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Survey of British and Irish orthoptists in the measurement of the AC/A ratio

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Abstract

Aims: **To determine what practising orthoptists consider to be a normal AC/A ratio and on what evidence this is based. To assess which method of measurement is most commonly used and whether the ratio itself contributes to the diagnosis and management of strabismus in current practice.**
Methods: **A prospective cross-sectional survey was designed and distributed to all orthoptists registered with the British and Irish Orthoptic Society (BIOS). The survey was web-based and consisted of 17 questions relating to the measurement of the accommodative convergence/accommodation (AC/A) ratio and its application to clinical practice. Prior to the survey being distributed nationally, a pilot survey was sent to a small group of practising orthoptists for validation.**
Results: **There was a significant difference ($p < 0.05$) in orthoptists' perception of the normal AC/A ratio (gradient and heterophoria) compared with published research. Ninety-three per cent stated that their definition of 'normal' was based on either clinical experience or what they were taught during training, with the gradient method at 33 cm being most commonly used (92.79%). The AC/A ratio is widely used (either 'always' or 'sometimes') in the diagnosis of convergence excess esotropia (CXS) (97.26%) and intermittent distance exotropia (IDEX) (93.75%) and (either 'always' or 'sometimes') in the management of CXS (88.89%) and IDEX (79.02%).**
Conclusion: **The majority of orthoptists who participated are primarily measuring the stimulus AC/A ratio clinically. There is a discrepancy between participants' perception of a normal AC/A ratio and published research, yet the ratio is still used in the diagnosis and management of certain types of strabismus.**

Key words: AC/A ratio, Accommodation, Accommodative convergence, Clinical practice, Gradient, Heterophoria

Introduction

The AC/A ratio is the expression of the amount of accommodative convergence (AC), measured in prism dioptres ($^{\Delta}$), that is exerted for every dioptre of accommodation (A) that elicits this convergence. Studies have shown that the AC/A ratios measured in visually normal subjects[1–4] (ranging from 2:1 to 3.5:1) differ from the traditionally taught values of between 3:1 and 5:1. An earlier study by the current authors measured the AC/A ratios of 50 visually normal subjects and revealed a significant difference ($p < 0.05$) between the traditional values and those measured by the gradient method at 1/3 m (2:1), the gradient method at 6 m (1:1), the gradient method using the synoptophore (1:1) and the heterophoria method (6:1).[5] These methods are often interchanged in clinical practice and the ratio itself has historically been used to help diagnose and manage specific types of strabismus. To our knowledge there has never been a survey taken of orthoptic practice in relation to the measurement of the AC/A ratio, or what ratio orthoptists believe to be 'normal' in light of published research. It would be useful to know what orthoptists consider to be a normal AC/A ratio, how they choose to measure it and why, and how important it is in their own diagnosis and management of certain conditions. Once that is understood, we can determine as a profession whether we need to update both our clinical practice and our education of undergraduates in order that evidence-based practice can be followed.

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Methods

Ethics approval was not required due to the survey not involving patients or patient records.

A web-based questionnaire was designed through www.kwiksurveys.com. The access link to the questionnaire was sent to all registered UK and Irish orthoptists via the British and Irish Orthoptic Society (BIOS) inviting them to take part. Participation was completely voluntary and anonymous. The questions were chosen based on the primary and secondary aims of the survey:

Primary aims

- What do practising orthoptists consider a normal AC/A ratio to be?
- Which method do clinicians routinely employ to measure the AC/A ratio, from a choice of near gradient (NG), distance gradient (DG), gradient using the synoptophore (SG), heterophoria (H) or another method?
- Are the answers to the above points based on current research findings or not?

Table 1. Survey questions with response options

Question	Response choices
1. What do you consider to be a normal AC/A ratio?	From 1:1 to ⩾8:1 for NG, DG, SG and H
2. What do you base the above statement on?	Personal clinical experience, what was taught in training, current research, other (please specify)
3. Which method of measurement do you most commonly use to measure AC/A ratio?	NG at 1/3 m, NG at 6 m, SG, H, graphic, fixation disparity, other (please specify)
4. When measuring the AC/A ratio, what do you base your method of measurement selection on? Please select all that apply	Type of strabismus, patient co-operation, personal clinical experience, current research findings, departmental protocol, other (please specify)
5. What fixation target do you use when measuring the AC/A ratio?	Patient VA equivalent, 6/60 equivalent, 6/6 equivalent, whatever is convenient, other (please specify)
6. If using the gradient method, what lens strength would you begin with?	±3.00DS, ±2.00DS, ±1.00DS
7. If using the gradient method, how would you ensure that the patient has successfully overcome the lens that they are viewing the target through?	Ask patient if target is clear, ask patient to read same level of VA as without the lens, ask patient to read same level of VA as without the lens and ask if target is clear, other (please specify)
8. In your normal clinical practice, in which cases would you measure AC/A ratio? Please select all that apply	FAE, CXS, IDEX, any accommodative condition, any deviation with near/distance disparity, deviation with near/distance disparity greater than 10^{Δ}, other (please specify)
9. In your clinical practice would you measure the AC/A ratio to aid diagnosis of convergence excess esotropia?	Always, sometimes, never
10. Does the AC/A ratio measurement influence your management decisions in convergence excess esotropia? If you answer no, move on to question 12	Always, sometimes, never
11. At what level would you recommend to treat convergence excess surgically rather than conservatively (i.e. bifocal treatment or orthoptic therapy)?	1:1 or higher to 10:1 or higher
12. Do you use the AC/A ratio to aid your classification of intermittent exotropia?	Always, sometimes, never
13. Does the AC/A ratio measurement influence your management decisions in convergence excess esotropia? If you answer no, move on to question 15	Always, sometimes, never
14. At what level of AC/A ratio would you decide to use minus lens therapy?	1:1 or higher to 10:1 or higher, do not use additional minus lens therapy, other comments
15. Do you routinely monocularly occlude your patient for a minimum of 30 minutes before measuring the AC/A ratio?	Yes, no, IDEX only, CXS only, IDEX and CXS
16. Which method of measurement do you consider to be the most accurate?	Gradient, heterophoria, fixation disparity, other (please specify)
17. Give your reasons for the above answer and please include the test name in your answer	

NG, near gradient; DG, distance gradient; SG, gradient using the synoptophore; H. heterophoria; IDEX, intermittent distance exotropia; FAE, fully accommodative esotropia; CXS, convergence excess esotropia; VA, visual acuity.

Secondary aims

- Does the AC/A ratio affect the diagnosis and management of particular conditions?
- Which methods of measurement are considered the most accurate?
- How is each method employed in clinical practice?

The specific questions along with the answer options can be seen in Table 1.

Validation

A pilot questionnaire was sent to a group ($n = 11$) of practising orthoptists for validation. They were specifically asked for feedback relating to ease of understanding of the questions, general ease of completion, whether any pertinent points or questions had been omitted relating to their own clinical practice (for example different methods of testing the AC/A ratio that the survey did not indicate as an option or management practices that the questionnaire did not address) and any technical issues relating to the hyperlink or the questionnaire itself.

Data analysis

Proportional data were automatically collected by the survey provider and further statistical analysis was performed using a statistical software package (SPSS). Answers to questions that required specific comment were reviewed and grouped for analysis.

Results

The response rate was 16% ($n = 218/1402$) and there were no reports of participants having any difficulty in completing the questionnaire.

Perception of the 'normal' AC/A ratio

Proportions for what was considered the 'normal' AC/A ratio were varied (Fig. 1), with the majority of participants using a range of 3–5:1 and more than half indicating 4:1 or more as the 'normal' individual value.

Fifty-seven per cent ($n = 124$) of participants indicated that their answer to the question of what was the 'normal' ratio was based on 'what they were taught during their training as orthoptists'. Four per cent ($n = 9$) stated that they based their answer on recently published research.

These responses were compared with the mean measured AC/A ratio values in visually normal subjects taken from the earlier study by the current authors[5] (which were comparable with earlier studies) using a

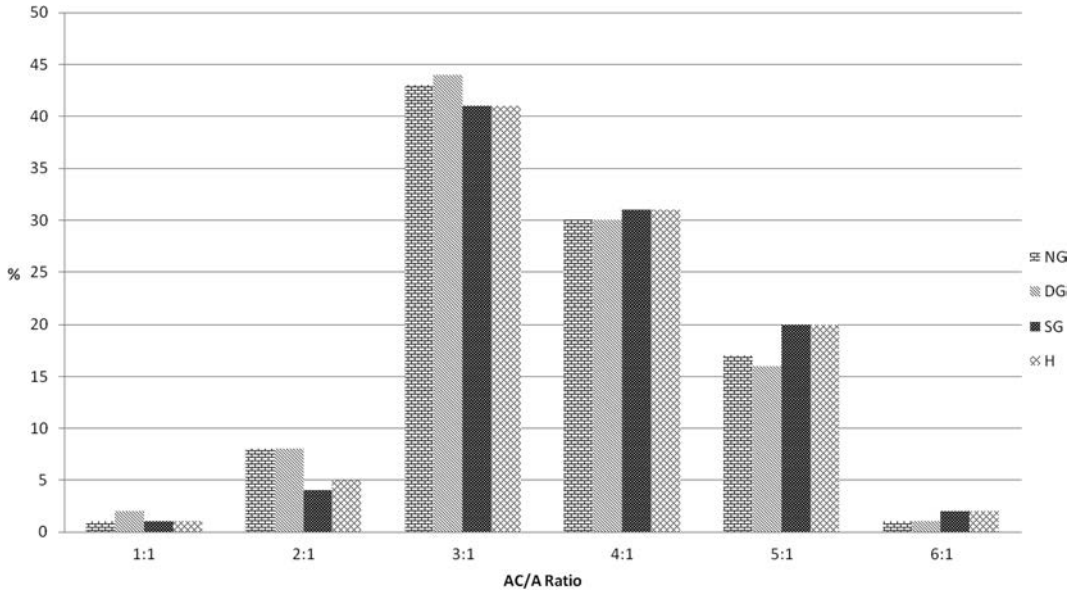

Fig. 1. Distribution of the perceived normal values for the AC/A ratio. NG, near gradient; DG, distance gradient; SG, gradient using the synoptophore; H, heterophoria.

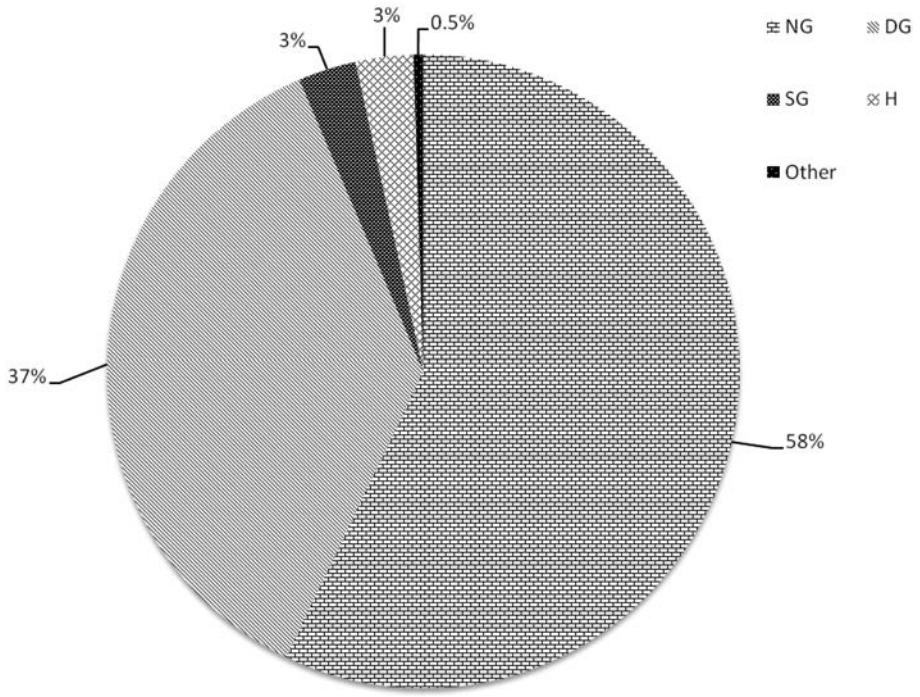

Fig. 2. Pie chart indicating proportional responses for each method of choice as participant preference. NG, near gradient; DG, distance gradient; SG, gradient using the synoptophore; H, heterophoria.

single-sample *t*-test. Participants' perception of the 'normal' AC/A ratio was significantly higher than that determined by research ($p < 0.05$) for all gradient methods.

Choice of method

The majority of participants (93%) selected the gradient method (NG or DG) as their preferred choice for measuring the AC/A ratio, with 95% considering this the most accurate method of measurement (Fig. 2). There were two other methods of AC/A ratio measurement that were specifically given as options but neither was used by any participant (the graphic and fixation disparity methods).

Of the two sub-types of gradient method, NG was the more popular (58%). As illustrated by Fig. 3, most participants indicated that this choice was based on the

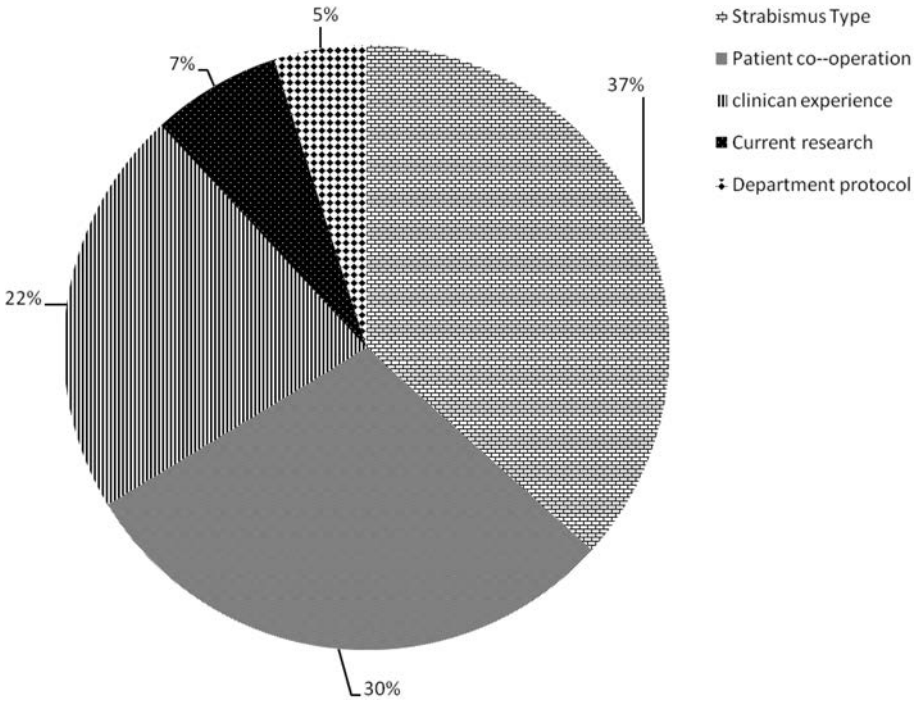

Fig. 3. Pie chart showing reasons for the choice of AC/A ratio measurement method.

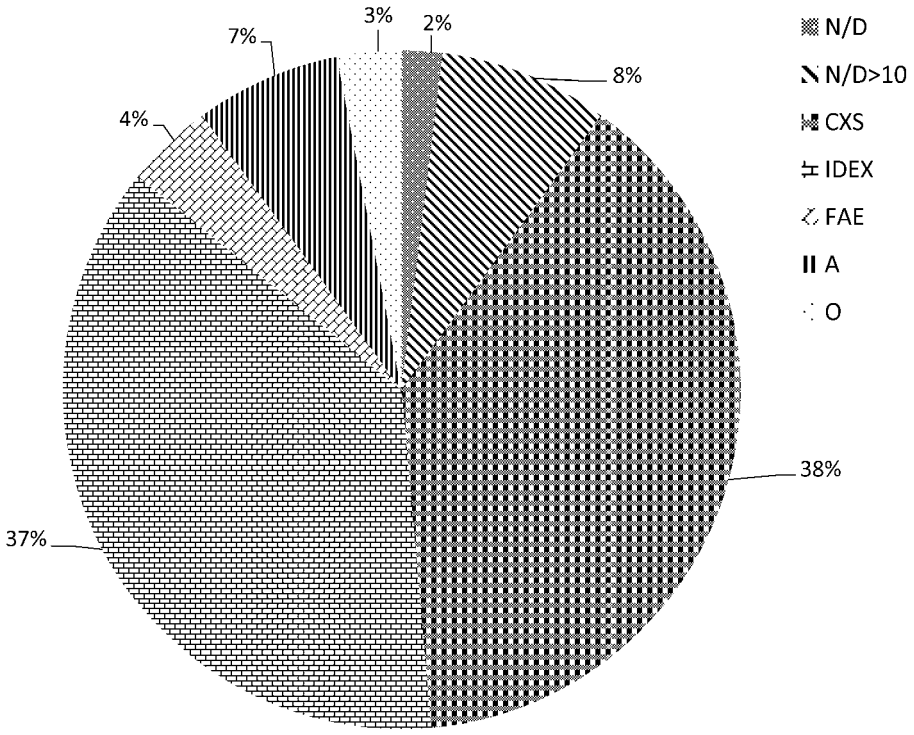

Fig. 4. Pie chart illustrating in which circumstances participants would measure AC/A ratio. N/D, all deviations with a near/distance disparity; N/D>10, all deviations with a near/distance disparity greater than 10^{Δ}; CXS, convergence excess esotropia; IDEX, intermittent distance exotropia; FAE, fully accommodative esotropia; A, any accommodative condition; O, other.

type of strabismus (37%), followed by patient co-operation (30%) and personal clinical experience (22%), with only 7% basing their choice on current research findings; a minority of participants' choice (5%) was dictated by departmental protocol.

When asked when they would measure the AC/A ratio in clinical practice, 38% and 37% stated that they would measure it in convergence excess (CXS) and intermittent distance exotropia (IDEX), respectively. Fig. 4 illustrates the full range of responses to the question of when

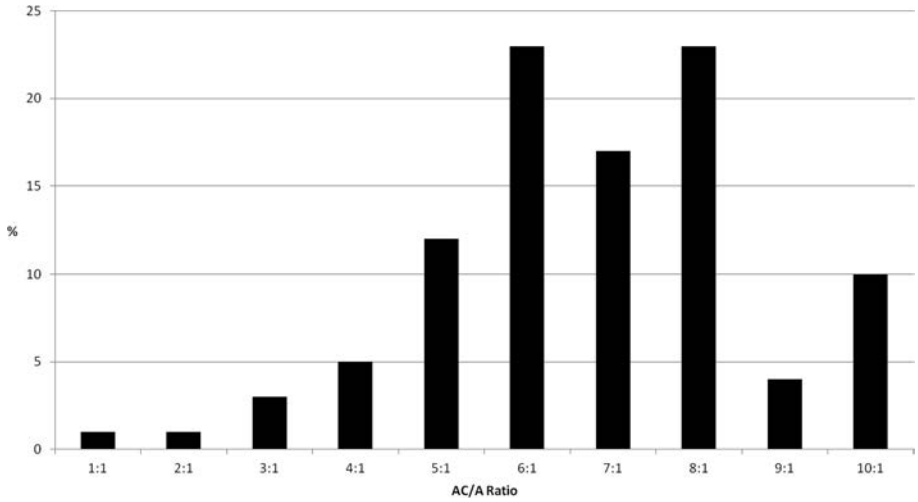

Fig. 5. Level of AC/A ratio when participants would advise surgical intervention for CXS treatment.

participants would measure the AC/A ratio. As the AC/A ratio has been traditionally used in the diagnosis and management of CXS and IDEX, further questions were asked relating to these. The vast majority (89%) of participants reported that the AC/A ratio 'sometimes' or 'always' influences their diagnosis of CXS, and 89% reported that the AC/A ratio 'sometimes' or 'always' influences their management of these patients. A similar pattern was found in IDEX, with 94% stating that the ratio either 'always' or 'sometimes' influences their diagnosis and 79% stating that it either 'sometimes' or 'always' influences their choices in the management of the condition.

Specifics of testing techniques

Participants were asked whether they routinely used monocular occlusion prior to measuring the AC/A ratio, with 62% stating that they did not at all and 28% stating that they only did this in suspected IDEX. The majority of participants (73%) used a fixation target equivalent to the patient's visual acuity for measurement of the AC/A ratio. The rest used 6/6 Snellen or equivalent (15%), 'whatever was available at the time' (6%), 6/60 Snellen or equivalent (4%) and 'other' (3%). When using the gradient methods, 94% of participants initially began testing with ±3.00DS lenses and 47% ensured that the lens had been successfully overcome by the patient by 'asking them to read the same level of text that they could without the lens and say if the target is clear'. Twenty-four per cent 'asked if the target was clear', 26% asked the patient to 'read the same level of text that they could without the lens' and 3% specified another method.

Impact on diagnosis and management

The majority of participants stated that the AC/A ratio influenced their diagnosis of CXS (97%) and IDEX (94%) either 'sometimes' or 'always'. A similar pattern emerged when participants were asked whether the AC/A ratio influenced their management of these conditions, with 89% stating that it did for CXS and 79% for IDEX.

Fig. 5 illustrates the wide range (1:1 to 10:1) of responses given by participants when asked about the level of AC/A ratio that indicates the need for surgical intervention in CXS esotropia. Ratios of 6:1 and 8:1 were selected most often as the level at which surgery would be indicated rather than conservative treatment, such as bifocals, as a long-term solution to the strabismus.

A less variable result was reported in the treatment of IDEX (Fig. 6), with 48% of participants indicating that they do not use minus lens therapy in the treatment of IDEX. Of those who did use minus lens therapy, there was again no one level of AC/A ratio that would determine the use of minus lens therapy in these patients.

Discussion

Perception of the 'normal' AC/A ratio

The results from this survey indicate a significant difference ($p < 0.05$) between research findings and what clinicians state as being the normal AC/A ratio. Over half of those surveyed stated that the 'normal' AC/A ratio is greater than 4:1 for all methods of measurement (Fig. 1). Not only is this higher than 'normal' AC/A ratios in published research, it is also higher than the traditionally taught normal values that are based on basic physiological and geometric principles.[6] The majority of participants (57%) stated that this answer was based on 'what they were taught during their training'.

Interestingly, there is little difference in the responses for H compared with NG, DG or SG, with participants stating 3:1 to be the normal ratio most often in all four methods, closely followed by 4:1 – yet anecdotal evidence and published data[5,7,8] have demonstrated that there are significant differences in measured AC/A ratios between these methods. Commonly clinicians will

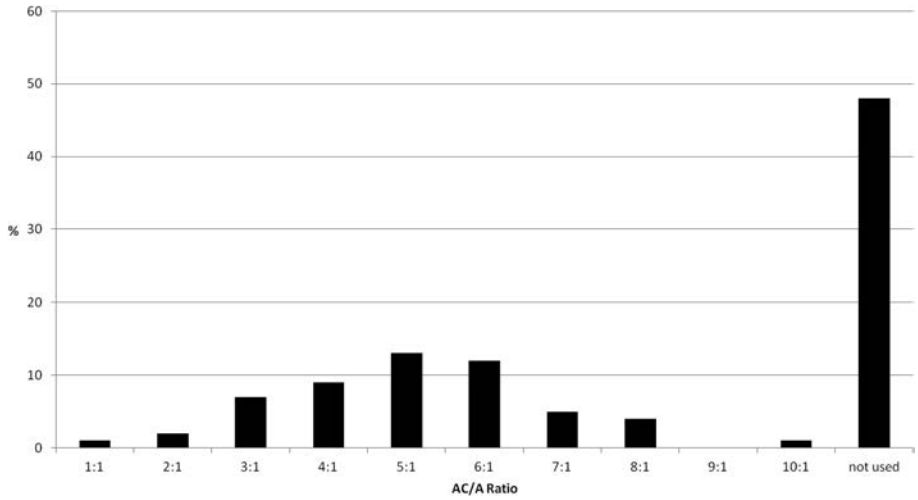

Fig. 6. Level of AC/A ratio when participants would use additional minus lens therapy for IDEX, including those who do not use this therapy in clinical practice.

anecdotally attest that H often over-estimates the AC/A ratio compared with either gradient method, and in fact Garretty[8] demonstrated a 5–6:1 ratio using H compared with 2–3:1 with NG and DG, which was statistically significant ($p < 0.01$). Even within gradient methods, which are often interchanged clinically, there have been differences reported.[5] A more recent finding reported by Horwood and Riddell[9] has further demonstrated that the 'clinical' NG method (stimulus), where the amount of accommodation exerted can only be presumed based on the lens strength used in the measurement of the AC/A ratio, does not correlate well with the response ratio at the same distance when the amount of actual accommodation exerted is measured with an autorefractor. The NG stimulus ratio test in fact correlated better with the CA/C ratio, suggesting that when as clinicians we are measuring the AC/A ratio at a particular distance, we assume that we are measuring one thing when in fact the evidence suggests that what is actually being measured may be something else. This point may reveal a slight limitation in scope of the questionnaire as a further question that may have been appropriate to ask would have been whether clinicians are aware of the difference between stimulus and response AC/A ratio, and which they are measuring in clinic.

Choice of method

The gradient method was the most popular (93%) and considered the most accurate (92%) method of choice. According to participants, the reasons for this generally fell into categories of: 'The gradient method has less variables and the ability to control the amount of accommodation' and that it also 'eliminated other convergence factors'.

These comments do reflect published evidence relating to the effects of proximal convergence on the AC/A ratio using H.[8,10,11] However, traditional teaching would state that using convex and concave lenses to stimulate a specific amount of accommodation allows the clinician to have the best control over how much accommodation is actually exerted or relaxed. This has been refuted[12,13] on the basis that unless the amount of actual accommodation is measured, with an autorefractor for example, only an assumption can be made about how much accommodation is physically exerted or relaxed through concave and convex lenses.

Fig. 3 illustrates the reasons why participants chose one particular measurement type. The most common reason was the type of strabismus (38%), rather than basing the decision on published evidence, for example. It would be interesting to know which types of strabismus result in a particular choice of measurement; however, that was beyond the scope of this survey. The fact that the majority of participants select one of the gradient methods (NG or DG predominantly) suggests that the answers given to this question about what is influencing method choice relate more to the choice between NG and DG rather than between any of the gradient methods and H, or even between NG, DG and SG.

Specifics of testing techniques

The practice of monocular occlusion prior to measurement has been advocated by Kushner[11] in a large prospective study of 304 patients in order to eliminate 'tenacious' fusion and gain a more accurate measure of a patient's AC/A ratio in IDEX. Kushner[11] further reported that a longer period of sustained occlusion prior to measurement significantly altered the ratio, which therefore changed the classification of the patient's condition. The use of monocular occlusion in this way has also been investigated in relation to CXS by Garretty,[14] who found monocular occlusion prior to measurement of the AC/A ratio resulted in two clinically and statistically distinct groups. The conclusion was that CXS could be sub-categorised in a similar way to IDEX. This obviously has implications in terms of classification and could potentially influence treatment if the two subgroups responded differently to treatment. However, until this has been investigated and reported further, one

would not expect clinical practice to shift significantly in respect to CXS, though there is evidence to suggest that the surgical treatment of IDEX should be different based on its sub-classification.[14] This classification is directly influenced by AC/A ratio measurement, and current clinical practice in relation to monocular occlusion does not appear to reflect this in the majority of this cohort.

The size of fixation target used has been shown to influence AC/A ratio measurements.[15] The majority of participants did use a fixation target that matched the patient's visual acuity, which does reflect evidence-based 'best' practice. Reasons for participants not practising in this way were stated as being due to patient age and/or co-operation. Due to reduced co-operation, using a larger target than is equivalent to a patient's visual acuity may be necessary in order to obtain any kind of measurement at all; however, if the patient is not required to accommodate much in order to view the larger object, it could well alter the accuracy of the result considerably. This may then raise the question of whether it is worth performing the measurement until there is a better level of control over how much accommodation is or is not being exerted in order to calculate the ratio accurately.

Participant choice of initial lens strength in gradient method testing showed similar trends in relation to patient compliance. The majority of participants would start testing with ±3.00DS lenses, which is established practice. However, those who commence with ±2.00DS or ±1.00DS stated that that choice was driven by patient age and co-operation with the test. Starting with the strongest lens may result in the patient not being able to perform the test immediately and therefore losing interest and concentration, leaving the orthoptist unable to obtain an AC/A ratio measurement.

Impact on diagnosis and management

Based on this cohort, management of CXS was influenced by the AC/A ratio, although more chose the option of 'sometimes' as opposed to 'always' in answering this question (67%). This suggests that the ratio is not as important in the planning of treatment as it is in the initial diagnosis, which is logical as it is not the AC/A ratio alone that will determine the management of a patient. Following this question, participants were asked further questions relating to treatment of CXS and the AC/A ratio, specifically, at what level of ratio they would recommend a patient to have surgical correction of their deviation. It is recommended that a ratio of $\geqslant$8:1 (alongside other factors) is too high for conservative treatment alone to result in long-term correction of the deviation[16] without continued bifocal use, for example. Although 6:1 (23%) and 8:1 (23%) were the two most popular choices, there was a wide range of ratios selected by participants in determining when to treat CXS surgically. This suggests that there is no overall consensus within this cohort as to what level of AC/A ratio would indicate surgical intervention as opposed to conservative treatment (usually bifocals); however, that may have been the result of slight ambiguity in the question. In CXS, those with very high AC/A ratios would be expected to respond to bifocals due to the fact that it is the interaction between accommodation and convergence causing the strabismus, and if that is removed with additional convex lenses, binocular single vision is restored. This question asked participants to indicate at what level of AC/A ratio surgery should be recommended but did not state specifically that this would be in order to permanently lower the AC/A ratio and restore binocular single vision at near without the need for long-term bifocal use. This could have potentially resulted in the variability in responses, with different participants interpreting the question slightly differently.

There has also been discussion in published research as to the best form of treatment for CXS and what the indications for each are: bifocal treatment[17] or surgery.[18] The variation in responses in this survey relating to CXS treatment may reflect the variability within published research, and although this would be an interesting question to answer, it was beyond the scope of this survey.

A further interesting finding of this survey was how the AC/A ratio affected the treatment of IDEX for these participants, as 79% reported that the AC/A ratio itself influenced their management choice. However, most participants (48%) also stated that they did not use minus lens therapy in practice in the treatment of IDEX. This would suggest that in this cohort the ratio itself is perhaps being used to determine surgical procedure rather than whether minus lens therapy should be employed when making treatment choices.

Data published over the last two decades suggest that, as a profession, orthoptists should be re-evaluating what the 'normal' AC/A ratio is in order to better understand the abnormal. Furthermore, there is more recently published evidence that challenges our basic assumptions about the relationship between accommodation and convergence in general and how it affects the behaviour of the visual axes in certain types of patients, in particular how it may not actually be accommodation but rather vergence that allows control of the deviation at near in IDEX.[13] If these findings are supported by further evidence, then we really do need to re-evaluate our basic understanding of the role the AC/A ratio plays in the diagnosis and management of strabismus.

Whilst there are clearly areas of practice and teaching that need updating in relation to AC/A ratio and published research, it is prudent to highlight evidence within other areas of orthoptic research, which demonstrates that it takes time for evidence-based practice to filter into common clinical practice for a number of reasons.[19] This is also an issue that goes beyond just orthoptic research, with one study reporting that it can take an average of 17 years for the evidence base to begin to influence and become common practice within other areas of medicine.[20]

Conclusion

From a relatively small cohort, the results of this survey illustrate the trend that current opinion relating to the normal AC/A ratio among UK and Irish orthoptists is significantly different from published research, with the latter being lower. For the profession to move toward

evidence-based practice in relation to the AC/A ratio, we must look to challenge our fundamental understanding of the normal AC/A ratio: how we measure it, how we interpret the results it yields, and the relationship between accommodation and convergence in different types of strabismus. Once that has happened then a revision of traditional values and practice may occur, with a shift towards the evidence base.

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