Comparison of Methods for Determining the AC/A Ratio in Accommodative Esotropia

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ABSTRACT

Purpose: The two most commonly used clinical methods of determining a high AC/A ratio are: 1) the gradient method, and 2) the distance/near disparity method. Significant differences can be found not only between these two methods, but also in the different techniques for the gradient method alone. The purpose of our study is to compare the gradient method using +3.00 lenses for near and −3.00 lenses for distance, and the distance/near disparity method.

Methods: Patients examined over a 2-year period (1995-1997) with a high AC/A ratio esotropia according to the distance/near disparity were grouped according to level of high AC/A ratio, then prospectively measured by the gradient method (using plus lenses for near and minus lenses for distance). All measurements were performed with full spectacle correction in place according to cycloplegic refraction, and with fixation on an accommodative target.

Results: Forty-five patients were included. Using both plus and minus lenses, a high AC/A ratio by the gradient method was found in 16 (36%) patients, (2 [12%] with a grade 1; 7 [44%] with a grade 2; and 7 [44%] with a grade 3, by the distance/near disparity method), a normal ratio was found in 6 (13%), and no patient had a low ratio. Twenty-three patients fell into a different category of AC/A ratio using plus lenses for near compared with minus lenses for distance.

Conclusions: The distance/near disparity method appears to diagnose a high AC/A ratio much more frequently than the gradient method. There was some variability in the AC/A ratio with plus versus minus lenses when the gradient method was used. Further study using the gradient method in patients without a significant distance/near disparity is required.


INTRODUCTION

The AC/A ratio is the amount of accommodative convergence, in prism diopters, that occurs for every diopter of accommodation exerted. In the literature, two types of AC/A ratio have been described: the stimulus AC/A and the response AC/A. The stimulus AC/A ratio is the amount of
convergence achieved by adding lenses or changing the fixation distance. The response AC/A is the ratio related to the accommodative response. Alpern et al stated that the response ratio could be reasonably predicted by multiplying the stimulus AC/A by 1.08.1 Von Noorden translated this to mean that the response ratio exceeds the stimulus ratio by about 8%.2

The management of accommodative esotropia is often dependent on the measurement of the AC/A ratio. In 1978, von Noorden et al reported on 84 patients treated with bifocals for esotropia greater for near fixation.3 All patients were also evaluated by the gradient method using +3.00 lenses at near. Thirty-one patients (37%) were either cured or improved with bifocals and the common factor in these patients was a high AC/A ratio by the gradient method. Patients who were not successful with bifocal therapy had a normal or low AC/A ratio by the gradient method, even though there was a significant distance/near disparity by prism cover test measurements. Clinical methods for determining the AC/A ratio measure the stimulus AC/A. The two most common clinical methods of assessing the AC/A ratio are:

• the gradient method, and
• the distance/near disparity method. The heterophoria method is a third, well-described calculation of the AC/A ratio. However, it does not account for proximal convergence, which is kept constant in the gradient method by performing both measurements at the same testing distance. The interpupillary distance is a component of the formula. This method is not routinely measured, and not often used clinically.

The gradient method involves altering the stimulus to accommodate by addition of plus or minus lenses at a given fixation distance, with measurement of the change in alignment by the alternate prism and cover test (APCT). The formula used for calculating the ratio is:

\[
\text{Deviation with or without lenses} \div \text{dioptic power of lenses}
\]

Plus lenses may be added for near fixation (1/3 m) to relax accommodation (with a +1.00 diopter [D] lens relaxing accommodation by 1 D), and therefore reduce an esotropia. Minus lenses may be added for distance fixation (6 m) to induce accommodation (with a 21.00 D lens inducing 1 D of accommodation), and therefore increase an esotropia. Usually ±2.00 or ±3.00 lenses are used and the normal AC/A ratio by this method has been reported to be between 3:1 and 5:1. Theoretically, there should be no difference in the AC/A ratio, using plus versus minus lenses for this measurement.

The distance/near disparity method, although not a method of quantifying the ratio, was described by Parks in 1958 and is commonly used to determine if a patient has a high AC/A ratio.4 It is based on the difference between the distance and near esotropia. The general guideline is, that if the esotropia for near fixation exceeds the esotropia for distance fixation by at least 10 prism diopters (Δ), the patient has a high AC/A ratio. Ludwig et al categorized the high AC/A ratio determined by this estimation into three grades, according to the amount of disparity.5 The grades described were: grade 1 (10 to 19 Δ), grade 2 (20 to 29 Δ), and grade 3 (30 Δ or greater). A disparity of 0 to 9 Δ is considered to be a normal AC/A ratio.

The purpose of this study is to compare the distance/near disparity method, the gradient method with plus lenses, and the gradient method with minus lenses in patients with an esotropia of at least 10 Δ greater for near fixation.

**METHODS**

All patients with a high AC/A ratio according to the distance/near disparity method (near esotropia exceeds distance esotropia by at least 10 Δ) seen over a 2-year period (1995-1997), were evaluated prospectively, prior to treatment of the esotropia, by the gradient method.

Amblyopia was treated prior to AC/A measurements used for the study. Patients with characteristics of infantile esotropia were excluded.

Patients were grouped according to the grade of the high AC/A ratio by Ludwig’s classification, ie, grade 1 (10 to 19 Δ difference), grade 2 (20 to 29 Δ difference), or grade 3 (30 Δ or greater difference).

The alternate prism cover test was performed using additional +3.00 lenses for near fixation (1/3 m) followed by −3.00 lenses for distance fixation (6 m). All measurements were performed with full spectacle correction in place and fixation on an accommodative target.
### Table 1

**Comparison of the Distance/Near Disparity Method and the Gradient Method**

<table>
<thead>
<tr>
<th>Gradient method</th>
<th>Grade 1 (N=20)</th>
<th>Grade 2 (N=14)</th>
<th>Grade 3 (N=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+3.00</td>
<td>-3.00</td>
<td>+3.00</td>
</tr>
<tr>
<td>(n=13)</td>
<td>(n=13)</td>
<td>(n=7)</td>
<td>(n=6)</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Normal</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Low</td>
<td>8</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

In keeping with generally accepted definitions, a normal AC/A ratio by the gradient method was considered to be between 3:1 and 5:1, a high ratio being considered greater than 5:1, and a low ratio less than 3:1.

Comparisons were made between the AC/A ratio assessed using the distance/near disparity method, (including the various grades of high AC/A ratio), the AC/A measured by the gradient method using plus lenses, and the AC/A measured by the gradient method using minus lenses.

The average age and refractive error were noted at the time of measurements.

### Results

Forty-five patients were evaluated. All patients were wearing correction for the full refractive error found on cycloplegic refraction, and amblyopia had been treated in all such that visual acuity in both eyes was at least 20/40. All patients had at least 10 Δ of distance/near disparity (the esotropia for near fixation being greater than the esotropia for distance fixation). All patients therefore had a high AC/A ratio according to the distance/near disparity method. Twenty (44%) had a grade 1 high AC/A ratio, 14 (31%) had a grade 2, and 11 (24%) had a grade 3.

Sixteen patients (36%) had a high AC/A ratio by the gradient method, using both +3.00 lenses for near and −3.00 lenses for distance. Two of the 16 (12%) had a grade 1, 7 (44%) had a grade 2, and 7 (44%) had a grade 3 by distance/near disparity. Six patients (13%) had a normal AC/A ratio with both +3.00 and −3.00, 5 (83%) with a grade 1, and 1 (17%) with a grade 2. No patient had a low AC/A ratio with +3.00 and −3.00.

Twenty-three patients were not in the same category of AC/A ratio (high, normal, or low) using +3.00 lenses for near and −3.00 lenses for distance.

The average age at the time of measurement was 4 years, 9 months. The average refractive error at the time of measurement was +2.8 D in the right eye and +2.9 D in the left eye.

### Comparison of the Distance/Near Disparity Method and the Gradient Method

Of the 20 children with a grade 1 classification, only 7 had the same category of AC/A ratio with both plus and minus lenses, (2 (10%) had a high AC/A ratio and 5 (25%) had a normal AC/A ratio). Thirteen (65%) did not fall into the same category of AC/A ratio when measured with +3.00 and −3.00. Table 1 shows 1 patient had a high AC/A ratio with +3.00 for near and seven had a high AC/A ratio with −3.00 for distance.

Of the 14 with a grade 2 classification, 7 (50%) had a high AC/A ratio by the gradient method using both +3.00 and −3.00. Six (43%) did not fall into the same category of AC/A ratio when measured with +3.00 and −3.00. Three had a high AC/A ratio with +3.00s for near and three had a high AC/A ratio with −3.00 for distance (Table 1).

Of the 11 with a grade 3 classification, seven (64%) had a high AC/A ratio by the gradient method using both +3.00 and −3.00. Four (36%) did not fall into the same category of AC/A ratio when measured with +3.00 and −3.00. Two had a high AC/A ratio with +3.00 for near and one had a high AC/A ratio with −3.00 for distance (Table 1).

### Comparison of Plus and Minus Lenses

Twenty-three patients (49%) did not demonstrate the same category of AC/A ratio (high, normal, or low) using +3.00 lenses for near and −3.00 lenses for distance.
TABLE 2
COMPARISON OF PLUS LENSES FOR NEAR FIXATION AND MINUS LENSES FOR DISTANCE FIXATION
(N = 23)

<table>
<thead>
<tr>
<th></th>
<th>High -6 (26%)</th>
<th>Normal -9 (39%)</th>
<th>Low -8 (35%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plus lenses</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Normal</td>
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</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>4 (67%)</td>
<td></td>
<td>2 (33%)</td>
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<tr>
<td></td>
<td>7 (78%)</td>
<td></td>
<td>4 (50%)</td>
</tr>
<tr>
<td></td>
<td>2 (22%)</td>
<td></td>
<td>4 (50%)</td>
</tr>
</tbody>
</table>

TABLE 3
COMPARISON OF MINUS LENSES FOR DISTANCE FIXATION AND PLUS LENSES FOR NEAR FIXATION
(N = 23)

<table>
<thead>
<tr>
<th></th>
<th>High -11 (48%)</th>
<th>Normal -8 (35%)</th>
<th>Low -4 (17%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minus lenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
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<td></td>
<td></td>
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<tr>
<td>Normal</td>
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<td>Low</td>
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<tr>
<td></td>
<td>4 (50%)</td>
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<td>2 (50%)</td>
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<tr>
<td></td>
<td>7 (64%)</td>
<td></td>
<td>2 (50%)</td>
</tr>
<tr>
<td></td>
<td>4 (36%)</td>
<td></td>
<td>4 (50%)</td>
</tr>
</tbody>
</table>

mal, or low) with plus lenses for near fixation and minus lenses for distance fixation. Tables 2 and 3 show the comparison between the level of AC/A ratio measured using plus lenses for near fixation and minus lenses for distance fixation.

**DISCUSSION**

According to the literature, and in our experience, accommodative esotropia seems to have an unpredictable course when nonsurgical treatment is considered, especially in the case of a high AC/A ratio. It would therefore seem appropriate to determine the most accurate method of assessing the AC/A ratio based on the presence of an esotropia greater for near fixation may be inaccurate. This is because patients may have a significant distance/near disparity with a normal or low AC/A ratio, or an insignificant disparity, but a high AC/A. Von Noorden and Avilla described 24 patients with a significant distance/near disparity esotropia (>10 Δ) in whom a high AC/A did not exist, shown by an insignificant reduction in the near esotropia with the addition of plus lenses. Tonic convergence is suspected of causing the convergence excess, and the AC/A ratio is normal or subnormal by the gradient method in these patients. All patients in this study required surgical management of the esotropia.

The goal in measuring the AC/A ratio, is to isolate accommodative convergence by neutralizing all other aspects of reflex convergence (proximal, fusional, and tonic). Proximal convergence can be kept constant by performing all measurements at the same fixation distance, or minimized by performing all measurements with fixation at 6 m. Fusional convergence is suspended by using the APCT to obtain the measurements. Tonic convergence is not considered a significant factor in these measurements.

The two most commonly used clinical methods for determining the AC/A ratio are:

- the distance/near disparity method, and
- the gradient method.

Both methods control fusional convergence by use of the APCT. The distance/near disparity method does not minimize proximal convergence. One measurement is performed at 1/3 m and the other at 6 m. The gradient method either minimizes proximal convergence by the fact that both measurements are performed at 6 m or, in the case of near measurements, proximal convergence remains constant with all measurements being performed at the same fixation distance.

Parks studied the ratio of accommodation to accommodative convergence, calling it the A/AC ratio, in 1249 children. He stated that a perfect A/AC ratio is clinically recognized by the APCT at
6 m and 0.33 m being identical. Any difference between the 6 m and 0.33 m prism-alternate-cover measurements that was 10 Δ or less was considered a normal A/A, a difference of greater than 10 Δ was classified as abnormal. We can only presume that all abnormal ratios of greater than 10 Δ were considered to be high based on the fact that these patients were considered for treatment with bifocal spectacles and pharmacologic agents.

Of 897 patients with esotropia, 414 (45.8%) had an abnormal A/A ratio; of 352 patients with exotropia, 207 (58.8%) had an abnormal A/A ratio. A total of 151 patients with esotropia and an abnormal A/A ratio were treated with bifocals; in 19 (13%) the condition was reported as improved. In 47 patients treated with isoflurane, improvement in 32 (68%) was still evident 1 year following the discontinuance of isoflurane.

In a study of deterioration in accommodative esotropia, Ludwig et al graded the A/A according to the difference between the near and distance measurements: normal included 0 to 9 Δ difference; grade 1 ranged from 10 to 19 Δ difference; grade 2 from 20 to 29 Δ difference; and in grade 3 the difference was 30 Δ or greater. They termed this the linear A/A relationship. This method of making the diagnosis of a high A/A ratio—thus indicating the need for bifocal glasses or pharmacologic therapy to alter the A/A ratio—is commonly used in children. Of 119 patients, 67 (56.3%) were given bifocals, and deterioration occurred in 36 (30%) within 2.16 years of treatment with spectacles. They also stated that, in direct contrast to the findings of von Noorden et al, the higher the A/A ratio, the greater the rate of deterioration.

Our study reports that 45 patients had a high A/A ratio by the distance/near disparity method, but only 16 (36%) of these had a high A/A ratio by the gradient method using both plus and minus lenses. Of the 20 (44%) with a grade 1 classification, only two (10%) had a high ratio by the gradient method using both plus and minus lenses, and five (25%) had a normal ratio. This data suggest that measuring the A/A ratio using the distance/near disparity and the linear A/A relationship may “overdiagnose” a high A/A ratio, when the disparity is from 10 to 19 Δ.

In our study, no patient demonstrated a low A/A ratio using both plus and minus lenses. Eight patients (18%) had a low A/A ratio with +3.00 lenses at near and all of them had a grade 1 high A/A ratio by the distance/near disparity method. Four patients had a low A/A ratio with −3.00 lenses for distance. Clearly, all 12 patients showing a low A/A ratio at either testing distance would have been considered to have a high A/A ratio by the distance/near disparity method.

The most interesting finding in this study is the high degree of variation in testing methods, not only between the linear A/A relationship and the gradient method, but within the gradient method itself, using plus versus minus lenses. We expected that any difference would have shown fewer patients with a high A/A ratio using minus lenses for distance. The reverse was the case. Overall, 22 (49%) had a high A/A with +3.00, and 27 (60%) had a high A/A with −3.00 for distance. A possible reason for this is that fusional convergence is not being completely controlled in any of the testing conditions.

Kushner, in his 1987 Scobee Lecture on the classification of exodeviations, stated that in most strabismic conditions, if the A/A ratio is high using one method, it is also high using the other method, although it may be quantitatively different. Our patients do not bear out this theory.

In this same lecture, Kushner discussed a group of patients in whom a high A/A was initially evident by addition of +3.00 lenses at near; however, with −2.00 lenses at distance the ratio was normal. The patients in Kushner’s group were measured at near with and without +3.00 lenses after 1 hour of monocular occlusion, and the A/A ratio was found to be normal. He attributed this apparent high A/A to tenacious proximal convergence, stating that proximal fusion must first be suspended before the A/A ratio can be calculated using near measurements. The A/A ratio was not measured with minus lenses at distance after occlusion in these patients.

We suggest that in most of the clinical methods used routinely, some form of fusional convergence is not controlled simply by performing the alternate prism cover test, and the variations therefore, can lead to anomalous estimation of the A/A ratio.

Finally, von Noorden also described a situation in which an insignificant distance/near disparity may be present but a high A/A ratio exists. Obviously, as only patients with a significant distance/near disparity were included in this study,
such a group of patients is missing from our population.

The distance/near disparity method appears to detect a high AC/A ratio much more frequently than the gradient method with plus and minus lenses. Of clinical significance is the finding that only 10% of patients with low-grade (level 1) high AC/A ratio by the distance/near disparity and linear relationship, also had a high ratio by the gradient method.

The distance/near disparity method definitely fails to detect a normal to low AC/A ratio in patients with accommodative esotropia. A normal or low AC/A ratio is an indicator of a poor prognosis for nonsurgical management; therefore, it is necessary to measure the ratio in a way that will detect such situations before considering nonsurgical management.

The gradient method also appears to be somewhat variable in detecting an abnormal AC/A ratio, secondary to the lack of control of various forms of fusion. This study suggests that the distance/near disparity method alone should not be used to make the diagnosis of a high AC/A ratio, or to make a decision to undertake nonsurgical management for this type of esotropia.

Further study, using the gradient method after a period of monocular occlusion, and inclusion of patients who do not appear to have a high AC/A ratio by the distance/near disparity method would be beneficial.

REFERENCES