Newer methods of investigating strabismus

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The methods of investigation will be discussed under the following headings:

- (1) Detection and measurement of squint;
- (2) Assessment of visual acuity and fixation;
- (3) Recording ocular movements and diplopia;
- (4) Assessment of binocular function;
- (5) Assessment of retinal correspondence.

I have not attempted to include all the newer methods which have emerged in the last few years, many of which are research tools and beyond the scope of most patients and most clinics. The methods to be described have practical application, and some of the tests are not new at all, but have been "re-discovered", or viewed in a different light.

(1) Detection and measurement of squint

The cover test is one of the oldest methods of detecting squint, but I include it because the interpretation of its results has changed. Marshall (1968) discussed the purpose and significance of the cover test at the First International Orthoptic Congress in 1967, and stated that:

"If there is no movement of either eye to take up fixation when the other eye is covered and the corneal reflections are central, then bifoveal fixation and binocular single vision are present".

This statement can, however, no longer be accepted. An apparent absence of movement to fix may be due to three possible factors:

- (a) Bifoveal fixation;
- (b) Microtropia with identity (*i.e.* the angles of deviation and eccentricity are equal);
- (c) The movement is too small to see.

According to Jampolsky (1971a):

"The trained observer will easily be able to detect 1 Δ of rapid eye movement and even the most amblyopic myopic ophthalmologist will be able to detect 2 Δ of rapid eye movement"

In a carefully controlled study, Romano and von Noorden (1971) concluded that trained observers could detect 2 Δ of movement 95 per cent. of the time, but they were working with trained normal subjects, and it is not always possible to be certain of a 2 Δ shift, especially with a child.

So great is our obsession with ultrasmall-angle squints that we sometimes see them when they are not there, mainly because the cover test is carried out too quickly. When the cover is removed from one eye and this eye makes a recovery movement there will be a conjugate movement of the other eye, which must then move again to resume foveal fixation: this last movement can be mistaken for a microsquint. The best way to detect a very small manifest deviation is first to ensure that the patient is fixing on a well-defined target and then to cover and uncover one eye very slowly whilst watching the other.

One is tempted to ask whether it matters if these small deviations are missed. It is

important only if it affects the treatment, and an accurate diagnosis of microtropia might save a child from needless occlusion in a fruitless effort to obtain equal vision, but he would not be treated differently in any other respect.

The amount of light in the room, and the amount permitted to enter the covered eye can influence the results of the cover test; for example, bright light makes an intermittent divergence larger and a convergence excess smaller. This suggests that an alternate cover test may not always reveal the maximum deviation, and thus the value of the prism cover test is questioned, but even so it is the most informative measurement available and there must be very few who believe that a synoptophore measurement is better. I would suggest that the use of the synoptophore in measurement should be confined to patients with suspected torsion and perhaps children with an "A" or "V" phenomenon unable to co-operate with a prism cover test in upward and downward gaze.

We are now more aware of the need to measure the AC/A ratio whenever a concomitant horizontal squint increases or decreases significantly from distance to near fixation. Although methods using fixation disparity curves or electro-oculography are claimed to be most accurate, they are impracticable for general use, and the gradient method, using a prism cover test with and without concave lenses whilst the accommodation is carefully controlled at 6 m., has proved the most reliable. We recently compared the results of this method with those obtained using synoptophore measurements with and without concave lenses, and found a significant difference between them, the synoptophore readings giving a higher ratio which varied when repeated.

Jampolsky (1971b) stated that a comparison of the near and distance measurement is sufficient, but a convergence excess type of squint can be due either to a high AC/A ratio or to a high proximal convergence, and the management differs accordingly, and this investigation is therefore necessary.

(2) Visual acuity/fixation

The Stycar and Sheridan Gardiner tests have largely superseded other illiterate tests in Great Britain because they are more accurate and provide a means of testing near vision: it is recognized that near vision often improves more quickly during the treatment of amblyopia, and it should therefore always be recorded if possible. A further advantage of the Sheridan Gardiner test is that it does not stop at 6/6 but is obtainable as small as 6/3. Single letter vision of 6/6 in each eye often means an amblyopia of two or three lines once linear tests are used; the use of smaller sizes may reveal this difference earlier and enable adequate treatment to be given. [The Ffooks symbol test, which is really a simplified version of the Sheridan Gardiner test, has not proved easier to most children, and it is found that those who can understand the one test will also understand the other, with the exception of some handicapped children used to occupational therapy involving the handling of similar shapes.]

We have found "hundreds and thousands" sugar-cake decorations very useful in studying younger children. Even a 9-month-old baby will attempt to pick one up if he sees it; if he knows it is there but cannot see it he straightens his fingers and feels for it. The performance of either eye can be compared, especially if a strong convex lens is placed in front of one eye instead of an occluder.

Interest has recently been revived in optokinetic nystagmus as a measure of visual acuity, and Catford and Oliver (1972) have described apparatus using graded stripes. This test works well with normal infants, but its greatest use is often with the mentally and

physically handicapped child, when it is especially important to know what he can see in order to co-ordinate his general treatment. We use an optokinetic drum or scarf for the patients seen at an assessment centre for handicapped children, and have been frequently unsuccessful in persuading those with severe retardation to fix. Bells sewn on to the scarf to add an auditory stimulus rarely help and one is left unaware whether the lack of response is largely visual or is due to lack of attention.

When the visuscope was first introduced into Great Britain it was used only in obvious cases of amblyopia. We now know it is advisable to use it whenever there is even one line of difference in vision, since parafoveal eccentric fixation is compatible with an acuity of 6/12 or 6/9, and assessment of those cases is crucial for the differentiation of microtropia with identity (*i.e.* when the angles of deviation, anomaly, and eccentricity are the same).

Recently we have seen a number of patients with apparently bilateral eccentric fixation, who have been diagnosed when the star consistently failed to coincide with the foveal reflex in either eye. All these patients have bilateral amblyopia of 6/12 or less tested with linear type: some have manifest squints but others appear to be orthophoric on cover test; some have high bilateral refractive errors and are classed as ametropic amblyopes, but others have little or no refractive error. In all cases the fixation is parafoveal but not always symmetrical. In two it is nasal in one eye and temporal in the other, and careful examination of the visual fields in the one who is old enough for this to be done has revealed a hemianopia and an unsuspected medical history which accounts for it. In the remainder of our series of fifteen cases, the fixation is nasal and usually superior in both eyes. This suggests to us that the fixation should be examined when there is equal but subnormal vision as well as in patients with unilateral amblyopia.

(3) Recording of ocular movements/diplopia

The Lees Screen is still to me the best method of permanent recording in paralytic squint providing the outer field is always plotted. As well as its greater diagnostic value it often shows early changes for better or worse while the inner field remains the same. We have found it useful in the diagnosis of myasthenia gravis and it is routine practice to plot the outer field immediately after an injection of Tensilon.

More recent adaptations of the Hess Screen, notably the Hess-Weiss test (Weiss, 1967), which is intended to record the dissociated and controlled deviations when the two differ, seem to me to add nothing to one's knowledge of the patient, whereas the extent of the field of binocular fixation is a very useful clue. The Hess chart shows the dissociated deviation, and the field tells the observer how well it is controlled.

Although this test is not new it does not seem to be widely used, but I believe it should be plotted in all cases of incomitant squint in which there is an area of binocular single vision.

In some patients diplopia occurs only at the extremes of gaze and the limitation of movement is not shown on a Hess chart, whereas in others there is a large deviation but a surprisingly good binocular field; therefore the two results of the two tests must be viewed together in planning the management of a case. Fig. 1 (*a, b*, overleaf) shows the Hess charts and binocular visual fields of the same patient. In Fig. 1 (*a*) the deviation is well controlled, and in Fig. 1 (*b*) the control has decreased but with no significant change in the Hess charts.

When there is significant torsion, mainly in superior oblique palsies, and especially when these are bilateral, it has been found useful to plot the binocular field with a linear target as well as with the conventional 2 mm. circular target. A smaller field with a linear target

may indicate that surgery should be planned specifically for the torsion (Fig. 2 *a, b*, overleaf).

If there is such deep suppression that the field can be plotted only with a light and diplopia goggles, then the test is valueless since there is dissociation, and it is unwise since it may make the patient aware of his diplopia.

A field of uniocular fixation may be useful as a permanent record for comparison in cases in which a Hess Chart is uninformative (for example, in myopathies, or in endocrine exophthalmos affecting both eyes), but it is a test requiring a high degree of co-operation and visual acuity if it is to be plotted accurately.

Interest has recently been shown in the tracking of saccadic eye movements using an electro-oculographic technique and recording the results on an oscilloscope. This seems to us to have real practical value.

Since it is a simple and comfortable test, it can be used with children and elderly patients and early results from it in our department are promising. We feel it is capable of much further development.

Prisms have been used diagnostically in paralytic squint for a long time, to assess how much deviation should be corrected surgically, to decide which component of a horizontal, vertical, and possibly torsional deviation requires correction, and possibly to find out if fusion is present when this is in doubt. Fresnel prisms now provide an alternative way of using prisms, but not all adult patients tolerate them as well as conventional prisms even though they welcome them as a cosmetic improvement. For those doing precision work the reduction in vision can be too great. We still use clip-on prisms in many cases, but have found the Fresnel type invaluable for use on one part of bifocal glasses.

(4) Assessment of binocular function

(a) *Diagnosis of the presence or absence of bifoveal fixation*

Since it is now known that the cover test alone cannot always ascertain whether or not there is bifoveal fixation, confirmatory tests must be used. Irvine (1944) described the use of low-power prisms for this purpose, and the use of what is now known as the 4Δ -test was recommended by Jampolsky (1962) as a routine objective screening test. Essentially this test should diagnose whether or not there is a central suppression scotoma. If the prism is placed base-out before the normal or better eye, this eye will move in 4Δ to fix; and if there is a scotoma in the other eye, then that eye will move out and remain there, since no effective stimulus has been received. This is the usual response in cases of microtropia with or without a shift on cover test, but Lang (1969) maintained that a central scotoma was not always present in microtropia—a statement which is very hard to accept.

This is not a simple test to carry out or interpret. Romano and von Noorden (1969) found that only a few of the 25 normal subjects they tested gave the same response consistently, and only six responded in the same way for near and distance. Their findings and our own observations suggest that several precautions should be taken before accepting evidence from this test:

- (i) It should be used for near and distance;
- (ii) It should be repeated on consecutive visits, preferably by the same observer;
- (iii) Time should be allowed for a recovery movement, which is often delayed;
- (iv) The test should not be used only objectively, but the patient should be asked whether he sees double at any stage, and if diplopia persists whether he can make an effort to fuse the images.

Romano and von Noorden described four atypical responses to this test, but they occur

FIG. 1 (a) Hess charts and fields of binocular single vision of patient with long-standing left lateral rectus palsy

FIG. 2 (a) Fields of binocular single vision plotted with 2 mm. circular target in a case of right superior oblique palsy. (b) Fields of binocular single vision in same patient plotted with linear target

FIG. 1 (b) Hess charts and fields of binocular single vision of same patient, showing marked decrease in size of binocular field but no change in Hess chart

so commonly that I suggest they are not atypical. The responses which may be obtained are as follows:

- (i) The observed eye makes no movement although the other eye converges behind the prisms. This is to be expected in esophoria, when the prism helps to compensate for the deviation.
- (ii) The observed eye moves out and may recover immediately, but quite often the recovery is delayed.
- (iii) Neither eye moves initially, the patient making no effort to fix; generally there is diplopia and usually there is eventual recovery. Sometimes the patient has diplopia and alternates from one image to the other.

The slow recovery in these responses is thought by Romano and von Noorden to be due to a defect of the fusional reflex, but I think it usually occurs because the patient is not immediately aware of what is happening.

- (iv) The observed eye moves out and stays there. Only in this last instance can one say for certain there is absence of bifoveal fixation.

Although this is a useful test it requires considerable practice, and Romano and von

Noorden's results suggest it must be used in more so-called "normal subjects" before it can be properly evaluated.

The recently introduced macular form of Worth's Lights for use at $\frac{1}{3}$ m. does not differentiate bifoveal from anomalous binocular single vision, but it is useful in determining whether binocular single vision or suppression is present.

Use of the Wirt stereotest can confirm the presence of bifoveal fixation since it is impossible to appreciate stereopsis on all the rings unless it is present. The converse does not apply, and bifoveal fixation can exist with defective stereo-acuity.

(5) Assessment of retinal correspondence

(a) Suppression scotoma

Methods of plotting the suppression scotoma in the deviating eye in binocular conditions were described by Travers (1936) and more recently by Pratt-Johnson (1969) and Parks (1971a), who use a method of binocular scotometry based on the use of complementary colours; Pratt-Johnson has adapted Travers' experiment, using two Bjerrum screens with the Lees screen. Lang (1969) uses Amsler charts both unilaterally and binocularly. These investigations need a very observant patient, and are impossible to use with very young children when this information would be most use.

Bagolini's filter bar is a good method of assessing the depth of suppression when it is used in patients with manifest squints to see when they can recognize diplopia.

(b) Correspondence

The two tests for retinal correspondence most discussed in recent years are binocular visuoscopy and Bagolini's striated glasses. Binocular visuoscopy assesses foveal projection provided the observer can maintain the visuscope star on the fovea of the deviating eye steadily enough for the patient to describe its position in relation to a spotlight, preferably as a Maddox Tangent Screen. We have found this test virtually impossible to use with patients with eccentric fixation, and even those with central fixation have difficulties because of suppression, or even because of retinal rivalry between the spotlight and the star.

However, the findings reported with this test in conjunction with Bagolini's striated glasses are largely responsible for the assumption that patients with microtropia of various types have abnormal retinal correspondence. I do not think that this is proved and the findings on these and other tests can also be explained by central suppression and peripheral fusion, aided by an enlarged Panum's area.

The use of Bagolini's glasses is a much simpler and therefore more practical test, and is used routinely with all patients with manifest squint old enough to co-operate with it. Our increasing use of it has led us to the view that there are very many possible responses, and a report of a symmetrical cross should not be accepted without very precise evidence. It is essential to use the glasses for near and distance, and to ask children to draw what they see. We have noted an increasing number of patients of all ages with small-angle squints who see a very slightly displaced cross, and others who describe more bizarre results, such as a cross which is symmetrical fixing with one eye and not with the other, or which is symmetrical on first opening the eyes, but becomes displaced almost at once.

I think these findings add to the value of this test rather than detract from it, but they support the contention of Parks (1971b) that a child under 8 years old is not capable of describing gaps or slight displacements of the lines he sees.

The introduction of Fresnel prisms has made it possible to use diagnostic prisms at higher strengths and with more patients, even with infants. Their use in the assessment of binocular

function largely consists of correcting or slightly over-correcting the deviation and observing the patient's reaction over a period. This was described by Jampolsky (1971c) as the Prism Adaptation Test. He stressed that it was necessary always to overcorrect the deviation. If prisms are used for this purpose the patient may react in various ways.

- (i) He may demonstrate binocular single vision, probably indicating early surgery for a functional result.
- (ii) He can revert to his original angle, implying that he has abnormal retinal correspondence, and is using motor fusion to maintain it. This is an interesting reaction in contrast to the results reported with Bagolini glasses, when a cross is apparently maintained, for example, on elevation and depression in a "V" phenomenon, suggesting that the mechanism is very labile and purely sensory.
- (iii) He may reach an in-between stage; that is, he may produce a smaller convergent squint, probably to avoid crossed diplopia, and then return to a suppression area. This implies a poor prognosis, or perhaps suggests treatment to overcome the suppression if practicable.

The great advantages of this investigation are that more time is allowed, weeks rather than just minutes in a clinic, and that no artificial testing conditions are introduced. Fresnel prisms reduce visual acuity appreciably in the higher strengths, so that it is difficult to be convinced of the adequacy of the stimulus in large angles, but since these patients will require surgery postoperative prisms can be used in a similar way but a lower strength. Above all, this is a practicable method of assessing binocular function in children incapable of subjective responses.

(c) Stereopsis and stereo-acuity

We are indebted to Lang (1971) for introducing us to a simple test for gross stereopsis as a means of diagnosing whether a patient with a manifest squint has a useful form of anomalous binocular vision. The patient is asked to place the bottom end of a pencil on top of a second pencil held and moved by the observer. In most cases even quite young children have no difficulty in doing this with both eyes open. The squinting eye is then occluded, the test repeated, and the results compared. If there is an obvious and repeatable deterioration in performance, this suggests that an abnormal retinal correspondence is present. If there is no change, there is suppression of the squinting eye.

The Wirt test for stereo-acuity is also useful in this type of assessment. Evidence of the house-fly alone is very flimsy and needs confirmation by rotating the picture before it can be accepted. We should like a variety of tests of this type to use for distance as well as for near; a distance polaroid test is in use in the United States but is not yet available in Great Britain.

More recent work on stereopsis has centred on Julesz' random-dot stereograms with total absence of uniocular clues, and we are currently using these made up into synoptophore and other slides as well as the anaglyphs published by Julesz (1971); we are hoping to compare our results with those obtained using conventional methods. Development of tests using Julesz' principle may well have practical value in the future as well as contributing to our knowledge of the physiology of stereopsis.

In conclusion, one must agree with Jampolsky (1971d) that objective methods of investigation are best, and that they are the only ones which can be used with very young children, but nevertheless much useful and interesting information can be obtained from subjective tests: here the emphasis has changed, and our dependence on artificial instrumental methods has happily been succeeded by more physiological means of investigation under more normal conditions of seeing.