saccadic velocities in response to
target steps of 5° to 20° in right gaze were 154.7° per second (89.6) (n = 59 saccades) and in left gaze were 99.7° per second (120.0) (n = 31 saccades). Normal values for comparison are more than 150° per second. The borderline low saccadic velocities are consistent with bilateral but asymmetric abducens palsies. Figure 3 demonstrates that some saccades are dysmetric, some hypermetric, and others hypometric. A horizontal optokinetic nystagmus (OKN) stimulus drifted at 15° per second and 30° per second in the rightward and leftward directions, respectively, elicited OKN gains of 0.84 and 0.90 in the right eye and 0.62 and 0.60 in the left eye.

Figure 4 shows the eye movement data for patient 7 with a posterior fossa medulloblastoma. A left-beating nystagmus of the left eye only was present at eccentricities of 15° left, up, and down. A right-beating nystagmus of the right eye only was present in right gaze. The monocular eye movements under binocular viewing were consistent with an internuclear ophthalmoplegia. Gains of the left eye to targets sinusoidally drifted along the horizontal at peak velocities of 10° per second and 20° per second were 0.76 (phase, 14.5; cycles = 4) and 0.26 (phase, 65.7; cycles = 12), respectively. Tracking was saccadic to targets drifted at 30° per second to the left and across all target velocities to the right. Mean (SD) saccadic velocities in response to target steps of 5° to 20° in right gaze were 175.6° per second (10.7) (n = 2) and in left gaze were 50.7° per second (52.4) (n = 4). A horizontal OKN stimulus drifted at a constant velocity of 15° per second, 30° per second, and 45° per second in both directions elicited OKN that was at or below the lower limits of normal in both eyes with 1 exception (gain in the left eye = 0.65 at 30° per second to the left).

We report 15 children and 17 adults with an esotropia greater at distance than at near and presumed full ocular rotations. Five features suggest that children, unlike adults, more likely had a subtle bilateral or unilateral abducens paresis rather than DI. First, children experienced the acute or subacute onset of esodeviation, whereas adults presented with the insidious onset of horizontal diplopia at distance. Second, most children presented to medical attention with a neurologic condition, unlike adults who uniformly presented with esotropia. Third, each of the underlying neurologic conditions can be associated with increased intracranial pressure, which is a common cause of abducens palsy in children.13,14 In previous series of abducens palsy in children, increased ICP is among the most common etiologies.15-18 However, an abducens palsy with increased ICP is a nonlocalizing finding in the absence of associated neurological signs.19,20
frequent association with increased ICP has been attributed to the long intracranial path of the abducens nerve with several sites of increased vulnerability or to shearing forces imposed by the differential shifts of the cerebral hemispheres relative to the fixed brainstem. In the only study that included children, Kirkham and colleagues\(^{15}\) reported that the peak saccadic velocities recorded with electro-oculography were reduced in 2 children with increased ICP. Taken together, the data suggest that children with esotropia associated with increased ICP are more likely to have an abducens paresis than DI.\(^{21-23}\)

The presence of an acute esotropia greater at distance than at near is due to abducens palsy or DI. Failure to detect an abduction deficit in lateral gazes and lateral incomitance led to an initial diagnosis of DI in our subjects. Detection of an incomitant esotropia is easily overlooked in acutely ill children because of the inability to control head positioning in primary and lateral gazes. As further evidence of this limitation, we report 2 children initially thought to have normal ocular rotations in whom eye movement recordings documented abducens paresis. Patient 4 had lateral incomitance with reduced peak saccadic velocities in 1 eye and borderline velocities in the fellow eye consistent with an ipsilateral or asymmetric partially recovered abducens paresis. Patient 7 had a bilateral abducens paresis with reduced mean saccadic velocities in both eyes, gaze-evoked nystagmus, and a partial internuclear ophthalmoplegia. The presence of associated neurological findings in patient 7 implicates the brainstem, whereas their absence in patient 4 implicates the peripheral abducens nerve.

Subtle unilateral and bilateral abducens pareses are best detected clinically with the prism cover test or Hess screen test.\(^6,24\) Analysis of lateral gaze shifts may reveal gaze-evoked nystagmus, which indicates reductions of innervational inputs to the lateral rectus muscle. Given the limitations of qualitative assessments, Lim and colleagues\(^6\) proposed objective measurement of lateral rectus function using eye movement recordings. Peak saccadic velocity is a sensitive metric of lateral rectus function. Lim et al\(^6\) reported peak saccadic velocity to be normal in adults with DI, unlike in abducens palsy in which it would be expected to be reduced.\(^{11,25-28}\) Although slowed saccadic velocity is a sensitive index of lateral rectus dysfunction, this finding is transient. In a longitudinal study of abducens palsy in adults, Wong and colleagues\(^{29}\) reported decreased velocity and amplitude of abducting (centrifugal) saccades in the early phase (<2 months). As partial compensation for the abduction deficit, saccade duration increases. In ischemic cases where abducens function typically recovers, the velocity, amplitude, and duration of the saccade can normalize within 2 months. Therefore, the presence of normal saccadic velocity can help to distinguish DI from acute, but not chronic, abducens palsy of peripheral origin. Abducens palsies of central origin are distinguished on the basis of progressive limitation of abduction and associated brainstem findings.

Adults with esotropia greater at distance have a different underlying mechanism than children. Shifts in visual fixation from near to far targets under binocular viewing normally elicit divergent eye movements that keep the fovea of each eye on the target. It has been shown that, on average, disparity-driven divergence amplitudes are normal in older adults.\(^{10}\) Divergence amplitudes, although normal, are ordinarily less relative to convergence amplitudes. Therefore, the decrease of convergence amplitudes with shifts to distance fixation are likely greater than the corresponding increase in divergence amplitudes. Furthermore, the ratio of accommodative vergence to accommodation is normally high (15-30) because of the age-related decline in amplitude of accommodation.\(^{30}\) Both limited relaxation of the medial rectus muscles during divergence and the high accommodative vergence to accommodation ratio may lead to secondary contracture of the medial rectus muscles. Supporting clinical evidence is the observation that bilateral medial rectus recession successfully corrects DI pattern esotropia in adults.\(^4,31\) Therefore, we propose that DI in older adults results from a relative convergence excess rather than a deficiency of divergence amplitudes.

In comparison with older adults, the subset of younger adults does not have age-related reductions of accommodation. This subset may have an increased accommodative vergence to accommodation ratio for a variety of different reasons. A relatively higher level of accommodative convergence can be seen with latent hyperopia and convergence spasm. Alternatively, lower levels of accommodative amplitude may be drug-induced or related to prior head trauma.

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REFERENCES


Web Quiz Winner

Congratulations to the winner of our October quiz, Muhammad S. A. Raja, MRCOphth, FRCS, Department of Ophthalmology, James Paget University Hospitals NHS Foundation Trust, Great Yarmouth, England. The correct answer to our October challenge was idiopathic pigmented vitreous cyst. For a complete discussion of this case, see the Research Letters section in the November issue (Gupta SR, Gupta N, Anand R, Dhawan S. Idiopathic pigmented vitreous cyst. *Arch Ophthalmol.* 2012;130[11]:1494-1496).