Article ▸ Calculation of CA/C Ratios by Binocular Cross Cylinder Test

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ABSTRACT

Background: Convergence accommodation to convergence (CA/C) ratios are rarely determined clinically, but they could be useful in understanding nearpoint visual function. The binocular cross cylinder (BCC) test has been suggested as a method for clinical measurement of CA/C ratios.

Methods: Data obtained from three separate data sets were analyzed retrospectively. CA/C ratios were calculated by dividing the difference in BCC findings at two different levels of convergence by the change in convergence.

Results: Mean CA/C ratios in the three data sets varied widely. The procedure that yielded CA/C ratios most like those previously reported in the literature was the performance of BCC tests with and without base-in prism.

Conclusions: BCC tests with and without BI prism may have potential use in the analysis of nearpoint vision disorders, but clinical application would require further evaluation and standardization of testing methods, establishment of norms, and development of analysis procedures which incorporate CA/C ratios with AC/A ratios and other clinical findings.

Keywords: binocular cross cylinder test, binocular vision, convergence accommodation, nearpoint vision disorders

Introduction

Determination of convergence accommodation to convergence (CA/C) ratios, in conjunction with routine binocular vision tests, could help in the understanding and analysis of visual function. For example, a patient with a normal AC/A ratio and a high CA/C ratio may be more likely to have accommodative error than a patient with normal AC/A and CA/C ratios.[1,2] However, it is rare for clinicians to determine (CA/C) ratios. To determine CA/C ratios, it is necessary to separate the effect of fusional vergence on accommodation from accommodation occurring due to other cues, such as blur. The fact that the elimination of other cues to accommodation is difficult may explain why CA/C ratios are rarely used clinically.

C.B. Pratt routinely determined CA/C ratios using the binocular cross cylinder (BCC) test.[3] He plotted AC/A and CA/C lines on an x,y coordinate graph and prescribed plus adds or prism based on the placement of those lines relative to the graph's demand line. Details of his analysis system are described elsewhere.[3,4]

In a study with six subjects ranging in age from 7 to 37 years, Schor and Narayan[1] performed the BCC and near dissociated phoria tests with and without 6^{Δ} BI prism. CA/C ratios were computed as the difference in BCC findings with and without prism divided by the phoria with and without prism. For each subject, the CA/C ratio reported was the mean of five CA/C ratio computations. They reported CA/C ratios in diopters per meter angle. With conversion into diopters per prism diopter, assuming interpupillary distances of 60 mm, the mean CA/C ratio was 0.107 D/Δ (SD=0.057), and CA/C ratios ranged from 0.042 D/Δ to 0.208 D/Δ.

Another study reported CA/C ratios for 19 young adults.[5] Two BCC tests were done with no prism, two with 8^{Δ} BI, and two with 8^{Δ} BO. A BI CA/C ratio and a BO CA/C ratio were determined by subtracting the BCC finding with prism from the BCC finding without prism and then dividing that difference by the prism power. BI prism was treated as a negative number and BO prism as a positive number, so positive values for CA/C were expected. The mean BI CA/C ratio was 0.036 D/Δ (SD=0.043). The mean BO CA/C ratio was -0.004 D/Δ (SD=0.043), which was not significantly different from zero.

This paper presents CA/C ratios from a retrospective analysis of BCC tests in three different data sets. Examination of these data may help to evaluate the feasibility of the use of the BCC test for clinical determination of CA/C ratios and start to identify typical values using the BCC.

Data Set 1

The first data set was taken from a student research project done by Davidson and Meyer at Pacific University.[6] Among the tests they performed were BCC tests with no prism, with 16^{Δ} BI, and with 10^{Δ} BO. We calculated CA/C ratios from their recorded test results by subtracting the BCC finding with prism from the BCC finding without prism and then dividing that difference by the prism power. A BI CA/C ratio and a BO CA/C ratio were calculated by treating BI prism as a negative number and BO prism as a positive number in the formula:

CA/C = (BCC with no prism – BCC with prism) / prism power.

Davidson and Meyer tested 20 subjects. Age was recorded for 19 subjects and ranged from 10 to 32 years, with a mean of 22.6 years. The BI CA/C ratios ranged from 0.016 to 0.125 D/Δ, with a mean of 0.068 D/Δ (SD=0.033). The BO CA/C ratios ranged from -0.125 to 0.162 D/Δ, with a mean of 0.052 D/Δ (SD=0.06).

Pearson correlation coefficients of age with CA/C ratio were not statistically significant. For age with the BI CA/C ratio, r = -0.17. For age with the BO CA/C ratio, r = +0.37.

Data Set 2

The second data set was taken from a student research project by Sponseller and Graham at Northeastern State University College of Optometry.[7] They tested 68 young adult subjects, most of whom were optometry students. They performed BCC tests with a 40 cm testing distance starting at +2.00 D over the subjective refraction. The BCC test was done first with no prism in place, then with 6^{Δ} BI, and lastly with 6^{Δ} BO. They recorded lens power when subjects reported that the vertical and horizontal lines were first equally dark or when the horizontal lines first became darker if there was no equal.

A BI CA/C ratio and a BO CA/C ratio were calculated with the formula: CA/C = (BCC with no prism – BCC with prism)/prism power, where BI prism was negative and BO prism was positive, so CA/C ratios would be expected to be positive numbers.

The mean BI CA/C ratio was 0.026 D/Δ (SD=0.06), with a range of -0.17 to 0.21 D/Δ. The mean BO CA/C ratio was -0.003 D/Δ, which was not statistically significantly different from zero. The standard deviation for BO CA/C ratios was 0.07 D/Δ, and the range was -0.17 to 0.17 D/Δ.

Data Set 3

The third data set used for analysis consisted of records of patients with myopia from a private optometry practice in Northern Illinois. The practitioner's examination data were obtained using the clinical methods in the Optometric Extension Program's (OEP) 21-point examination sequence.[8,9] For the purposes of this analysis, exclusion criteria were astigmatism over 2.50 D, strabismus or amblyopia, contact lens wear, ocular disease, or systemic disease which might affect ocular findings.

The test results used in the calculation of CA/C ratios were the induced phoria at near (OEP test #13B), unfused cross cylinder (OEP test #14A), and fused cross cylinder (OEP test #14B). It was reasoned that the change from unfused (monocular) to fused (binocular) cross cylinder findings would be due to convergence accommodation, and that the amount of convergence occurring on the fused cross cylinder would be equal to the near phoria. Thus, CA/C ratios were calculated by the following equation: (#14B – #14A)/#13B. Only subjects with exophoria or esophoria on the near phoria were included, so that there would be no cases of zero in the denominator as in orthophoria.

In the formula, esophoria was positive and exophoria was negative. With esophoria, fusion would be achieved by divergence, so the accompanying decrease in accommodation would be expected to result in #14B being more plus than #14A. With exophoria, fusion would be achieved by convergence, so the increase in accommodation occurring with convergence would be expected to result in the #14B being less plus than the #14A. With the formula above, positive values for CA/C would be expected in both esophoria and exophoria.

The 154 subjects ranged in age from 7.2 to 20.2 years, with mean age of 11.6 years. Exophoria at near was found in 66 of the subjects and esophoria at near in 88. The mean CA/C ratio for all 154 subjects was 0.048 D/Δ (SD=0.259).

Much different results were obtained in exophoria and esophoria. The mean CA/C ratio in the 66 subjects with nearpoint exophoria was 0.169 D/Δ (SD=0.338). That is a higher value than found in other data. The median CA/C in exophoria was 0.083 D/Δ, and the range was from -0.5 to 2.0 D/Δ. When only cases in which the exophoria was at least 2^{Δ} were considered, the mean CA/C ratio was 0.086 D/Δ (n=51; SD=0.118), with a median of 0.063 D/Δ and a range of -0.1 to 0.5 D/Δ. Thus, it would appear that the outliers could be explained by small numbers in the CA/C denominator.

The mean CA/C ratio in subjects with nearpoint esophoria was an unexpected negative value, -0.043 D/Δ (SD=0.114). The range was much narrower than in exophoria, -0.5 to 0.25 D/Δ. When only subjects with esophoria of 2Δ or more were included, the mean CA/C ratio was -0.026 D/Δ (n=83; SD=0.084), with a median of -0.021 D/Δ and a range of -0.375 to 0.25 D/Δ.

Discussion

Table 1 summarizes findings of studies where CA/C ratios were determined with cross cylinder measurements of accommodation, including both previous studies and the data analyzed in the present study. CA/C ratios have also been examined in several laboratory studies using optometers for the measurement of accommodation. A survey of nine of those laboratory studies found the mean CA/C ratios to range from 0.055 to 0.14 D/Δ.[5] The CA/C ratios in most laboratory studies have been higher than those reported in the present study.

One of the factors which could affect CA/C ratios is the time between the insertion of prism and the measurement of accommodation in the testing procedure. Convergence accommodation is associated with fusional vergence but not with vergence adaptation. Immediately upon insertion of a prism, the resultant fusional vergence will induce convergence accommodation. As the subject views through prism, fusional vergence will be replaced by vergence adaptation, and the amount of convergence accommodation will decrease accordingly.[10,11] Therefore, as the time the subject views through prism increases, the CA/C ratio decreases. Some of the laboratory determinations of CA/C ratio involve measurements

Table 1. Mean CA/C ratios in studies using cross cylinder tests to find change in accommodation. Standard deviations are in parentheses.

Study	Subjects	Mean CA/C using BI prism	Mean CA/C using BO prism
Schor& Narayan[1]	n = 6 7-37 years old	With 6Δ BI: 0.107 D/Δ (0.057)	
Goss, Vatnsdal, Babinsky, & Candy[5]	n = 19 23-30 years old	With 8Δ BI: 0.036 D/Δ (0.043)	With 8Δ BO: -0.004 D/Δ (0.043)
Present study, data set 1	n = 20 10-32 years old	With 16Δ BI: 0.068 D/Δ (0.033)	With 10Δ BO: 0.052 D/Δ (0.06)
Present study, data set 2	n = 68 young adults	With 6Δ BI: 0.026 D/Δ (0.06)	With 6Δ BO: -0.003 D/Δ (0.07)
		Mean CA/C using #14A, #14B, and #13B tests	
Present study, data set 3	66 with exophoria 88 with esophoria 7-20 years old	In exophoria: 0.169 D/Δ (0.338) In esophoria: -0.043 D/Δ (0.114)	

of convergence accommodation which are nearly instantaneous with the change in fusional vergence, so those CA/C ratios will be higher than those with the BCC where the subject is viewing through the prism for some period of time. It is unclear whether a CA/C unaffected by vergence adaptation or one reduced by vergence adaptation would be preferable for clinical analysis. It could be argued that a CA/C unaffected by vergence adaptation would be preferable because it would give an indication of the full initial convergence accommodation response. But it could also be argued that because vergence adaptation is part of everyday seeing, it should be allowed to occur in measurements of CA/C.

Two of the three mean CA/C ratios with BO prism in Table 1 were negative, although not significantly different from zero. Most persons have greater vergence adaptation to BO prism than to BI prism. The fact that the BI CA/C ratio was higher than the BO CA/C ratio in all three sets of data (Table 1) where both were done seems likely to be due to greater adaptability to BO than to BI. Schor and Narayan[1] suggested that BI prism be used for clinical measurement of CA/C ratios because vergence adaptation would be less with BI than with BO.

As can be seen in Table 1, the mean BI CA/C ratio was higher in the Schor and Narayan data than in the other data sets. A possible explanation is that they based their convergence value in the CA/C denominator on the difference in phorias before and after viewing through prism rather than the amount of prism. Therefore, vergence adaptation would affect both numerator and denominator, and the CA/C ratio would be somewhat higher. Due to the limited repeatability of dissociated phorias,[12,13] use of the mean of multiple repetitions of convergence accommodation and phoria measurements would be advisable, as was done by Schor and Narayan.

Another factor that affects CA/C ratios is amplitude of accommodation. The laboratory data of Kent[14] suggest that CA/C starts declining with amplitude of accommodation once the amplitude is below about 10 D. The correlation coefficients of age with CA/C ratio in data set 1 from the present study were not statistically significant. The CA/C ratios in the six subjects in the Schor and Narayan study did show a significant correlation with age ($r = -0.88$; $p < 0.05$). One laboratory study using stigmatoscopy to measure accommodation found a significant correlation of CA/C ratio with age in 41 subjects between the ages of 22 and 65 years ($r = -0.43$).[15]

For data set 3 in the present study, CA/C ratios were calculated using the #14A, #14B, and #13B tests in the OEP 21-point examination. Very different results were obtained in patients who had exophoria and esophoria at near. A negative CA/C ratio would not be expected in either exophoria or esophoria, but that is what was found for patients with esophoria at near. A negative CA/C could potentially occur in esophoria if the examiner had a bias in expecting less plus on the #14B than on the #14A. A problem with using these tests for CA/C calculation is that a CA/C is not found when the #13B is ortho. Also in cases of low phorias, either eso or exo, the denominator in the CA/C calculation will be low, and, as in data set 3, very high CA/C ratios could result. As a consequence, the standard deviations of CA/C using data set 3 are much higher than any other standard deviations in Table 1. It appears that the #14A, #14B, and #13B tests may not be useful for determination of CA/C ratios on a routine basis, although this does not negate the value of these tests for other analytical purposes.

It has been suggested that another clinical procedure for determining CA/C ratios would be to perform dynamic retinoscopy with and without prism while using a target with minimal blur cues. Mean CA/C ratios in three studies using Nott retinoscopy ranged from 0.023 to 0.09 D/Δ.[1,5,16] Two of those studies had six subjects each, and one study had 19 subjects. A fourth study using Nott retinoscopy did not report a mean CA/C, but the median was about 0.035 D/Δ.[17] One study which determined CA/C ratios by doing MEM retinoscopy with and without prism reported a mean CA/C of 0.06 D/Δ in 100 subjects.[18]

One can also ask whether theoretical considerations make the BCC test an optimal choice for clinical measurement of CA/C ratios. In measuring convergence accommodation, it is thought that blur cues to accommodation should be eliminated or reduced so that any accommodation changes observed can be attributed to changes in convergence. It is often assumed that the induced cylinder and reduced illumination on the BCC test reduces optical cues to accommodation. However, as lenses are changed on cross cylinder testing, there is some change in accommodative response,[19,20] indicating that accommodation is responding to blur. It may also be noted that there is more variability in BCC findings than on dynamic retinoscopy in non-presbyopes.[21,22] Because of this variability, questions have been raised concerning the usefulness of BCC testing in non-presbyopes.[11,23] Nevertheless, the fact that CA/C ratios are positive with BCC testing in each of the four entries under BI prism in Table 1 suggests that they did register changes in convergence accommodation.

Conclusions

Although there are theoretical concerns about the use of BCC tests to determine CA/C ratios, it is possible that BCC tests with and without BI prism may have potential use in the analysis of nearpoint vision disorders. Clinical application would require further evaluation and standardization of testing methods, establishment of norms, and development of analysis procedures which incorporate CA/C ratios with AC/A ratios and other clinical findings.

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