CLINICAL MEASURE OF THE CA/C RATIO:

A study of recently proposed techniques

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ABSTRACT

A new, simple gradient method of determining CA/C ratios in a clinical setting is described and compared to Schor's proposed dynamic skiametry and binocular cross cylinder techniques of measuring the same.

INTRODUCTION

The concept of convergence accommodation is by no means a new one, as it was formulated by Cross[1] in 1911. It has been described as the amount of accommodation which is the result of, or occurs with, an innervation to convergence.[2] Fry's[3] definition elaborates upon the need to open the accommodative loop, calling convergence accommodation "that amount of accommodation which is fully associated with convergence when the need for exact focusing has been eliminated." More recently, Fincham,[4] Kent,[5] and Balsam and Fry[6] have shown a reduction of convergence accommodation with increasing age and decreasing accommodative amplitudes. Their findings suggest a maximum CA/C ratio of 1 D per meter angle in young adulthood, which declines with advancing age and the resultant decreasing amplitude of accommodation.

The CA/C ratio has not been included in graphical analysis, nor has it been investigated intensively. The reason for this, is that there have been no routine ways of opening up the accommodative loop in a clinical setting.[5] Consequently, little use has been made of the CA/C ratio, not because its value or existence was questioned, but because there was no simple way of determining it clinically. This is not to say that there is no known way of determing the CA/C ratio, as elaborate methods using haploscopes,[7] lasers, and coincidence optometers[8] can accurately determine its value. These methods have been of little practical use for the clinician however, as they are expensive, cumbersome, and time consuming.

Recently, Schor[9] has proposed two ways of determining CA/C ratios in a clinical setting. We modified his technique, making it simpler, then developed a study which compared test results from our method to his two techniques.

Schor's methods of deriving the CA/C ratio are similar to those used to find the gradient AC/A. The gradient AC/A,[10,11] which equals the change in convergence resulting from a unit change in accommodation, is derived from the difference in two open loop convergence responses divided by the difference between their accommodative stimuli. This difference technique cancels all factors such as tonic and proximal convergence that are common to the two responses and reveals their difference: accommodative convergence. Similarly, the difference in two measures of quasi open loop accommodative posture taken by binocular cross cylinder or dynamic skiametry divided by the difference in fusional convergence stimuli during these two measures yields a gradient measure of the CA/C ratio. Schor's[9,12] first method consists of dynamic skiametry performed as the subject views a target at 40 cm. +3.00 lenses added before each eye to the distance correction are reduced until the retinal reflex shows a very fast against motion just outside of neutralization. The remaining plus add equaled the test result. Schor's second method employed the binocular cross cylinder test, which was conducted at the same distance, with the +.25 -.50 cylinder placed axis 90 before each eye. Plus spheres were added before the eyes until the vertical lines of a cross fixation pattern appeared darker than the horizontal lines. The plus add was then reduced until the horizontal lines appeared darker. The mean of the adds indicated by these two criteria equaled the test result. These tests of accommodation were conducted under two states of convergence; with and without 6^{Δ} BI prism before the eyes. The patients' near phoria was immediately determined after each test by placing a vertical 6^{Δ} prism before one eye and adjusting a horizontal Risley prism before the other eye until the eyes' targets were aligned vertically. Gradient CA/C ratios were computed as the ratio of differences in skiametry or crossed cylinder results measured with and without 6^{Δ} BI prism, divided by the difference in the near phoria, also measured with and without 6^{Δ} BI prism addition. Schor[9] measured the near phoria in this manner, rather than simply using the difference in prismatic amounts, because he felt prism adaptation would occur. In other words, he felt the vergence demand would be less than 6^{Δ} prism due to prism adaptation, and that the only true way to find the actual vergence demand would be to take phoria readings with and without the 6^{Δ} BI prism addition.

We felt that prism adaptation would not occur during the time span needed to complete these procedures, and that Schor's concern for this was complicating his methods. We devised a simple gradient technique in which the lag of accommodation was determined using Nott retinoscopy[13] through 6^{Δ} BO prism and 4^{Δ} BI prism. The difference between these two measures yielded the accommodative component. Simple division of this figure by the 10^{Δ} of prism used between the lag determinations would produce the CA/C ratio in a simplified fashion. A study was developed to compare the results derived from this method, to the results produced by Schor's techniques.

METHODS

All procedures were conducted with an American Optical phoropter, using a target distance of 40 cm. Schor's dynamic skiametry and binocular cross cylinder techniques, along with our simplified gradient method were performed on each subject with the order of their presentation varied. The subjects were refracted first, with the procedures performed immediately following.

Schor's dynamic skiametry technique was conducted as follows: +3.00 lenses were added before each eye to the distance correction. The subject was asked to view, and keep clear a 20/25 line at 40 cm. The tester positioned his retinoscope at 40 cm and reduced the plus lenses until the retinal reflexes showed a very fast against motion just outside of neutralization. This remaining amount of plus equaled the test result. Next, a near phoria reading was immediately taken. A vertical 6^{Δ} prism was introduced before one eye and a horizontal Risley prism before the other. The horizontal Risley was adjusted until the eyes' targets were aligned vertically, all the while reminding the subject to keep the targets clear. Next, the vertical prism was removed and the horizontal Risley was adjusted to 6^{Δ} BI. Dynamic skiametry was performed, as before, with reduction of the +3.00 up to neutralization. The 6^{Δ} vertical prism was reintroduced, and another near phoria measure was quickly taken over the 6^{Δ} BI prism. The gradient CA/C ratio was computed as the ratio of differences in skiametry results measured with and without 6^{Δ} BI prism, divided by the difference in the near phoria, also measured with and without the 6^{Δ} BI addition.

Schor's second method employed the binocular cross cylinder test,[14,15] and was conducted exactly as the dynamic skiametry technique, except the binocular cross cylinder was used to measure the accommodative component. The cross fixation pattern was placed at 40 cm, and the cross cylinders were placed before each eye over the distance correction. Plus lenses were added binocularly until the subject reported the vertical target lines as darker than the horizontal lines. The plus add was then reduced until the horizontal lines were reported as darker.

The mean of these two adds was the test result.[16,17] This was done with, and without 6^{Δ} BI prism before the subject, with the near phoria measurements taken immediately following, exactly as in the dynamic skiametry technique. The CA/C ratio was computed just as with the dynamic skiametry method also.

Our simple gradient method was conducted as follows: 6^{Δ} BO prism was placed over the distance correction, and the subject was asked to keep the target 20/25 line clear at 40 cm. Nott retinoscopy[13] was done, moving the retinoscope from the plane of the target, to the exact plane of neutralization. The difference in the accommodative demand between these two points (target and point of neutralization) was the test result; that is, 100 divided by the target distance of 40 cm equals a 2.5 diopter accommodative demand, and the difference between this and the accommodative demand of the point of neutralization (100 divided by the point of neutralization distance) yielded the test component. Next, a 4^{Δ} BI prism was placed before the eyes, as the 6^{Δ} BO prism was removed. Nott retinoscopy was conducted as before, yielding the second accommodative component. The gradient CA/C ratio was calculated by taking the difference between the two accommodative measures and dividing it by 10^{Δ} prism (the difference between the 6^{Δ} BO and 4^{Δ} BI prisms.)

SUBJECTS

Twenty subjects whose ages ranged from 6 to 43 years were examined. Most of these subjects were randomly selected from a population presenting at the Ferris State College of Optometry Clinic for eye examinations. The rest were selected simply upon the basis of subject availability with no other selection criteria.

RESULTS

Table 1 compares the CA/C ratios of individual subjects, as measured clinically by our simple gradient method, and Schor's dynamic skiametry and binocular cross cylinder techniques. Convergence accommodation is expressed in terms of prism diopters rather than meter angles (prism diopters equals meter angles multiplied by interpupillary diameter.)

Comparison of Schor's dynamic skiametry and binocular cross cylinder techniques (table 1) reveals a general equivalency for most subjects. This is further substantiated by a Pearson correlation coefficient (r) of +.641, indicating significant positive correlation.

Comparing our simple gradient method to either the binocular cross cylinder, or dynamic skiametry technique (see table 1) reveals a non-equivalency. However, once the scatter diagrams (tables 2 and 3) are inspected, a pattern of consistency is revealed. Additional support to this consistency lies in the Pearson r values, with $r = +.644$ for the simple gradient method versus the dynamic skiametry technique, and $r = +.652$ for the simple gradient method versus Schor's binocular cross cylinder technique. These r values show a high positive correlation. Further analysis of the results in table 1 shows a 4.6×10^{-3} p (chance occurrence) for the results of Schor's dynamic skiametry versus our simple gradient method, and a 4.0×10^{-3} p (chance occurrence) for the binocular cross cylinder results versus our simple gradient results. We found these values to be highly significant.

DISCUSSION

Our results show, in answer to our original question, that our simple gradient method, in itself, will not give responses equivalent to those garnered from either of Schor's techniques. The simple gradient technique consistently gave a much lower value to the CA/C ratio than either of Schor's techniques. However, although it was not in itself accurate, it was very consistent. Very high positive correlation was shown between our method and Schor's techniques with the Pearson correlation coefficient (r). This consistency can be used to relate the values found with our method, to those of Schor's, by way of regression equations. The dynamic skiametry technique's results were found to be related to the simple gradient method by the regression equation $Y = 4.97 \times 10^{-3} + .223X$, where Y = the dynamic skiametry CA/C, and X = the simple gradient method's CA/C. $Y= 6.86 \times 10^{-3} + .204X$ similarly relates the binocular cross cylinder CA/C (Y) and the simple gradient method's CA/C (X). Therefore, once the simple gradient method had been used, insertion of its results into the regression equations would give CA/C ratios equivalent to those derived solely from Schor's techniques. Inspection of the regression equations suggests that simply multiplying the simple gradient result by 4.5 would produce an approximate CA/C ratio, that would be a reasonable estimate. Further study is needed in this area, but the consistency and high correlation can not be ignored. Naturally, the question arises, as to why our method provided lower CA/C ratio results than Schor's? Reasonable guesses would be (1) prism adaptation, and (2) subject variation in accommodative response. Prism adaptation would tend to make the simple gradient method's results of a lower value than Schor's, but not by a factor of 4.5. It seems reasonable that the difference in the mechanical aspects of the design of the tests caused a variation in the subject's accommodative responses. For example, Schor's techniques require one accommodative measurement be made with prism before the subject, and one be made without. Our method had the subject looking through prism for both measures. Also, the subject's accommodative lag was determined by decreasing a +3.00 add before the subject in Schor's dynamic skiametry method. This would tend to produce a larger accommodative component than the Nott method we employed. This also would give lower values to the simple gradient method than to Schor's methods.

It is clear that our proposed simple gradient method, of deriving CA/C ratios in a clinical setting, did not produce equivalent results with Schor's techniques. However, the results our method produced could be converted by way of the regression equations (or roughly multiplied by a factor of 4.5) to yield results equivalent to those produced by Schor's methods. The exact nature of the components that necessitated this conversion factor can only be speculated upon, as more research is needed in this area to fully answer the question.

Table 1

COMPARISON OF CLINICAL MEASURES OF CA/C RATIOS

		CA/C RATIO - MEASURED IN DIOPTERS/PRISM DIOPTERS		
Subject	Age	Schor's Dynamic Skiametry	Schor's binocular cross cylinder	Our Simple Gradient
SS	26	.125	.100	.018
JT	22	.167	.125	.014
DS	36	.071	.083	.014
MS	12	.143	.167	.050
RS	9	.111	.167	.033
AT	7	.170	.125	.067
EV	15	.224	.143	.056
PW	43	.050	.041	.015
JS	34	.105	.067	.025
KS	23	.167	.091	.027
BC	22	.210	.222	.048
SO	23	.143	.222	.022
CG	6	.194	.250	.056
MR	11	.071	.143	.053
PK	41	.053	.091	.013
BS	27	.131	.083	.024
BJ	31	.083	.143	.025
SJ	31	.077	.059	.015
JR	8	.224	.200	.056
AH	8	.170	.222	.067

TABLE 2

SCATTER DIAGRAM

r= +.644

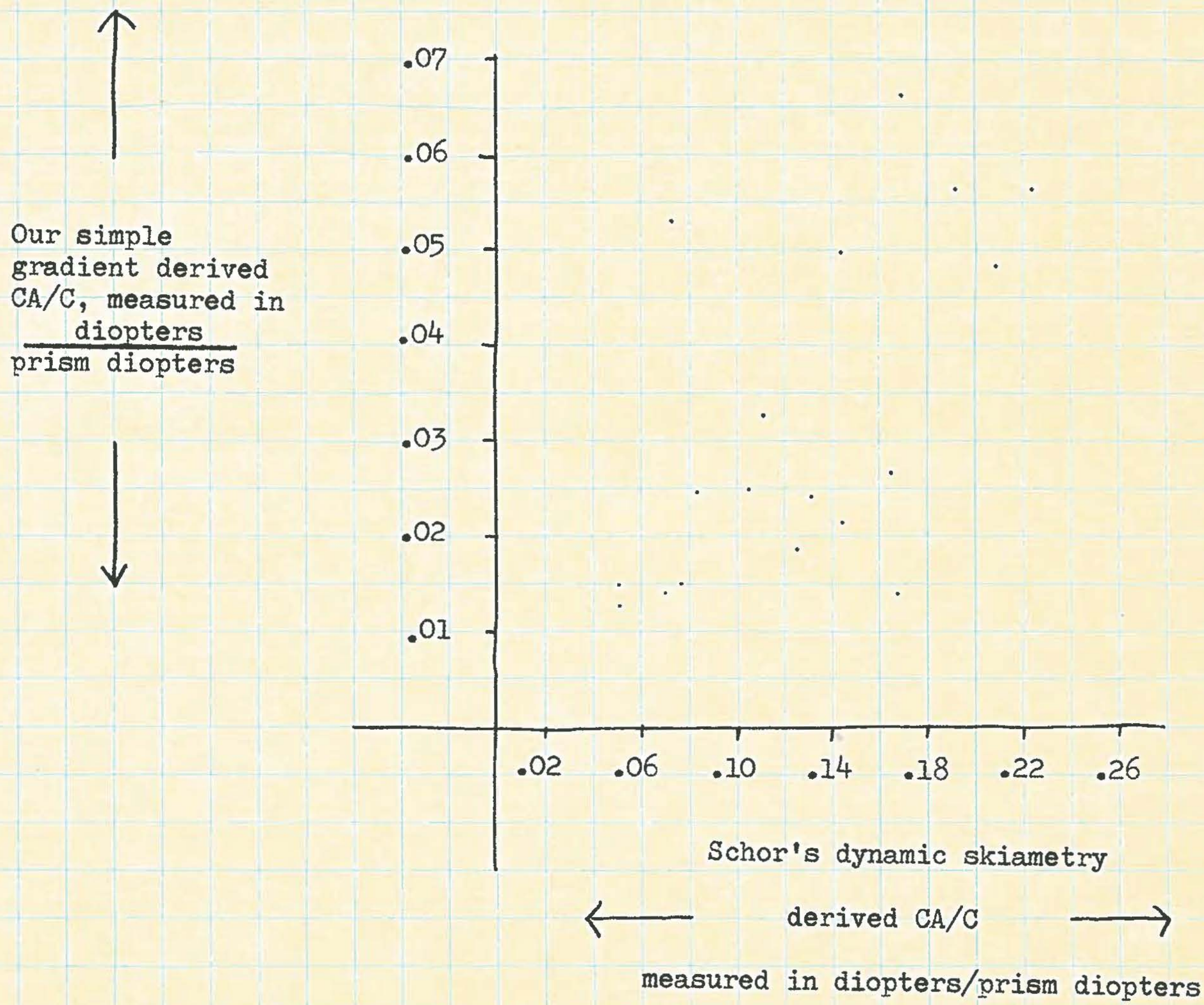
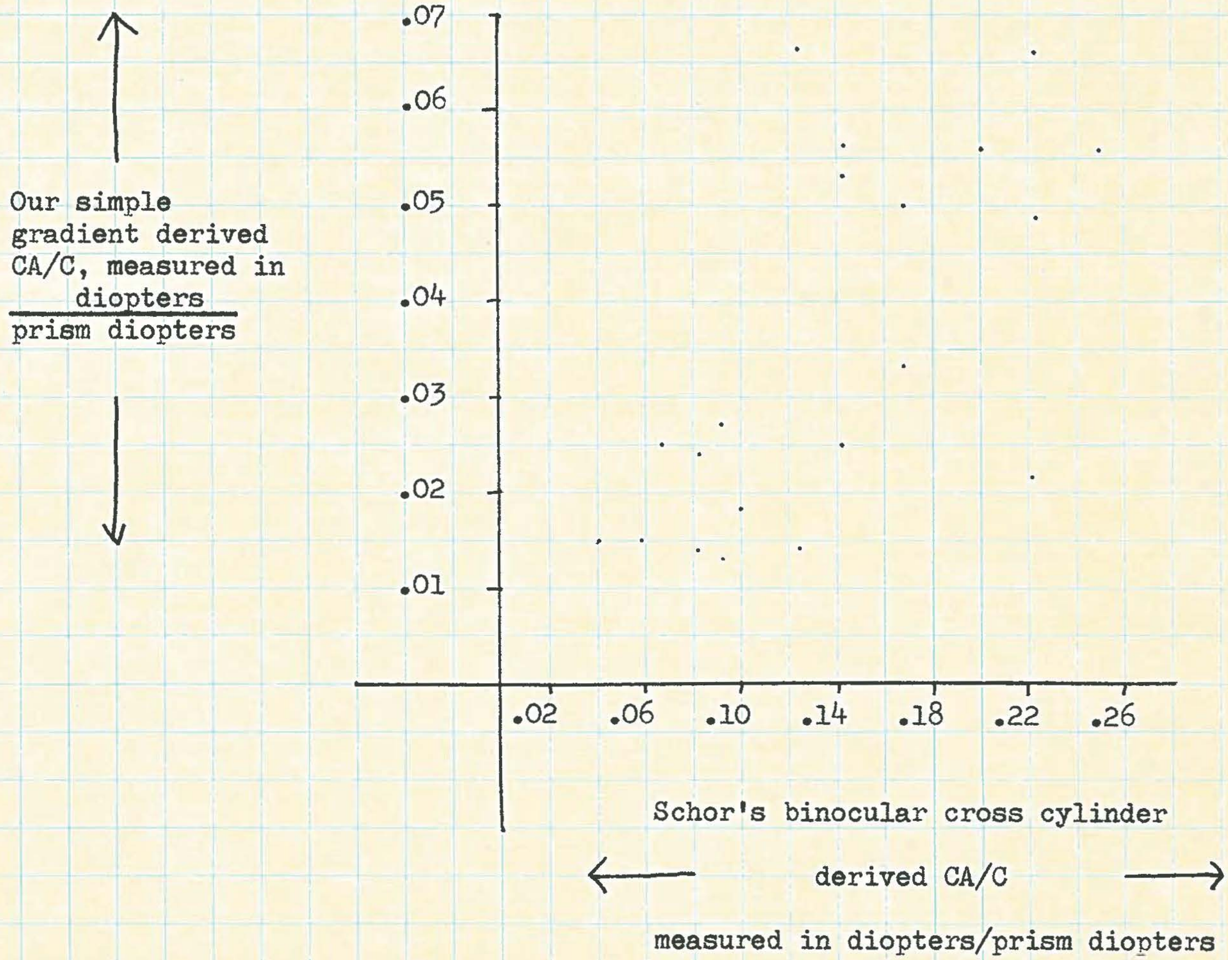


TABLE 3

SCATTER DIAGRAM

r= +.652



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