ETIOLOGIC FACTORS IN ACCOMMODATIVE ESODEVIATION*

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INTRODUCTION

THE TERM ACCOMMODATIVE ESODEVIATION APPLIES TO A CONVERGENT DEVIATION attributable (at least in the early stage) to an excess of the particular convergence linked to the innervational stimulus for accommodation. The following features constitute a typical case profile:

1. Onset during childhood, most commonly at age two or three years.
2. Intermittency of the deviation for a variable period from onset.
3. Possible absence of misalignment at distant fixation although it usually is evident. The deviation at near fixation is the same or greater than that at distance.
4. An angle of deviation under fusion-free conditions usually of 40 prism diopters or less.
5. A refractive error of above-normal hypermetropia (spherical and/or astigmatic), or of hypermetropia within the usual range for childhood in the presence of excessive accommodative convergence (high AC/A ratio).
6. Elimination of the deviation by reducing the accommodative demand; this is accomplished by the appropriate optical correction, or by anticholinesterase miotics.
7. Often an amblyopic eye, particularly when the deviation is constant; anisometropia, especially in the hypermetropic range of refractive errors, contributes to the development of amblyopia.
8. Demonstrable fusion capacity (normal or anomalous), even if it is not exercised in ordinary binocular visual circumstances.

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TR. AM. OPHTH. SOC. vol. LXXX, 1982

Accommodative esodeviation is observed classically in either of two contexts; one, referred to as *refractive* and solely attributable to excessive hypermetropia and normally-linked accommodative convergence acting under this disadvantageous optical circumstance, and another termed *nonrefractive* and associated with modest hypermetropia and an abnormal convergence mechanism.[1-3] An entity similar to nonrefractive accommodative esodeviation was identified by Costenbader[1] and labeled hypoaccommodative; its mechanism is the excessive focusing effort required for close viewing by an individual having a subnormal amplitude of accommodation. The distinction between nonrefractive and hypoaccommodative esodeviation usually is not made by the clinician; many ophthalmologists do not routinely measure the amplitude of accommodation; nor is this possible in much of the childhood age group. From the standpoint of therapy this is not a critical omission; the common goal of treatment in any form of this entity is the curbing of accommodative effort.

Another variation is the occurrence in the same individual of both major etiologic factors, ie, above average hypermetropia and an abnormal accommodation-convergence synkinesis; not only is the accommodative demand in the interest of clear vision excessive, but the obligate associated convergence response is further exaggerated. Logically an accommodative esodeviation patient with both major etiologic factors might be expected to pose a more challenging management problem.

The usual criterion for identifying an esodeviation as purely accommodative consists of demonstrating its disappearance or reduction to 10 prism diopters or less under the influence of the appropriate optical correction for hypermetropia, the use of topically applied anticholinesterase miotics, or at times both measures. This upper limit of residual deviation is in conformance to the observations of Parks[4] and of Lang,[5,6] who found that it was a requisite for the development of at least peripheral fusion, and that anywhere within this small degree of residual deviation the expectable best binocular function essentially is the same. Long-term management consists of supplying the appropriate optical or pharmacologic dampening of the accommodative response, and therefore of the associated convergence, until the natural tendency toward improvement appears in later childhood. This gradual reduction in accommodative overconvergence does not take place in every case.

There are exceptions to this prototype. For example, the diagnosis is not precluded by a myopic refractive error. In this instance any convergent misalignment at distant fixation is nonaccommodative unless the myopia has been overcorrected, since the improvement in distant vision gained by exact correction of myopia does not require accommodative

effort. Also, an accommodative mechanism plays a part in many cases of exodeviation. This can be an associated primary motor anomaly; in other cases it demonstrates characteristics of an adaptive response and disappears when the eyes are surgically straightened, since it no longer is required.[7]

Several aspects of accommodative esodeviation invite further scrutiny. This report is based on my personal experience with this condition and with factors thought to influence its natural course. The aims of this study were to examine:

1. How closely my own patient group conformed to traditional concepts with respect to the prevalence of etiologic factors.
2. The incidence of deterioration in cases showing each major etiologic factor.
3. The natural course of hypermetropia in this population of strabismus patients, and whether it differed from that in the general childhood population.
4. The occurrence of accommodative esodeviation as a sequel to surgically altered congenital esotropia.

BASIC AND CLINICAL CONSIDERATIONS

It is appropriate to review and comment on important features of accommodative esodeviation, namely (1) the accommodation-convergence synkinesis; (2) hypermetropia and refraction techniques; (3) deterioration to nonaccommodative esodeviation; and (4) accommodative convergence in the infant. Selected references will be cited.

ACCOMMODATIVE CONVERGENCE AND THE AC/A RATIO

The synkinetic innervational relationship between accommodation and convergence has been well established since the classic studies of Helmholtz[8] and Donders.[9] Miosis, another component of this synkinesis, is thought by some investigators to be linked to accommodation, and by others to convergence. This controversy has been reviewed by von Noorden.[10] The sophisticated neuroanatomic centers and pathways for these activities have been described.[11,12] Parks[7] has pointed out that the amplitude of accommodative convergence makes it by far the largest of the motor vergences associated with binocular vision, in the range of 70 to 84 prism diopters in the typical child with an interpupillary distance of 5 to 6 cm. This is from three to four times the amplitude of fusional convergence

elicited under conditions of constant accommodation, and larger still than the fusional amplitudes of horizontal and vertical divergence and of torsional vergence in normal subjects.

A more familiar and clinically more useful expression of the accommodation-convergence synkinesis is the AC/A ratio, whose excess or deficiency is comparable to that of the accommodative convergence amplitude. The two are similar in that they are parameters separable from the influence of fusion; in fact, to study either accommodative or fusional convergence clinically requires testing methods designed to insure this separation.[13] The advantage of considering the accommodative factor in terms of the AC/A ratio rather than of the total accommodative convergence amplitude is that the former encompasses events related to the optically useful application of the accommodation-convergence synkinesis under normal visual circumstances; the latter reflects an occurrence under maximal (and quantitatively unmeasurable) innervational effort, a condition which is extraordinary and on most occasions optically purposeless.

Accommodative convergence plays a part in exo- as well as in esodeviations,[7,14] and can be high, normal, or low in either. The classification by Duane[15] of horizontal deviations in terms of abnormal convergence and divergence did not emphasize the role of accommodative convergence (there is no accommodative divergence) in these entities.

How best to measure the AC/A ratio has been the object of much controversy. For investigational purposes the *gradient method* (spectacle lens-induced variations in accommodation at a constant fixation distance) generally is preferred, if the ratio is derived from measurements employing multiple stimuli (at least three) over a span of several diopters;[16] as such it is found to be linear in most subjects with normal ocular muscle balance over the range of accommodative demand likely to be utilized under ordinary visual circumstances.[17] Most investigators have used either a 6 meter fixation distance and graded minus lenses, or 33 centimeters and plus lenses in these computations; except for differences in numeric values for the AC/A ratio, linearity has been a repeated finding. Sloan and co-workers[16] also found linearity in subjects with esophoria and high AC/A ratios. This method of investigating the accommodation-convergence synkinesis virtually eliminates from consideration proximal convergence ("awareness of nearness"), which some observers consider to be a cortically mediated non-reflex application of this innervational phenomenon.[7]

Another way of deriving the AC/A ratio, which has not found a place in clinical use, is to compare *fixation disparity* induced by manipulating convergence with the disparity produced under varying accommodative

stimuli.[18] In such studies too, a linear relationship has been found. In contrast to other techniques to examine the synkinesis, the fixation disparity approach maintains the exercise of fusion during the determinations.

Awareness of nearness, whatever its basis, most likely contaminates the heterophoria comparison method of determining the AC/A ratio. In this derivation, which for accuracy requires an equation that takes into account the subject's interpupillary distance, the difference in binocular alignment at two fixation distances is related to the dioptric change between these distances. Ogle[19] compared AC/A ratios as determined by the heterophoria and fixation disparity methods, concluding that both are linear and quantitatively similar. He observed separately the phenomenon of proximal convergence, finding it also to be linear in relation to varying accommodative stimuli by the fixation disparity technique and in a higher ratio than that revealed by the heterophoria method. He emphasized that subject selection may have influenced this otherwise unexplained result. Of interest is Ogle's additional observation that "convergence excess" (in Duane's familiar classification) was associated with a high AC/A ratio but not with increased proximal convergence. The existence of a method to investigate accommodative and proximal convergence individually and to observe such differences emphasizes the enigmatic nature of the latter phenomenon.

Beyond these considerations and common to both the gradient and heterophoria methods is the difference between the stimulus and response AC/A ratios, reflecting the discrepancy between the demand for accommodation as determined by optical stipulations and the response based on a modified demand (eg, by presbyopia, depth of focus, etc). Studies[20-22] have shown that these ratios are parallel but not identical.

Despite its nonquantitative nature, the AC/A ratio as estimated simply by comparing the distance and near heterophorias is by far the most useful in the clinical setting. It is easier to ascertain since it employs conventional examination techniques and requires no calculations. Second, it is more practical in terms of examination time, a feature which becomes important in the diagnostic evaluation of young children.

That this distance-near alignment comparison is not actually either the stimulus or the response AC/A ratio should be kept in mind; however, the AC/A ratio as an exact number is of little diagnostic practical value. It has been pointed out that the true AC/A ratio, stimulus or response, can be studied only by observation and comparison of the innervational events which generate each of its components, and that the proper reference for considering the accommodation-convergence synkinesis is in terms of

accommodative effort that initiates this event.[23,24] Tait[17] has confirmed my own experience with several aphakic children, in whom an overconvergence at reading distance disappears when the appropriate plus-lens addition is supplied. This occurrence is not confined to childhood.

That acceptance of the distance-near comparison, apart from its clinical convenience, as an estimate of the AC/A ratio can at times be totally misleading is illustrated by the findings of von Noorden and co-workers.[25] In this study, designed to examine the role of bifocals in the treatment of accommodative esotropia, the AC/A ratio as determined by the gradient method was low, despite more overconvergence at near than at distance, in the one subgroup of patients whose response to bifocal therapy was poor.

Available evidence based on precisely measured AC/A ratios[16,21,26,27] as well as on its clinical substitute[7] indicates that surgery on the horizontal recti is somewhat helpful, orthoptic exercises are ineffective (they aid by increasing fusional divergence), and that optical correction and anticholinesterase "miotic" drugs assist by lessening accommodative demand during the time they are employed but not permanently. Parks[23] found that time alone was beneficial, especially after age seven years.

A parallel observation that incomplete cycloplegia increases the AC/A ratio during the period of action of the drug employed also has been made by Christoferson and Ogle.[28] The same effect was not evident in presbyopia, a superficially similar condition. These authors considered, as an explanation for these contrasting results, the possibility that the accommodation-convergence synkinesis has two components: one a fixed linear relationship which predominates in a slowly progressive loss of accommodation ability (presbyopia), the other similar to a conditioned reflex which holds sway in a more acute stress (partial cycloplegia).

Because of and despite the complexity of the AC/A ratio, clinicians continue to favor the less exact distance-near comparison.

REFRACTION AND THE CHOICE OF A CYCLOPLEGIC AGENT

There is difference of opinion as to how frequently the accommodative esodeviation patient must be examined under cycloplegia, to insure control of his deviation and to rule out the possibility that the appearance of a nonaccommodative component is not spurious.[29,30]

An element of this controversy derives from the contradiction of an earlier doctrine[31] that infants are at least moderately hypermetropic at birth and that this refractive state regularly diminishes over childhood. The investigations of several authors,[32-37] apparently confirmed by the clinical experience of many contemporary authorities,[29,30] suggest instead

that hypermetropia shows a tendency either to remain stable or to increase over the first seven years of life. Despite this evidence in non-strabismic subjects, there is no clear consensus as to whether this characteristic is exaggerated in patients with accommodative esodeviation.

At the same time, there is little agreement concerning which of the several available cycloplegic drugs is most suitable for the routine refraction of children, let alone for this crucially important determination in the esotropia patient. Classic teaching holds that only atropine is capable of overcoming the major portion of latent hypermetropia and that this is essential to the identification in esotropia cases of an accommodative element where none initially appears to be present.

Gettes,[38] applying the standard that an effective cycloplegic agent should leave no more than 2.00 diopters (D) of residual accommodative amplitude, found poor reliability of both tropicamide (Mydriacyl®) in strengths up to 1% and homatropine up to 4%. He concluded that cyclopentolate 2% (Cyclogyl®) gave findings entirely comparable (by his criterion, noted above) to those under atropine. He later refined his recommendation to one or at most two instillations of cyclopentolate 1% (2% for very dark irides), allowing maximum cycloplegic effect in 45 to 90 minutes.[39] Since such a regimen can be carried out entirely as an office procedure, the problem of extra visits is obviated.

Ingram and Barr[40] found that one or two doses of cyclopentolate 1% uncovered 0.40 D less hypermetropia and 0.19 D less astigmatism after 30 to 40 minutes than did atropine 1% used for four days. They considered these results clinically as well as statistically significant.

For usual examination requirements, the choice must be dictated by factors which go beyond the established pharmacologic properties of the various drugs. The use of multi-day atropine instillations, despite techniques to limit systemic absorption, undoubtedly present the dangers of tachycardia, fever, dryness, and psychic disturbances that, although frequently described as "allergy" by the lay person, are actually a poisoning effect, as was suggested by Knapp.[30] Apart from this, the prolonged wear-off time and the necessity of a repeat visit merely to accomplish the refraction are distinct hardships.

The less formal clinical experience of many strabismologists, sometimes comparing agents by successive refractions in the same individual or by measuring residual accommodation, indicate that several combinations of drugs other than atropine are entirely satisfactory for clinical purposes. In a recent round table discussion between several recognized authorities in this field,[30] the recommendations of no two participants were alike, ranging from office instillation of Mydriacil® to the routine use of atropine in

concentrations of up to 1% over a three-day period. In some schemes, age below four or five years was an important determinant of the need for atropine in esotropia cases. Others did not draw this distinction. The controversy has not completely subsided.

DETERIORATED ACCOMMODATIVE ESODEVIATION

A prominent characteristic of accommodative esodeviation is the presence in many cases of a nonaccommodative component as well, ie, some portion of the total crossing that does not respond to the reduction of accommodation effort. Progress to this state has been referred to as "deterioration." Usually the deterioration is not complete; there is at least a partial retention of the original accommodative component. Proper case management demands that the examiner be certain, by means of adequate cycloplegic refraction, that the residual deviation is not spurious and capable of improvement when an additional increment of hypermetropia is compensated.

The nature of this change is not completely clear; it has been attributed to contracture of the medial recti or of surrounding tissues thought to be the result of sustained convergence,[2,41] such that they are no longer entirely capable of relaxing when accommodation is discouraged. Conceivably, progressive increases in hypermetropia, such that treatment lags behind need, could contribute to deterioration. In instances where fusional divergence can reduce the residual overconvergence, this explanation based on anatomic changes would be inadequate; a tonic innervational change is an alternate consideration.

Deterioration is a frequent sequel in the untreated or inadequately treated patient, but it may occur also in patients diagnosed early and initially responsive[3,41] who under careful management and close observation develop the nonaccommodative component. When such a case first is seen at this stage, it is difficult to explore retrospectively the possible causative factors and circumstances that may have prevailed earlier in the patient's course. In such mixed esodeviations, with both accommodative and nonaccommodative portions, each must be identified and quantitated, since, as has been mentioned, there is general agreement that surgical measures should be applied only to whatever portion of the convergent misalignment is not eliminated by relaxing accommodative effort.[2,3,23,41]

This concept of deterioration requires one additional qualification. Often the deviation may be controlled adequately without resulting in the exercise of fusion, even though the condition is known to be acquired and the capacity for fusion can reasonably be presumed to remain. A more

common occurrence is for an accommodative deviation to be only partially reduced but due to a well-developed compensatory fusional divergence amplitude, to be kept latent and therefore result in straight eyes in ordinary binocular viewing. Management of accommodative esodeviations is based prominently on this second eventuality.

THE ROLE OF ACCOMMODATIVE CONVERGENCE IN THE INFANT

The most important primary nonaccommodative esodeviation of childhood is so-called "congenital" or infantile esotropia. The conventional view of congenital and accommodative esotropia is that they are distinct entities whose etiologic backgrounds are mutually exclusive. In the neurologically normal infant, anatomic characteristics of the extraocular muscles or their insertions, or more importantly a tonic innervational imbalance in favor of the medial recti have been considered responsible for the former anomaly. The definitive treatment of congenital esotropia is held to be exclusively within the province of extraocular muscle surgery as the means of restoring normal binocular alignment.

In addition to treatment differences, there are prognostic implications in the differentiation between accommodative and primary nonaccommodative esotropia. There are no proven cases of bifoveal fusion after restoration of alignment in congenital esotropia; even peripheral fusion is not obtainable in every case, and the age period during which this result is possible is a subject of controversy.[1,42-53] Some of this data is based on what is now an unacceptably broad definition of congenital esotropia for investigative purposes; thus the appropriate age for surgery in these patients is unresolved.

Several investigators[54,55] have shown that the accommodative mechanism is capable of functioning within the first few months of life. However, mere existence of this capacity is not sufficient to cause strabismus at this early age. An additional basic assumption traditionally has been that in the child of only a few months, irrespective of his degree of hypermetropia (if any), visual alertness and the necessity to explore his environment by means of visual information are at best rudimentary; accordingly, the need to apply the accommodation-convergence synkinetic response would be minimal; intermittency of convergence in a neurologically normal infant, corresponding to the intermittency of its accommodative response, would identify such an esodeviation. This postulate that a constant esodeviation in the infant only a few months of age is not based on sustained accommodation recently has been questioned.[56-59]

CASE EVALUATION

In this section I shall indicate some modifications of the routine strabismus examination which I have found helpful in the initial diagnostic assessment and in ongoing monitoring of the patient's response to treatment. It is assumed without further elaboration that the importance of estimating or quantitating visual acuity and of determining the presence of amblyopia, of evaluating the ocular rotations and characterization of any rotation deficiencies, and of excluding by inspection and careful ophthalmoscopy an organic sight-impairing condition to which the strabismus may be secondary, are well appreciated. Extensive descriptions of available tests for both sensory and motor aspects of strabismus evaluation are available.[13,60] Many of these procedures, although the information they yield is desirable, go beyond usual clinical requirements, or cannot easily be carried out in the childhood strabismus population.

Since intermittency at onset is a valuable clue to the presence of an accommodative component, the examiner should at the outset make every effort to assess the young patient's overall neurologic status. Many abnormal conditions, the prototype being cerebral palsy, show a high incidence of strabismus of several types[61,62] sharing with accommodative esodeviation the characteristics of intermittency and variability. In cerebral palsy these features tend to become less prominent after 18 months of age. Hiles and co-workers[61] reported true accommodative esodeviation in 20% of their series of patients with cerebral palsy. This was manageable by conventional methods.

The history is very valuable as a rapid screening device not only for neurologic status, but for systemic abnormalities and family history as well. Table I lists a series of screening questions that can efficiently uncover this information. Replies in the negative tend to eliminate most of our pertinent concerns. Overall body muscle tone and general alertness can be evaluated by the ophthalmologist as an incident of his examination, with a reliability generally commensurate with the extent of his (her) experience with children.

TABLE I: KEY QUESTIONS TO DETERMINE GENERAL HEALTH AND NEUROLOGIC STATUS

What was the child's birth weight?
Anything unusual in the pregnancy or delivery?
Did the child go home from the hospital "on time"? Any special treatments? Transfusions?
Is the child "on schedule" in development and skills?
Any "slowness" or seizures?
Is the child taking any medications regularly?
Any family members or relatives who are blind, visually handicapped, or who have had eye surgery?

The elements of pseudostrabismus are generally familiar to ophthalmologists.[46] Within the first months of life the differential diagnosis traditionally has lain between pseudostrabismus and congenital esotropia. A convergence response to increasing strengths of base-out prism (Fig 1) strongly infers the presence of binocular awareness, a state not likely to exist in the infant in the presence of a constant deviation. Moreover, the examiner can encourage accommodation by displaying a small detailed target at a viewing distance closer than the conventional 33 cm. With appropriate fixation attention, this exaggerated near stimulus usually will elicit an obvious overconvergence in the susceptible patient which, in casual seeing or under less stringent examination conditions, may be only suggested. An advantage of this variation in technique is its applicability whether excessive hypermetropia or an abnormal accommodation-convergence synkinesis is present. An additional advantage in examination of the infant is that there is greater likelihood of visual attention if a close fixation object is employed in this age group.

Although the prism and alternate cover test is the preferred method of measuring alignment, it is inappropriate in the presence of dense amblyopia and in practical terms, is usually impossible to perform in infants and retarded children. Under these circumstances, the Hirshberg and Krimsky light reflex methods are a less accurate but acceptable substitute.

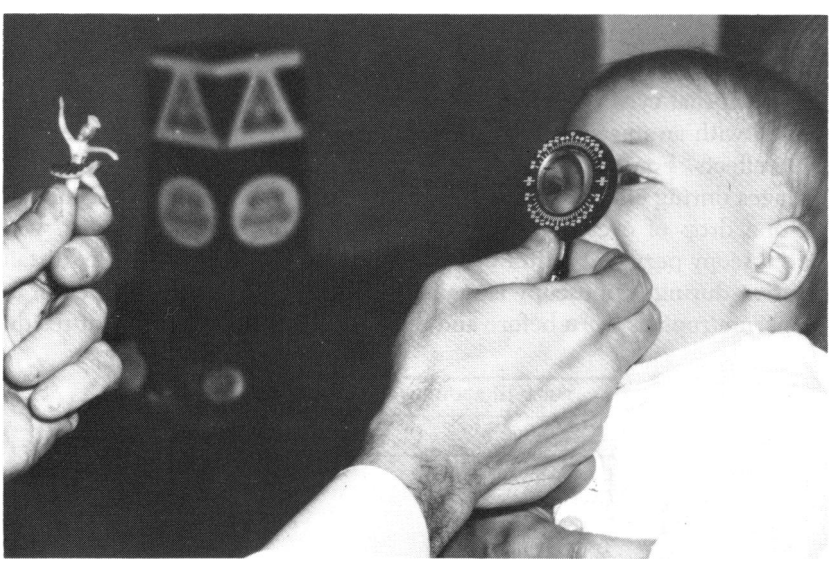

FIGURE 1
Convergence to base-out rotary prism as a test for binocularity in the infant.

Often overlooked when these alternatives are employed is that control of accommodation still is required. It is better not to employ the light generating the corneal reflection as the fixation target. The light and a separate target can be presented in an essentially coaxial manner to minimize this potential inaccuracy.

Observation of pupil size variation is an indirect way to monitor accommodative activity. This is especially helpful in the preliterate subject whose attention cannot be maintained on "accommodative targets." Detection of an overconvergence response synchronous with miosis suggests strongly that there is a contributing accommodating factor, if the observation is made under conditions of constant lighting. Light used as a fixation target will cancel the value of this observation.

The use of +3.00 D spherical lenses to uncover pseudodivergence excess in exodeviations is familiar to most ophthalmologists. This test also serves as a valuable clue in the accommodative esodeviation patient to the presence of residual uncorrected hypermetropia either prior to or over the course of treatment, if the near deviation immediately reduces to an amount less than that at distance with whatever correction, if any, is then being worn. This application of the "plus-3" test has been helpful on many occasions in predicting whether additional hypermetropic spectacle power is likely to reduce further a residual overconvergent alignment at distant fixation.[63]

Table II shows the various routines for cycloplegia that I have employed. Atropine is conspicuously absent from this list. My experience has been that cyclopentolate 2%, formerly employed routinely, was associated with an unacceptably frequent occurrence of particularly cerebral side effects. For the past several years my preferred regimen, applied at all ages during childhood and irrespective of pigmentation, has consisted of one drop of cyclopentolate 1%, repeated in 5 to 10 minutes, with retinoscopy performed after 60 to 75 minutes. Wherever possible, distant fixation during retinoscopy is maintained, and any existing correction for hypermetropia is worn before and during the examination, so that residu-

TABLE II: ROUTINES FOR CYCLOPLEGIA

AGENT(S)	NO OF INSTILLATIONS
Cyclopentolate 1%	2
Cyclopentolate 2%*	1
Cyclopentolate 1%*	1
Tropicamide 1% and miscellaneous	1 or 2

*Occasionally with tropicamide 1%.

al accommodation will be stimulated as little as possible. Often an attempt is made to grossly estimate residual accommodation by an additional brief measurement with fixation on the examiner; however, this is impractical to do precisely on a routine basis.

In the studies that follow, the refractive findings reported were not obtained during periods of use of miotics, nor within several weeks of their discontinuance. However, as a parenthetic observation, it has become apparent to me that the findings on refraction under cyclopentolate are not altered by echothiophate (Phospholine®) iodide used according to several customarily employed schedules (0.06% or 0.125%, from three to seven times weekly) even after several months, when retinoscopic measurements are compared during, and three or more weeks after, discontinuance.[64] Such information was not obtained regarding other miotics or other cycloplegics.

TREATMENT PROGRAM

This report is not concerned primarily with the details or results of treatment. The reader will recognize that the following summary indicates general conformance to commonly accepted principles of management of this strabismus entity.[2,3,41]

The cornerstone of management of accommodative esodeviations is to diminish the effort of accommodation, either by eliminating the demand (optical compensation) or by facilitating the accommodative response pharmacologically. The latter typically is accomplished by anticholinesterase agents, which although termed "miotics" because of such an auxiliary effect, act in this context as potentiators of innervation at the ciliary muscle.[21]

My preference is for spectacles (bifocals when indicated), and these are prescribed at the time of diagnosis. For most cases the full or within 0.50 D of the full cycloplegic measurement is ordered, unless the patient is already under satisfactory control through prior therapeutic efforts. Bifocal additions given for the first time are usually +2.50 D. Both the distance and near (if any) powers are reduced periodically by an amount determined by office trial to maintain bi- or (more frequently) monofixational fusion; however, single reductions of more than 0.75 D arbitrarily are not made irrespective of the trial result; unless there has been intervening surgery for a distance nonaccommodative component, such changes of lens power earlier than age five years usually are not possible. No special effort is made to coordinate lens power reduction with serial cycloplegic refraction, although most often these do coincide, since the

least assistance necessary is intended irrespective of the total hypermetropia.

The anticholinesterase miotics are well known to ophthalmologists,[22,65,66] and another review of their favorable properties, side effects and use in strabismus management is not needed here. That they have been employed only sparingly in the subjects of this report is based more on a personal assessment of reliability for both diagnosis and treatment than to any instances of detrimental effects from these agents, either local or systemic. When miotics have been employed, the indications usually have been short-term in patients whose clinical course was stable and satisfactory, or in those who were being treated adequately with these agents prior to having come under my care. Although drug treatment may be preferred to bifocals for V-pattern deviations, well-fitted spectacles serve acceptably. Moreover miotics do not compensate astigmatism nor, even more important, the anisometropic refractive errors which frequently are present in these patients, since only the accommodation of the less ametropic eye will be facilitated and this will not remove an important predisposing factor in amblyopia development. As much as for any of these reasons, a question of human nature enters: I have observed regularly that parents eager to avoid confrontation with their child over the use of spectacles will be comparably less than firm when faced with the substituted conflict of topical instillation.

Amblyopia is managed by conventional occlusion programs. Other than attempts to minimize the contribution of spectacles as described above, fusional divergence training by orthoptics or expansion by a schedule of tapered miotics has not been attempted routinely. Small essentially comitant accompanying vertical deviations are treated by incorporating prismatic correction in the glasses; larger deviations and particularly inferior oblique overaction occasionally require surgery even if horizontal alignment is acceptable.

MATERIALS AND METHODS

In a review of the records of patients in my practice, 287 were identified as having presented initially with pure accommodative esodeviation, ie, their distance misalignment was reducible to 10 prism diopters or less by measures to relax accommodation. Seventy-two patients were examined by me within six months of the reported time of onset of their strabismus. One of the more difficult items of information to obtain was an accurate history of onset age, due to imperfect recollection on the part of many parents. A best estimate based on other items in the history was made. In

some cases, records of prior evaluation and treatment were available. These were relied upon if necessary to establish age of onset and confirmation, and initial response to treatment, but only when they evidenced an approach to evaluation and management consistent with my own. Data pertaining to previous refractions and to alignment were not utilized.

All examinations were conducted personally by the author of this thesis. Of the 287 patients classified as having presented with pure accommodative esodeviation, 89 were examined on only one occasion, and could not be included in analyses based on longitudinal followup.

Measurements of binocular alignment were made in most cases by the prism and alternate cover method. Amblyopia persisting despite treatment which did not impair accurate fixation (a requirement for this method of measurement) was not regarded as grounds for exclusion. Light reflex measurements were relied on, if alignment changes were obvious, where prism and cover measurements could not be accomplished, as in very young or uncooperative subjects.

It is recognized that small deviations or changes in alignment of ten prism diopters present difficulty in measurement by light reflex testing. Even in these patients, a brief cover test enabling at least an estimation of the size of the refixation shift usually was possible. The same efforts to control accommodation at both distant and near fixation were made as for the prism and cover test.

Despite its limitations, the distance-near alignment comparison was designated the AC/A ratio. A high AC/A ratio was defined as an alignment at 33 cm more convergent by over 10 prism diopters than that at distance fixation, with the refractive error corrected. In patients examined several times, some fluctuations in these parameters occurred; in such cases the recorded contemporary impression was relied on in this retrospective study.

Patients with ophthalmoscopically visible organic lesions or significant cornea or lens opacification precluding useful vision were eliminated. Additional criteria for rejection were known major generalized neurologic or neuromuscular disorders, prominent congenital or other nystagmus, horizontal noncomitance due to paretic or restrictive causes, and prior surgery on the extraocular muscles. A or V pattern variations of the horizontal deviation were ignored, as was any vertical deviation not considered to be an element of a paretic or restrictive condition.

Refraction findings, when not tabulated separately for each eye, are for the spherical equivalent of the less ametropic eye. A spherical equivalent of 0.00 D (two patients) was allocated arbitrarily to the hypermetropia group. In the studies of changes in hypermetropia, the cycloplegic rou-

tines were those listed in Table II. To this extent these comparisons of cycloplegic measurements are not strictly uniform. However, no data are included in which tropicamide was the only cycloplegic agent used.

Most patients had one or more additional cycloplegic refractions within each one's own study interval and beyond. Although this might indicate that a cycloplegic determination was performed approximately once each year, no such regularity is implied. Interim examinations usually were done if accommodative control seemed precarious or to confirm the applicability of a contemplated reduction in plus spherical power, whenever such judgements were made. Although many retinoscopic measurements are expressed to 0.12 D, this is not meant to imply this degree of accuracy by the examiner, but rather that such values have been obtained by the arithmetic involved in determining spherical equivalents.

It already has been stated that, while fusion is an important element in the discussion of any strabismus entity, the distinction between latent and manifest esodeviation was ignored. Thus, a residual convergent misalignment of greater than ten prism diopters with fusion suspended and with control of accommodation, was held to be nonaccommodative even though fusion may have compensated part or all of it.

For convenience, additional methodologic details will be given in the sections of the study where they specifically apply.

It became apparent early in this project that gathering both historical and examination data, the latter especially in the youngest subjects, is very difficult to do with precision. This is exactly the dilemma confronting the ophthalmologist dealing with these problems in clinical practice.

PREVALENCE OF ETIOLOGIC FACTORS

Above-average hypermetropia and an abnormally high AC/A ratio are considered equally important etiologic factors in accommodative esodeviation.[2,23] The present patient group was scrutinized to determine how closely it adhered to this finding.

OBSERVATIONS

The AC/A ratio could be determined from the chart in 274 patients in the entire group. A normal AC/A ratio was recorded in 137 (50%), and a high AC/A ratio in 137 (50%). The distribution in Parks' esotropic patients is given for comparison (Table III). The differences in these two series are not significant (chi-square = 3.49, $P > 0.05$).

TABLE III: AC/A RATIO IN PURE ACCOMMODATIVE ESODEVIATION PATIENTS

AC/A	RAAB SERIES	PARKS[23] SERIES**
Normal	137 (50%)	289 (43%)
High	137 (50%)	378 (57%)
Total*	274 (100%)	667 (100%)

*No information available for 13 patients.
**Esodeviations only.

The refractive errors associated with each AC/A ratio in the 274 patients for whom both data were available is shown in Table IV. These findings were determined at the initial examination. Employing the unpaired *t*-test, the difference between mean hypermetropia in the normal and high AC/A ratio groups was significant ($P < 0.001$).

Table V indicates the distribution of refractive errors associated with each AC/A ratio (vertical columns), and the occurrence of each AC/A ratio at different magnitudes of refractive error (horizontal rows). Analysis of the occurrence of myopia and of different levels of hypermetropia in each AC/A ratio population indicates that the difference is significant (chi-square = 47.41, $P < 0.001$).

For convenience of inspection, the entire range of the 265 hypermetropic refractive errors has been condensed into three clinically more relevant groups (Table VI). With respect to distribution of normal and high AC/A ratios, the differences between these three subpopulations are statistically significant (chi-square = 25.76, $P < 0.001$).

TABLE IV: AVERAGE AND RANGE OF INITIAL REFRACTIVE ERRORS ASSOCIATED WITH EACH AC/A RATIO IN ACCOMMODATIVE ESODEVIATION

AC/A	NO OF PATIENTS	MEAN ± SD (D)*	RANGE (D)*
Normal			
Hypermetropia	137	+3.97 ± 1.75	+1.00 to + 9.75
Myopia	0		—
Total	137		
High			
Hypermetropia	128	+2.78 ± 1.60	0.00 to +9.00
Myopia	9	−1.78 ± 1.50	−0.37 to −4.25
Total	137		

*Spherical equivalent by cycloplegic retinoscopy of less ametropic eye.

TABLE V: RANGE OF REFRACTIVE ERRORS AND ASSOCIATED AC/A RATIO AT INITIAL EXAMINATION OF ACCOMMODATIVE ESODEVIATION PATIENTS

REFRACTIVE ERROR (D)*	NO OF PATIENTS	NORMAL AC/A RATIO	HIGH AC/A RATIO
> −2.00	3	0	3
−1.12 to −2.00	2	0	2
−0.12 to −1.00	4	0	4
0.00 to +1.00	17	2	15
+1.12 to +2.00	47	18	29
+2.12 to +3.00	69	33	36
+3.12 to +4.00	51	25	26
+4.12 to +5.00	41	25	16
+5.12 to +6.00	21	21	0
+6.12 to +7.00	11	8	3
> +7.00	8	5	3
Total	274	137	137

*Spherical equivalent by cycloplegic retinoscopy of less ametropic eye.

DISCUSSION

Parks'[23] refraction findings in hypermetropic subjects, using maximum rather than initial determinations, were +4.75 D and +2.25 D, in association with a normal and a high AC/A ratio, respectively. These figures referred to "acquired concomitant esotropia"; presumably this classification includes a predominance of patients with accommodative esodeviation. The lower mean of the present study (+3.97 D) still was sufficient to define this statistically separate variety. These results generally confirm the characteristics of accommodative esodeviation and support the finding of two distinct and equally prevalent clinical classes, each emphasizing one of the two major etiologic factors. While superficial inspection of Table V suggests similarities in the distributions of AC/A ratios at various refractive errors, analysis of the data established that this is not the case.

It is not surprising that accommodative deviations associated with myopia (9 of 9 cases) or with minimal hypermetropia (+1.00 D or less; 15 of

TABLE VI: AC/A RATIO ASSOCIATED WITH DIFFERENT LEVELS OF HYPERMETROPIA IN ACCOMMODATIVE ESODEVIATION

HYPERMETROPIA (D)*	NO OF PATIENTS	NORMAL AC/A RATIO	HIGH AC/A RATIO
+2.00 and lower	64	20 (31%)	44 (69%)
+2.12 to +4.00	120	58 (48%)	62 (62%)
+4.12 and higher	81	59 (73%)	22 (27%)
Total	265	137 (52%)	128 (48%)

*Spherical equivalent by cycloplegic retinoscopy of less ametropic eye.

17 cases) are characterized almost exclusively by a high AC/A ratio. The high AC/A ratio in the myopic individual with accommodative esodeviation is actually a matter of definition, since this refractive state does not call for accommodation for clear vision at distance when the myopia is corrected appropriately.

However, the separation into high hypermetropia-low AC/A ratio and its opposite is far from absolute. At the level of hypermetropia between +1.00 and +2.00 D, where a high AC/A ratio almost automatically is assumed to exist, 20 of 64 cases (31%) of accommodative esodeviation cases did not show this characteristic (Table VI). The exceptions are not easily explainable, except as they might illustrate a difficulty of substituting the distance-near comparison for a precisely determined AC/A ratio.

Parks' mean finding of +4.75 D for the high hypermetropia-normal AC/A ratio case suggests that this etiologic factor is capable of working alone at that magnitude. However, even at higher levels of hypermetropia, an associated high AC/A ratio appeared in a clinically important frequency. Thus the ophthalmologist would be well advised to be persistent in efforts to detect and control this additional element. The same suggestion applies to moderate levels of hypermetropia where this overlap of characteristics is common.

DETERIORATION AND ITS ASSOCIATION WITH EACH MAJOR ETIOLOGIC FACTOR

The prognosis for an uncomplicated course requiring simpler management and involving a small risk of deterioration generally is considered better for the high hypermetropia-normal AC/A ratio subject. This case material was examined to determine its conformance to this impression.

OBSERVATIONS

Of the 193 patients in this series followed longitudinally and for whom there was sufficient information, 32 (17%) showed deterioration and the appearance of at least a partial nonaccommodative component, at distance as well as at near. All 32 showed an increase in the distance deviation with accommodation controlled of more than ten prism diopters over their previous best position, irrespective of whether fusion had been lost.

Thirteen patients had been classified prior to deterioration as having a normal AC/A ratio; in two of these the AC/A ratio had become abnormally high with the appearance of deterioration. Nineteen patients were originally among those in the high AC/A ratio group; six of these had altered to a normal AC/A ratio with deterioration and the increase in their distance misalignment. Hypermetropia, age at deterioration, and the duration

TABLE VII: DETERIORATION IN PATIENTS PRESENTING WITH PURE ACCOMMODATIVE ESODEVIATION

AC/A RATIO	NO OF PATIENTS	NO DETERIORATED	HYPERMETROPIA* (D)	AGE AT DETERIORATION* (MO)	DURATION FROM ONSET (MO)
Normal	102	13 (13%)	+3.32 ± 1.68 (+1.00 to +6.50)	82 ± 45 (28 to 178)	42 ± 37 (5 to 136)
High	91	19 (21%)	+2.37 ± 1.57 (+0.87 to +6.75)	72 ± 22 (24 to 111)	46 ± 16 (21 to 75)
Total	193	32 (17%)			

*Mean ± SD (range).

from reported age of onset for each group is given in Table VII. Using the *t*-test, these differences are not significant.

Based on the prevalence of AC/A ratio in all serially followed patients, 13 of 102 (13%) of those with a normal, and 19 of 91 (21%) of those with a high AC/A ratio, showed deterioration. This difference is not signficant (chi-square = 2.30, $P > 0.05$).

Overaction of one or both inferior obliques was present in 11 (34%), and dissociated vertical deviation in 4 (13%) of cases showing deterioration; in the 161 cases remaining controlled, 22 (14%) and 7 (4%), respectively, showed these associated anomalies (Table VIII). For this small sample, the difference in the incidence of inferior oblique overaction was significant (chi-square = 7.97, $P < 0.01$). For DVD, the difference was not significant (chi-square = 3.26, $P > 0.05$).

TABLE VIII: INFERIOR OBLIQUE OVERACTION AND DISSOCIATED VERTICAL DEVIATION IN DETERIORATED ACCOMMODATIVE ESODEVIATION

DETERIORATION	NO OF PATIENTS	OVERACTION IO	DVD
Present	32	11 (34%)	4 (13%)
Absent	161	22 (14%)	7 (4%)
Total	193	33 (17%)	11 (6%)

DISCUSSION

Although deterioration to nonaccommodative esotropia is a prominent and anticipated complication of this entity, it is difficult to obtain a firm impression as to its incidence. Manley and Parks[67] cited an overall frequency of 20%, heavily weighted to the magnitude of the abnormal AC/A ratio. Baker and Parks[57] noted an incidence of 48% deterioration in 21 infants presenting with pure accommodative strabismus. Folk[68] reported that 11% of nonaccommodative but intermittently esotropic children

evolved to constancy. The 17% incidence reported here is statistically within the range of these authors' pooled experiences; however, the present group resembles only that of Manley and Parks in composition.

Deterioration is said to occur almost exclusively in cases showing a high AC/A ratio;[2,41] however this analysis shows that deterioration is not a characteristic of this group exclusively.

The change from a normal to a high AC/A ratio in two patients concurrent with their deterioration is difficult to account for, since to the extent that the distance-near comparison reflects the true AC/A ratio, such an occurrence would not be expected.[16] This may illustrate again the conceptual discrepancy in this approximation. The approach to a normal AC/A ratio in six deteriorating cases appears to be only an arithmetical paradox, reflecting the increase of the nonaccommodative distance deviation.

The normal and high AC/A ratio groups were very similar in their means and ranges of hypermetropia. This is in keeping with a previous observation and indicates that the comparable rates of deterioration were not influenced by a "leavening" effect of unequal hypermetropia. The comparative incidences of inferior oblique overaction and DVD are mentioned almost anecdotally, since the sample of deteriorated cases is small. These parameters were observed in an attempt to identify a possibly associated diathesis which in some way is etiologically linked to, or at least predictive of, the tendency to deteriorate. Predictive clues, whether or not completely understood, would be of considerable value in clinical management of many strabismus problems. These results suggest, but only tentatively, that inferior oblique overaction, but not DVD, might prove to be prognostically helpful. Many additional observations will be necessary to make any such determination.

CHANGES IN HYPERMETROPIA IN ACCOMMODATIVE ESODEVIATION

The refractive errors of these subjects were surveyed for changes in hypermetropia occurring over the first seven years of life. This age span encompasses the time of onset in the vast majority of accommodative esodeviations, and terminates at the expected peak of hypermetropia.[33-35] Therefore clinically important early increases would less likely be obscured than might happen if part of the age span in which decrease from maximum hypermetropia takes place had been included.

Although other authors, to whose studies these findings are compared, derived their results from subjects examined at intervals as short as one year, here two years was chosen in order to better approximate linearity;

this was done at the sacrifice of an additional 45 patients whose data otherwise might have been included. The longest possible time interval (of at least two years and not beyond the seventh birthday) for each subject was employed. The total spherical equivalent change of each eye over the interval in question was divided by the number of months in the interval and expressed as an annual change. Although elsewhere in this paper I have concentrated on characteristics of the less ametropic eye only, in this section both eyes of each subject were observed, as was done in the cited reports.

It was possible to identify 68 subjects (136 eyes) for whom the results of at least two cycloplegic refractions over a minimum of two years, ending no later than their seventh birthdays, were known. Mean values are compared and discussed in clinical rather than in statistical terms.

OBSERVATIONS

The age at first refraction, interval to last included refraction, initial hypermetropia, and annual change in spherical equivalent hypermetropia are shown in Table IX. There was an increase of $+0.19 \pm 0.36$ D (range -1.26 to $+1.03$ D) per year. The corresponding mean change from the study of Slataper,[34] interpolated for the same interval and commencement age, was an increase of $+0.28$ D per year.

Of the changes in hypermetropia, 92 (68%) were increases and 32 (24%) were decreases; 12 (8%) of the eyes showed no change (Table X). The corresponding findings are not stated by Slataper, but those of the earlier study of Brown[32] for "strabismus" patients (type not specified) are included for comparison. No significant differences are noted (chi-square = 0.52, $P > 0.05$).

TABLE IX: CHANGE IN HYPERMETROPIA TO AGE SEVEN YEARS IN PATIENTS WITH ACCOMMODATIVE ESODEVIATION

Number of patients	68
Number of eyes	136
Age at first refraction*	35 ± 13 mo
Initial refraction*	+3.71 ± 1.91 D
Observation interval*	37 ± 12 mo
Annual change* in hypermetropia**	+0.19 ± 0.36 D (range −1.26 to +1.03 D)

*Mean ± SD.
**Spherical equivalent.

TABLE X: DIRECTION OF CHANGE IN HYPERMETROPIA TO AGE SEVEN YEARS IN PATIENTS WITH ACCOMMODATIVE ESODEVIATION

	RAAB	BROWN[32]
Increase	92 (68%)	307 (69%)
Decrease	32 (24%)	107 (24%)
Same	12 (8%)	31 (7%)
Total eyes	136 (100%)	445 (100%)

It was possible to isolate 30 of these patients (60 eyes) whose initial and last included refraction had been performed using cyclopentolate 1% (two doses) on each occasion. These findings were tabulated separately to observe any effect of this added uniformity in examination technique. The change of hypermetropia over the interval of observation was an increase of +0.24 ± 0.45 D per year (Table XI). Interpolation in Slataper's study for comparable changes gives an increase of +0.25 D. In the present group, 42 (70%) of the hypermetropic eyes showed an increase, 14 (23%) a decrease, and 4 (7%) no change (see Table X for comparative data).

Increases in hypermetropia also have been considered a contributing element to deterioration, especially if undetected. In the previous section, mean hypermetropia at the first examination was the same for members of both AC/A ratio groups. Of the 32 patients demonstrating deterioration, 18 conformed to the criteria for inclusion in the study of refraction changes prior to age seven years. In these 36 eyes, hypermetropia showed an increase of +0.22 ± 0.26 D per year (Table XII).

In the same manner, changes in hypermetropia also were studied in 56 patients (112 eyes) over at least a two-year period from their 7th to their

TABLE XI: CHANGE IN HYPERMETROPIA (CYCLOPENTOLATE 1%) TO AGE SEVEN YEARS IN ACCOMMODATIVE ESODEVIATION

Number of patients	30
Number of eyes	60
Age at first refraction*	36 ± 7 mo
Initial refraction*	+4.04 ± 1.96 D
Observation interval*	35 ± ? 9 mo
Annual change* in hypermetropia**	+0.24 ± 0.45 D (range −1.25 to +1.03 D)

*Mean ± SD.
**Spherical equivalent.

TABLE XII: CHANGE IN HYPERMETROPIA TO AGE SEVEN YEARS IN PATIENTS WITH DETERIORATED ACCOMMODATIVE ESODEVIATION

Number of patients	18
Number of eyes	36
Age at first refraction*	29 ± 14 mo
Initial refraction*	+2.95 ± 1.46 D
Observation interval*	41 ± 13 mo
Annual change* in hypermetropia**	+0.22 ± 0.26 D (range −0.31 to +1.03 D)

*Mean ± SD.
**Spherical equivalent.

13th birthdays. This age span corresponds to that associated with lessening severity of accommodative esodeviation. Such cases included any from the group under age seven years who fulfilled the criteria for both determinations; this is consistent with the method in other studies cited in this report. The change in hypermetropia was a decrease of −0.18 ± 0.25 D per year (Table XIII). The previously reported corresponding finding was −0.22 D.[34]

Of these 112 hypermetropic eyes, the change was an increase in 19 (17%), a decrease in 87 (78%), and none in 6 (5%). Corresponding findings in other series were not stated.

TABLE XIII: CHANGE IN HYPERMETROPIA FROM AGES 8 TO 13 YEARS IN PATIENTS WITH ACCOMMODATIVE ESODEVIATION

Number of patients	56
Number of eyes	112
Age at first refraction*	92 ± 7 mo
Initial refraction*	+3.90 ± 1.62 D
Observation interval*	47 ± 14 mo
Annual change* in hypermetropia**	−0.18 ± 0.25 D (range −0.95 to +0.43 D)

*Mean ± SD.
**Spherical equivalent.

DISCUSSION

It is a common perception that childhood refractive errors undergo sizeable changes. Particularly has this been said of hypermetropia leading to the recommendation that patients with accommodative esodeviation be refracted at very frequent intervals and especially when their state of control is precarious. Moreover, this perception undoubtedly is, at least in part, responsible for the traditional preference for atropine in cycloplegic refraction even among those ophthalmologists who would rely on an alternate drug in routine examinations.

Another aspect of this question concerns the appearance of astigmatism and its changes over childhood; this is of great importance in the consideration of amblyopia and its prevention, but is not the particular concern of this report.

The most widely quoted surveys of refractive errors in children are those of Brown[33] and Slataper.[34] Although in Brown's effort the determinations were made by several observers, they were based on findings in a large number of subjects followed longitudinally. A three- to four-day atropine regimen was employed in all examinations. He found that over the first seven years of life, hypermetropia underwent an average yearly increase, greatest over the first three years and then decreasing progressively, of between +0.41 and +0.02 D (average increase +0.18 D per year). Thereafter a trend toward decreasing hypermetropia was apparent, averaging −0.23 D per year between ages 8 and 13 years, and −0.14 D per year between ages 14 and 20 years. Brown stated that children with strabismus (type not specified) comprised the greatest portion (73%) of subjects aged one to eight years; and that the results were similar in both strabismic and nonstrabismic subjects of either sex.

Slataper's study, in which the characteristics of his patients are not stated, combined his findings over the first ten years of life with those of Brown, with closely similar results. Slataper employed homatropine 2% as the agent for cycloplegia in all but "young children," who received a two-day course of atropine. His discussion suggests that this exception applies up to approximately age seven years. These authors studied refraction changes over several decades, information which is not relevant here.

Neither of these very comprehensive series indicate clearly their composition with respect to strabismus; both suggest a high preponderance of such patients in the years examined here. In an earlier report[32] Brown had noted in a much smaller sample that 69% of strabismic children (type not described) showed this increase in hypermetropia, contrasted to 47% in children without strabismus. Similar percentages of children in the

present group showed these changes; however, the magnitudes were unimpressive in most patients.

One recent report[69] dealing with strabismic children (not specified further) has indicated that 11% of eyes initially hypermetropic by at least +3.50 D, and 35% with less hypermetropia, increased by only a mean of +1.00 and +1.02 D, respectively, over a three to five year interval prior to age seven.

The present investigation is an attempt to resolve this question with respect to accommodative esodeviation. The results reported here indicate that for clinical purposes such changes in hypermetropia as were found would not appear to be of sufficient degree to influence either the prognosis or the method of management of accommodative esodeviation. The prominent warnings with respect to possibly undetected hypermetropia predisposing to deterioration and requiring the intense vigilance of frequently repeated cycloplegic examinations are not well supported by the fractional increases revealed here. It is of course true that clinically meaningful individual departures from these overall figures occur; in this group of patients, the largest single annual increase was +1.03 D. However, the results are not consistent with the suggestion that an accelerated rate of increase in hypermetropia is characteristic of most cases of accommodative esodeviation. Moreover, although a larger number of observations would have been preferred, cases that evolved to a deteriorated state showed increases in hypermetropia clinically comparable to the overall results.

The decrease in hypermetropia after age seven years found here was in general agreement with the data of Brown and Slataper. The rate of this decrease suggests that the natural tendency of accommodative esodeviation to improve during that age period probably also involves etiologic influences other than changes in the refractive error. This question was not studied directly.

The comparisons pointed out with respect to other series are inexact for several reasons. In the present report, although the findings are those of one examiner, several cycloplegic drugs (excluding tropicamide and homatropine, generally considered the least reliable) were employed. Moreover, the number of observations is relatively small and statistical comparison is not altogether feasible.

Nevertheless, these results suggest that the evolution of hypermetropia in childhood in individuals with accommodative esodeviation is similar clinically to that of a population of a corresponding age range not selected for this particular variety of strabismus.

ACCOMMODATIVE ESODEVIATION ASSOCIATED WITH CONGENITAL ESOTROPIA

In addition to the development of a nonaccommodative esotropia component in initially pure accommodative esodeviation, the reverse sequence is possible. In this section I shall describe an additional group of apparently typical congenital esotropia patients, in the majority of whom this latter progression occurred and very often was accelerated.

The records of 37 neurologically normal infants with a reliable history of esotropia which began by age six months and was confirmed by age one year were reviewed. Seventeen had their deviation confirmed by age six months, and a total of 30 by eight months. Within the limitations of examination in this age group, these infants appeared to present constant, moderate to large angles of overconvergence. Cases were excluded if there had been ocular muscle surgery previously performed elsewhere, a true subnormal horizontal rotation (as opposed to cross fixation), resistance on traction testing at operation, a preoperative accommodative esotropia component, consecutive exotropia after initial surgery (three cases), or less than a two-year followup after the first operation.

Each patient had undergone one or more surgical procedures. A large recession of both medial recti was included in the initial operation in every case. Thirty-two of the 37 patients had initial surgery by age 1 year, and all by age 15 months. Inferior oblique weakening for dysfunctional overaction was performed in conjunction with initial or subsequent horizontal rectus surgery if indicated. Twenty patients (54%) required at least one additional operation for residual esotropia. Postoperative alignment was assessed beginning at the sixth week after surgery and thereafter, regardless of observations made during the initial healing period. Overconvergence attributable to accommodative effort was considered to be present if a decrease in the esodeviation was caused by plus lenses or anticholinesterase drops or if an obvious increase in esotropia occurred in changing fixation from a distant to a near object. The change required in either event was more than ten prism diopters.

All subjects were hypermetropic. The annual change in refraction was determined by the method utilized in the previous section, except that the interval scrutinized encompassed the first visit (age one year or earlier) through the refraction nearest the fourth birthday. This span included the time of appearance of all but one of the accommodative esodeviations in these patients, and also is that of the greatest incremental change of hypermetropia.[33,34] Changes for both eyes were tabulated.

TABLE XIV: ASSOCIATION OF CHANGE IN HYPERMETROPIA TO AGE FOUR YEARS WITH ACCOMMODATIVE ESODEVIATION APPEARING AFTER CONGENITAL ESOTROPIA SURGERY

	POSTOPERATIVE ACCOMMODATION ESODEVIATION	
	YES	NO
Number of patients	27	10
Number of eyes	54	20
Initial refraction*	+2.68 ± 1.78 D	+2.33 ± 1.30 D
Observation interval*	30 ± 9 mo	37 ± 9 mo
Annual change* in hypermetropia**	+0.36 ± 0.75 D	−0.06 ± 0.43 D

*Mean ± SD.
**Spherical equivalent.

OBSERVATIONS

Twenty-seven (73%) of the 37 patients showed accommodative esodeviation after surgery, with or without residual nonaccommodative esotropia. This occurred at a mean age of 24 ± 11 months, with 12 cases presenting by age 18 months.

All ten infants not showing postoperative accommodative esotropia were at least 24 months old at the time of their last examination, the mean being 64 ± 22 months. When accommodative overconvergence appeared, it did so in 8 patients (30%) within three months and in a total of 11 patients (41%) within six months of their first operation.

The initial refraction, interval of observation, and annual change for those with and without a consecutive accommodative component is given in Table XIV. The first recorded refractive error and the time of the final studied determination were closely similar ($P > 0.05$). The accommodative component when present may have appeared at any time within this interval. The different degrees of change in hypermetropia between those

TABLE XV: DIRECTION OF CHANGE IN HYPERMETROPIA TO AGE FOUR YEARS ASSOCIATED WITH POSTOPERATIVE ACCOMMODATIVE ESODEVIATION

	POSTOPERATIVE ACCOMMODATIVE ESODEVIATION	
	YES	NO
Increase	38 (69%)	10 (50%)
Decrease	10 (19%)	10 (50%)
Same	6 (12%)	0 (0%)
Total eyes	54 (100%)	20 (100%)

who did and those who did not develop postoperative accommodative esodeviation is significant ($P < 0.01$). The direction of change in hypermetropia in the two groups is shown in Table XV. The difference is significant (chi-square = 8.51, $P < 0.05$).

DISCUSSION

Accommodative esotropia in patients showing only that anomaly most often begins at age two years or later. In Parks' series,[23] in only 182 (28%) of his 659 cases was the deviation present by age 18 months, whether the principal contributing factor was an abnormally high AC/A ratio or excessive hypermetropia. The overall incidence of postoperative accommodative esodeviation is difficult to establish because it depends in part on the length of followup of patients without such a finding. The emphasis here is on the accelerated appearance of the accommodative component when it did occur.

Baker and Parks[57] reported 21 esotropic patients first evaluated below one year of age who were converted to proper alignment by antiaccommodative therapy. Fifteen showed intermittency at onset, while six presented with constant esotropia. Seven of the 15 intermittent, and 3 of the 6 constant patients deteriorated and required surgery. Of interest is the observation that, of the ten deteriorated cases, there was an equal distribution of normal and high AC/A ratios and a longer duration to deterioration in the latter group. Only four of these ten patients had hypermetropia greater than +2.50 D in the less ametropic eye.

Although the reverse sequence was thought to be present in the cases reported here, a high incidence of postoperative accommodative esotropia occurred despite a preponderance, as was found by Fulton and coworkers,[70] of hypermetropic refractive errors within the range expected for this age. The direction of change in hypermetropia, rather than the initial level, seemed to be the determining feature of the susceptibility to this sequel, although in clinical terms the increases in hypermetropia were far less prominent than commonly held opinion would suggest.

Granted the difficulty of precisely evaluating infantile strabismus, one must consider the possibility that these patients were in fact unrecognized cases of pure accommodative esodeviation. This has seemed unlikely, since perpetually sustained accommodative activity is not required in children of this age group in relation to their visual demands. Moreover, generous weakening of the medial recti, on the basis of a mistaken diagnosis, would be expected to have resulted very often in consecutive exodeviation at least intermittently, although appropriate surgery too might produce such a result. Except for three cases which were excluded,

this was not observed other than occasionally and transiently in the first postoperative days.

Pollard[56] described constant esotropia in two infants with above normal hypermetropia who were staightened with glasses and had not deteriorated over six and nine months, respectively. Baker and Parks[57] observed a prominent tendency toward rapid fixed angles in their infants with accommodative esotropia, when initial hypermetropia was +3.00 D or higher. In both of these reports, the response to treatment indicated clearly the accommodative nature of the esodeviations, whether they were intermittent or constant.

The accounts of Rethy and Gal[58] and of Rethy[59] have introduced the hypothesis of "stabilized accommodative squint." These authors believe that the constancy of an esotropia at any age does not establish a nonaccommodative nature merely by failure to respond to accommodation-discouraging measures. They dispute the conventional notion that medial rectus contracture accounts for the nonaccommodative portion of the deviation, advocating instead that it is the accommodative response ("motor tonus") that becomes unrelievable in such instances, even when appropriate measures are taken. The angle of convergent misalignment based on this mechanism depends on the AC/A ratio of the particular individual. This explanation includes the possibility that this partial or complete stabilization in accommodative esotropia can occur suddenly, especially when not modified by the influence of fusion during the straight intervals of an early and still intermittent deviation. Rethy emphasized that the accommodative response may not be totally subdued even by atropine, generally conceded to be the most profound cycloplegic agent. This is based in part on an assumption that one of the several varieties of neuromuscular junction in the ciliary muscle observed by Ishikawa[71] subserves the "volitional" (rather than the "reflex") innervation of that structure. Accordingly, it is impossible to know, in a given instance, whether the refractive findings represent the uncovering of all latent hypermetropia, or in any event, whether accommodation innervational stimuli are completely subdued. Rethy cites, as additional evidence in support of his premise, the change in alignment (often to one of divergence) noted by himself and others[72] of the constantly esotropic patient under general anesthesia, stating that this occurs simultaneously with a change of retinoscopic measurement toward additional hypermetropia. Although I have not employed atropine cycloplegia routinely, in my experience retinoscopic findings under cyclopentolate (done to verify office examination findings and for various other reasons) rarely have shown this tendency.

Rethy's stabilization hypothesis is meant to account for all constant infantile esotropia. He found that "disaccommodative treatment" (optical overcorrection over time) was successful in 97% of 1,040 patients with constant esotropia,[58] although his youngest patients were at least two years old. Thus his results may not extend to cases in the age range of congenital esotropia. Burian and von Noorden[3] also have expressed doubt that this concept would apply to most congenital esotropes.

Still another aspect of infantile strabismus has been offered by Folk,[68] who described cases of intermittent esotropia in 47% of neurologically normal infants with what he considered to be nonaccommodative esotropia, although their deviations were smaller than expected for typical congenital esotropia. Since 14 patients eventually achieved straight eyes with glasses and no surgery, and 10 others responded when their amblyopia was corrected, the exact nature of these cases is not clear.

For the patients described here, two other possibilities arise: (1) that an accompanying accommodative overconvergence present before surgery had been masked by a large, fixed-angle infantile esotropia; or (2) that the former was a sequentially appearing anomaly as part of a strabismus diathesis. Either of these would support the observation that there appears to be a predisposition of the infantile esotropic child to partial or complete accommodative esotropia. Surgery is more likely to have been a fortuitous intervening step than a cause of this sequel. Of the many characteristics which are available for comparison, only changes in hypermetropia have been examined here. Further attention by prospective study is desirable. The essence of this description and review is that the correct identification of the infant with esodeviation remains one of the most difficult diagnostic problems in ophthalmology. No longer is confirmation of the deviation by age six months totally sufficient for differentiation. While accommodative and nonaccommodative esotropia typically have separate identifying characteristics, any one patient of whatever age may demonstrate both deviations together or consecutively, and in the latter case in either order. These findings are similar to those of Hiles and co-workers,[73] who reported on the associated abnormalities in children with congenital esotropia. They found that 65% of their patients required antiaccommodative therapy at various times after their initial surgery. The accommodative component should be suspected in every esotropia, and particularly looked for early as an "unmasked" factor in the operated infantile esotropia patient.

MISCELLANEOUS SETTINGS FOR ACCOMMODATIVE ESODEVIATION

Accommodative esodeviation has been observed as an associated finding in other strabismus entities. One of these appears as a sequel to surgery

for exotropia. Initial moderate overcorrection has been shown to be the most desirable immediate postoperative alignment in this condition.[74] Typically the esodeviation is greater at distance and subsides within several weeks. On occasion, and whether or not the ultimate alignment at distance has become satisfactory, a persisting larger esotropia at near is observed, which responds to the usual accommodation-relaxing measures. Particularly when the eyes are straight at distant fixation (with or without antiaccommodative treatment) and when there are normal rotations and no noncomitance, it is difficult to attribute this result to the surgery. Such an occurrence suggests that, coincident with the exodeviation, a second masked anomaly (accommodative esodeviation) was present. All of the several cases I have observed, operated by myself and by other surgeons, have been of the high AC/A ratio type without amblyopia and either myopic, or hypermetropic by no more than +2.50 D (spherical equivalent of the less ametropic eye). All showed the pattern of "divergence excess"[15] before surgery.

It is difficult to suggest how such an event might be predicted preoperatively, other than perhaps by the failure of the exodeviation at near to increase after monocular or alternating occlusion. The familiar "plus-3" test would not distinguish between an innate and an adaptive increase in the AC/A ratio.

Other and more uncommon associations that I have encountered personally are mentioned here anecdotally and largely for interest.

The presence of an accommodative deviation has been reported with both unilateral and bilateral Brown superior oblique tendon sheath syndrome.[75-77] Most such patients have been female. In one the vertical anomaly was intermittent, demonstrating the "click" attributed to tenosynovitis. The accommodative deviation in these cases was not otherwise unusual (Fig 2), nor was its character appreciably altered by surgical intervention for the abnormal rotation in those cases requiring operation. There was no obvious causal relationship in the simultaneous occurrence of these two conditions.

Similarly, I have observed three instances of an associated accommodative esodeviation in Duane retraction syndrome.[78] Two cases were unilateral (Type I), and one bilateral (Types I and III). They were distinguishable from four others demonstrating a pattern of "convergence excess," by the absence of a response to treatment in the latter; observations on these and other Duane syndrome patients with convergence/divergence-excess/deficiency patterns suggest that these are expressions of the retraction syndrome, and that they are associated most prominently (9 of 11 instances) with the Type III[79] form of this entity.

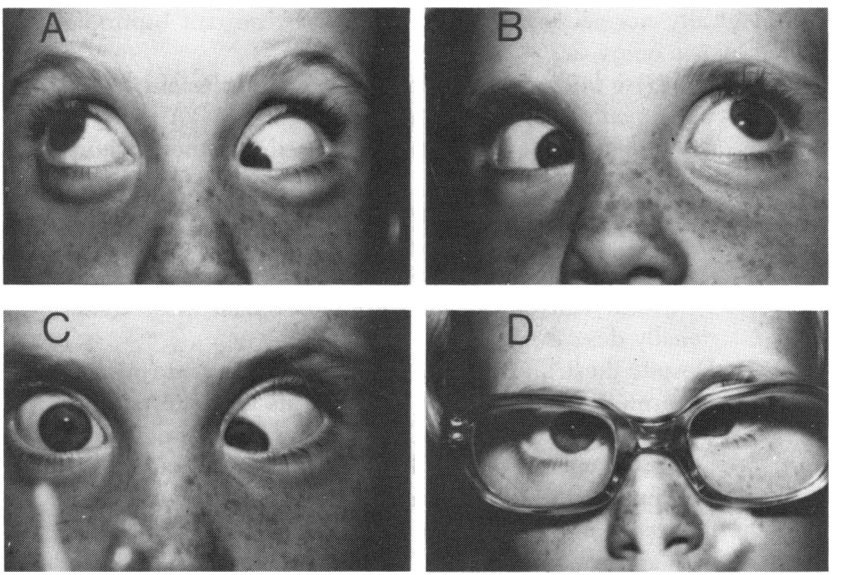

FIGURE 2
Accommodative esodeviation associated with bilateral Brown syndrome. A: Gaze up and right. B: Gaze up and left. C: Large esotropia at near fixation. D: Near esotropia markedly reduced by hypermetropic correction.

The relationship of congenital nystagmus to esotropia is complex and will not be discussed.

SUMMARY

A retrospective study was undertaken to define further the etiologic factors in accommodative esodeviation and their influence on deterioration, and to explore the role of abnormal accommodative convergence in congenital esotropia. Traditional concepts of the AC/A ratio and its clinical approximation, the natural course of hypermetropia, and of the classification of accommodative esodeviations were examined, and recent awareness of this entity in various clinical settings in the infant was discussed.

The records of 287 patients presenting initially with pure accommodative esodeviation were available for study. Of these, 198 were followed longitudinally. Tabulation was made of AC/A ratio, initial refractive error and annual rate of change, and presence or absence of deterioration. The first three determinations also were made on a separate group of 37

neurologically normal infants presenting with constant esotropia confirmed by age one year.

Analysis of these findings led to the following conclusions:

1. The equal distribution of normal and high AC/A ratios in accommodative esodeviation described by other authors was confirmed.
2. The difference in mean hypermetropia associated with a normal and with a high AC/A ratio in accommodative esodeviation was confirmed and was statistically significant, although the means were closer than those traditionally described.
3. Despite these findings, the separation of cases into normal hypermetropia-high AC/A ratio and its opposite pattern was not absolute; a high AC/A ratio was found prominently throughout the various levels of hypermetropia.
4. Contrary to traditional views, there was no significant difference in the incidence of deterioration between cases with and without a high AC/A ratio, although sample size was relatively small.
5. The rate of annual increase in hypermetropia up to age seven years was small in clinical terms and similar to that found by other authors in large age-matched populations containing both normal and unclassified strabismic individuals. The proportion of subjects in whom hypermetropia increased, decreased, or remained the same was not statistically different from those of other studies.
6. The rate of increase of hypermetropia in cases showing deterioration, for a small sample, was similar to that of the overall group and to that of other studies of populations not selected for strabismus.
7. Between ages 8 and 13 years hypermetropia in accommodative esodeviation patients decreased at a rate similar to that of other series not selected for strabismus.
8. Accommodative esodeviation, although typically commencing after age one year, can be a prominent feature of infantile strabismus, and may occur alone, or concurrent with or following correction of congenital esotropia.
9. Increase in hypermetropia, but not the mean initial level, was associated with the consecutive development of accommodative esodeviation in infants after surgery for congenital esotropia.

10. Accommodative esodeviation appearing after correction of congenital esotropia, and also when noted in association with even more remotely related ocular motility anomalies described here may be part of a strabismus diathesis.

ACKNOWLEDGMENTS

Several individuals deserve mention for the very important assistance they provided during the preparation of this report. I am extremely grateful for their efforts and concern.

Dr Steven M. Podos reviewed the manuscript and offered many valuable suggestions for its improvement. I thank him also for putting so much of the ophthalmology department's resources at my disposal at critical times.

Drs Michael E. Yablonski and Joel S. Mindel generously shared their experience with data analysis. Additional assistance in this aspect of the project was provided by Mr Phil Cook and Mr Larry Alvarez.

Ms Elizabeth L. Wilkins typed several drafts of the manuscript with skill and much patience. My secretary, Ms Helene Keyser, assisted invaluably in the large task of record coding and retrieval. Mr Calvin Dilligard obtained many of the references.

Support for this study, as well as for many of our institution's activities in pediatric ophthalmology, has been provided generously over many years by the Jack Martin Fund.

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