Diagnosing Extraocular Muscle Dysfunction in Clinic: Comparing Computerized Hess Analysis, Park’s 3-Step Test and a Novel 3-Step Test

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ABSTRACT

Background: Determining the primary underacting or overacting extraocular muscle (EOM) or muscle pair in ocular mis-alignment cases can frequently be challenging to eye care practitioners, especially if the mis-alignment is bilateral or longstanding. The purpose of this study was to compare the results of a commercially available computerized Hess Lancaster test to a proposed novel 3-step test and to the commonly used Park’s 3-step test.

Methods: Ten patients with recent onset or longstanding EOM dysfunction were seen at the primary author’s private optometric office for a binocular vision evaluation. In addition to a complete eye examination and binocular vision work-up, which included Park’s 3-step test, all patients were examined using both a commercially available computerized Hess Lancaster test and the proposed novel 3-step test.

Results: In all 10 cases, which comprised of both longstanding and recent onset deviations, the dysfunction indicated using the novel 3-step method agreed well with the EOM(s) identified using computerized Hess-Lancaster testing. Park’s 3-step test did not prove useful in any of the presented longstanding or recent onset cases.

Conclusions: Results attained using established computerized Hess Lancaster testing agreed well with results attained using a novel 3-step test. In the absence of Hess Lancaster testing, the proposed 3-step test appears to be a viable alternative in arriving at a potential diagnosis of the primary underacting and overacting EOM(s). Park’s 3-step test did not prove useful in any of the presented cases as they were either bilateral or had no significant vertical deviation or change in vertical deviation in dextroversion or levoversion. The proposed novel 3-step test appears preferable over Park’s 3-step test as it also detects bilateral and/or longstanding deviations that have undergone a spread of comitance.

Keywords: Binocular vision, Hess, 3-step test

Introduction

Binocular diplopia and asthenopia are frequent symptoms caused by manifest or latent ocular mis-alignment of the extraocular muscles (EOMs).1 Binocular vision is desirable as it has been shown to be superior compared to monocular vision in...
many different areas such as letter identification, colour perception and depth perception.\textsuperscript{1,3} Thus, an incomitant deviation, be it longstanding or recent onset in nature, can present a significant impairment to the visual system. Incomitancy has been defined as a change in ocular misalignment of five prism dioptres or more when the eyes are moved in different positions of gaze.\textsuperscript{4} Of course it is highly likely that small degrees of misalignment between the eyes are present under normal circumstances, as evidenced by the phi phenomenon, but these small misalignments are rarely troublesome to the visual system. If the deviation becomes excessive however, patients can experience clinically significant and sometimes debilitating symptoms such as double vision and headaches.

A frequent challenge to the eyecare practitioner engaged in a primary care environment is to determine the exact nature and the underlying aetiology of a presenting ocular misalignment prior to the application of any therapy. The first step in this process is attempting to identify the EOM(s) primarily responsible for the ocular deviation. Whilst this task is challenging in recent onset cases, it is especially challenging in longstanding cases due to subsequent spread of comitance. This spread of comitance often makes it very difficult to determine the primary affected EOM(s) as both the ipsilateral and contralateral ocular muscles will adapt and compensate for the initial deviation. Thus, a relatively fast and accurate method is desirable in the clinical setting to aid in isolating underacting or overacting EOMs in both recent onset and longstanding cases.

The contribution of this paper is a novel three-step test for identifying the EOMs underlying these types of misalignment.

There are six EOMs surrounding the human eye. The medial rectus (MR) and lateral rectus (LR) do not pose a major diagnostic challenge as their actions of adduction and abduction respectively are relatively straightforward to diagnose clinically. The other four EOMs pose more of a diagnostic challenge as they have more complex actions depending on the position of the eye within the orbit. When considered in isolation, the actions of the superior rectus (SR), inferior rectus (IR), superior oblique (SO) and inferior oblique (IO) have vertical, horizontal and torsional effects. The relative contribution of each of these effects will of course change depending on the position of the eye within the orbit and the relative contribution of both the ipsilateral and contralateral agonist and antagonists.\textsuperscript{5}

There are many available tests which attempt to identify the EOMs primarily involved in ocular deviation cases. One of the most commonly used tests in the clinical setting is Park’s 3-step test.\textsuperscript{6,7} This test was originally designed to identify cyclovertical muscle involvement in EOM dysfunction with a vertical element.\textsuperscript{6} Three clinical features are used to arrive at a diagnosis; (i) the nature of the vertical deviation in the primary position (ii) whether the vertical deviation increases on left or right gaze and (iii) whether the vertical deviation increases with the head tilted to the left or right. A template is then used to extract a diagnosis based on the findings (Figure 1).
This test has however been criticized, for several reasons. Park’s 3-step test has been shown to overdiagnose oblique muscles even when the deviation has been shown to be due to a vertical rectus paresis.8,9 The reason suggested was that on the head tilt section of Park’s (Step 3, Figure 1), less difference in the vertical deviation is present between the two positions with paretic vertical recti muscles compared to paretic oblique muscles.8 Additionally, as it was not designed to work on deviations with no vertical component,6 this test cannot be completed if there is no significant vertical deviation found when the eyes are in the primary position. However, cyclovertical EOM dysfunction, when bilateral, can give a pattern with no vertical component if the deviation is relatively symmetrical causing further confusion of the diagnostic result. This short-coming of Park’s is significant if one considers that these types of bilateral deviations tend to be a common finding in clinical practice.4 Furthermore, Park’s also only deals with underactions, which is significant if one considers that the most common issue encountered in practice is an overaction of one or both inferior oblique (IO) muscles leading to the commonly observed V-pattern exo-deviations.4 The final issue with Park’s 3-step test is that it does not appear to extract a diagnosis in longstanding cases where there has been a spread of comitance, presumably as the other EOMs have adapted to the initial paresis leading to a reduction in the amount of change in vertical imbalance seen on testing.9

Another method used in clinical practices with a special interest in binocular vision is the Hess test. This test can be either wall mounted or more recently, tested using a computerized format. This test is relatively accurate at mapping out the magnitude of misalignment of EOMs in different positions of gaze.10,11 The computerized version of this test is especially attractive as it is time efficient and also allows comparisons of results over time. In addition, each position of gaze can instantly be quantified in either prism dioptres or degrees of visual angle. In the computerized version, the patient’s eyes are dissociated using coloured filters (red/blue) and the task of the patient is to superimpose two circles (one smaller than the other) in different positions of gaze on the computer screen using a mouse (see Figure 2). This is done first with the right eye fixing and then with the left eye fixing. Hess testing is very useful in clinical practice as it can allow the practitioner to determine if an ocular deviation is of recent onset or longstanding in nature, as the latter has relatively equal sized Hess plots and more than two sequelae present. Hess testing is also useful in determining the effect of therapy on the EOM alignment status in positions other than primary gaze (see Figure 3 for examples). It should be noted that all Hess test results are shown by projection and not confrontation as with other binocular vision techniques, i.e., Park’s 3-step test.

In binocular vision testing, it is often prudent to have at least two clinical tests with similar results before diagnosing a particular EOM (or EOM group) as being defective. However, in the absence of Hess testing, practitioners often have to use other methods of testing to determine the EOM paresis, such as Park’s 3-step test mentioned above. It is thus prudent to validate any “quick” clinical tests to ensure they are comparable to a given set standard, which in this paper is considered to be computerized Hess analysis. However, it must be clearly stated that there is no universally recognized “gold standard” in binocular vision in terms of determining EOM mis-alignment.

A novel test for identifying the EOMs primarily responsible for ocular mis-alignment is presented in this paper. The aim of the proposed diagnostic test is to correctly identify a paretic EOM or group of EOMs in a comparable manner to Hess analysis. The purpose of this paper is to compare the EOM(s) identified using computerized Hess testing to the results attained using the proposed novel 3-step test in a sample of 10 patients with both longstanding and recent onset EOM dysfunction. Park’s 3-step test was unable to be completed in all 10 cases presented due to either a lack of any vertical deviation in the primary position or a lack of change in vertical deviation on dextroversion or levoversion.

**Sample**

Ten subjects (mean age 34, SD 9.8 years, 6 male) were examined in the primary author’s private practice. All subjects gave informed consent prior to examination to have their clinical results presented and discussed for research purposes. All subjects were
symptomatic and had intermittent double vision, headaches or a combination of these two symptoms. All subjects had a best corrected acuity of 6/6 in each eye and confirmed normal retinal correspondence. Mean refractive error was –1.23DS (SD 1.86DS) and –0.72DC (SD 1.22DC). All subjects included in the study tested negative for anomalous correspondence (AC) using Bagolini lenses and negative for eccentric
fixation (EF) using the fixation grid on direct ophthalmoscopy.

**Methods**

All subjects were seen for a binocular vision work-up following a full comprehensive eye examination upon detection of a binocular vision anomaly. This work-up generally followed a pyramidal approach (Figure 4). This approach attempts to find the aetiology of a binocular vision anomaly by starting at the most fundamental level of the pyramid and working upwards until dysfunction is found. All patients in the sample used in this paper had intermittent or constant dysfunction detected at the “Extraocular Muscle Function” stage using computerized Hess analysis.

The computerized Hess test used in this paper is a commercially available test for ocular mis-alignment which is capable of quantifying the magnitude of mis-alignment in either degrees of visual angle or prism dioptres. The program uses a pair of glasses with a blue filter over one eye and a red filter over the other which can be worn over the patient’s habitual correction (shown in Figure 2 directly in front of the keyboard). The test is calibrated using a custom calibration tool within the commercially available software. Patient instructions are automated. The task for the subject is to move a large circle (the “following eye” target) so that it superimposes the smaller fixed circle (the “fixing eye” target). This test is done with both the right and left eye fixing. A total of 25 positions are assessed for each eye. All subjects were monitored for compliance during the test. At the end of the test, the software automatically generates a Hess plot which allows the practitioner to see the size of each plot as a “percentage” allowing the underacting and overacting eye to be differentiated.

The term “percentage” used in the context below refers to the area of the patient’s Hess plot compared to the area of the template plot (indicated by the black circles on the plots, representing unity or 100%). The following rules are thus used in interpreting the results from the computerized Hess plots for the purposes of this paper: (i) the smaller % field corresponds to the underacting eye and the larger % field corresponds to the overacting eye, (ii) in the underacting eye, the EOM with the largest underaction is the primary affected EOM and is called the “Primary Underacting EOM”, and (iii) in the overacting eye, the EOM with the largest overaction is termed the “Primary Overacting EOM”. The differentiation between a recent and longstanding deviation is often reflected in the degree of symmetry (or lack thereof) in a Hess plot. For the purposes of this paper, a difference in the “field” of each eye of more than 30% was used as a threshold to distinguish recent versus longstanding deviations. All patients with an identified EOM anomaly using Hess testing were also tested using the proposed 3-step method and Park’s 3-step test.

**Overview of the logic behind the proposed novel 3-step test:** The proposed novel 3-step test is designed to be quickly and easily done by the clinician using a decision tree template. It is not meant to be quantitative, but is intended to give the practitioner...
a reasonable idea of the main EOM(s) responsible for a given ocular mis-alignment. The decision tree was constructed using known anatomical EOM information. There are two main diagrams currently used in determining deviations in binocular vision (Figures 5A and 5B). Figure 5A, the more commonly used diagram, shows the action of EOMs only in a very narrow range of extent: when the eye is abducted by 23° or adducted by 51-54°. These angles of ocular movement are important as they represent the ocular position at which the four “diagonal” EOMs (i.e., SO, IO, IR, SR) have for the most part actions of elevation or depression. Outside of this range, Figure 5A does not fully describe the interactions seen, and causes confusion when used to interpret observations made at other angles of abduction/adduction. Figure 5B, which is less commonly used, shows a similar schematic which shows the actions of the EOMs when they are considered in isolation.

The logic of the decision tree (Figure 6) is best served by an example. Let us take an example of a patient with a V-pattern exo-deviation and a right hyperphoria (or left hypophoria). If we first consider the V-pattern exo-component, which is commonly attributed to an inferior oblique (IO) overaction issue, we must ask the question: “which schematic diagram matches the logic of an IO overaction and the observations clinically that the eyes increased their abduction in upgaze?” Only Figure 5B matches this logic, as according to this diagram if the IO muscles overacted the eyes would indeed move “outwards in upgaze”. Thus, there seems to be a disconnect between these two diagrams in that the predicted pattern based on anatomical data (i.e., Figure 5B) seems to match the clinical observations, but the schematic diagram commonly used in practice and for Hess analysis (i.e., Figure 5A) would seem to indicate an IO underaction.

If we return to our example and use only Figure 5B, we can see that a V-pattern exo-deviation could only be explained by two potential EOM issues, (i) an IO overaction or (ii) a SR underaction (which eye is unknown as yet). If there is no vertical deviation present, then the abnormality must be bilateral, in which case both the vertical deviation options are circled on the flow tree in Figure 6 (i.e., both R/L and L/R options). However, if there is a vertical deviation (in this example it is a right hyperphoria/left hypophoria, abbreviated to R/L), this observation can be used to narrow the possible EOM(s) responsible as the vertical actions of the IO and SR are known. Thus, if a patient has a V-pattern exo-deviation and a right hyper-deviation, and we already know that both the
IO and SR are elevators, the higher eye must be the overacting eye and the lower must be the underacting eye. In this particular example, the decision tree leaves us with only two possible options (an underacting and overacting EOM as a cause for the ocular deviation, in this example a right IO overaction/left SR underaction combination). These two EOM options appear to be the only EOM permutation that is able to explain the ocular deviation when considering the EOMs in isolation (i.e., using Figure 5B).

However, we must consider the fact that the Hess test, the proposed 3-step and Park’s 3-step test do not assess the EOMs in isolation. Thus, what we are essentially doing is using the EOMs suggested by the ocular mis-alignment pattern in Figure 5A and applying it to Figure 5B in order to predict the Hess results. Although Figure 5A was only intended to be used in 23° abduction and 51-54° adduction positions, it appears to be in widespread use in Hess testing which certainly assess ocular motility in other positions of gaze. Presumably, Figure 5A is more widely accepted as it gives an approximate idea of the EOM with the “most influence” in any given particular direction of gaze. Of course, when the eye moves out of the primary position they are not just in the 23° abduction or 51-54° adduction position. The exact relationship between the EOMs in any given position is thus very difficult to determine accurately as the relationship between all six EOMs in each eye will change depending on the position of gaze in question.5

As can be seen from the flow diagram (Figure 6), there is a “translational step” required between the 3-step test result using anatomically known data (Figure 5B) and what one would expect to see on Hess analysis (Figure 5A). Figure 6 shows the decision tree for any given permutation of results using the novel 3-step test and has the results from the above example.

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**Figure 6:** The proposed 3-step test procedure which can be done either subjectively (using the alternate cover test and phi movements) or objectively (neutralizing the deviation with a prism bar). Step 1: Does the patient have an exo-deviation or an eso-deviation in the primary position? Step 2: Is there an A or V pattern present? Keep in mind that the largest deviation with eso-deviations corresponds to the apex of the A or V and the largest deviation in exo-deviations corresponds to the widest element of the A or V. If no definitive A or V pattern found, both options are circled. Step 3: Is there a vertical deviation? This can easily be done using phi movements (as was done in the cases presented in this paper) as they are more sensitive to detecting EOM mis-alignment. One can use a Maddox rod or phi movements (prism to neutralize phi movement if required). If no vertical deviation is found, both options are circled. The first set of EOMs indicates the EOMs in isolation most affected whereas the bottom EOMs show the pattern on the Hess plot to be expected. In this figure, the patient shows the pattern expected for a V-pattern exo-deviation with a right hyperphoria. Note that the terms R/L and L/R simply refer to a vertical heterophoria (i.e., R/L = right hyperphoria/left hypophoria). This terminology assumes the vertical deviation is relatively equal with each eye fixing.
circled in red. One can see that the EOMs identified using the 3-step test before the “translational step” are identical to those identified after the translational step. The only difference is that underactions become overactions and vice-versa. This change was made in order to predict the Hess pattern, which makes sense if we consider that V-pattern exo-deviations are due to a bilateral IO overaction and match Figure 5B, yet this EOM dysfunction appears as a bilateral IO underaction on Hess analysis which matches Figure 5A.

Although the logic behind the novel 3-step test is moderately complex, the resulting template is quite simple and only requires three pieces of information to formulate a diagnosis using the decision tree (Figure 6). In addition, the flowtree can still be used if the patient has no definitive A/V pattern or no definitive vertical deviation as one simply circles both options on the decision tree. This would of course result in more than one pair or EOMs being identified.

**Results**

A summary of the results are shown in Table 1 and Figures 7i-7x. In all subjects, the underacting EOM and overacting EOM on Hess testing were correctly predicted using the novel 3-step test. In some cases the spread of comitance makes the diagnosis quite challenging even using both Hess testing and novel 3-step testing. Of note, Park’s 3-step failed to be completed in all 10 cases presented.

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Primary underacting EOM(s) using 3-step test</th>
<th>Primary overacting EOM(s) using 3-step test</th>
<th>Primary underacting EOM(s) Hess</th>
<th>Primary overacting EOM(s) Hess</th>
<th>Match (Y/N)?</th>
<th>Park’s result (NA = not attainable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DG)</td>
<td>Bilateral IO underaction</td>
<td>Bilateral SR overaction</td>
<td>Bilateral IO underaction</td>
<td>Bilateral SR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>2 (BM)</td>
<td>Bilateral SO underaction</td>
<td>Bilateral IR overaction</td>
<td>Bilateral SO underaction</td>
<td>Bilateral IR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>3 (IM)</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>4 (CC)</td>
<td>RIR underaction</td>
<td>LSO overaction</td>
<td>RIR underaction</td>
<td>LSO overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>5 (SS)</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>6 (MS)</td>
<td>RSO underaction</td>
<td>LIR overaction</td>
<td>RSO underaction</td>
<td>LIR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>7 (KS)</td>
<td>LSR underaction</td>
<td>RIO overaction</td>
<td>LSR underaction</td>
<td>RIO overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>8 (TS)</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>LSO underaction</td>
<td>RIR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>9 (RP)</td>
<td>RIR underaction</td>
<td>LSO overaction</td>
<td>RIR underaction</td>
<td>LSO overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>10 (RS)</td>
<td>Bilateral SO underaction</td>
<td>Bilateral IR overaction</td>
<td>Bilateral SO underaction</td>
<td>Bilateral IR overaction</td>
<td>Y</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 1: The results from both Hess testing and testing with the proposed novel 3-step test. The results are not quantitative but rather are intended to determine whether a similar diagnosis is attained from each technique. In the above results, it can be seen that virtually every case shows good agreement between Hess results and the diagnosis indicated using the novel 3-step test. The Hess plot and 3-step test results are also given below (see Figures 7(i) to 7(x)) for reference. Each case is discussed briefly in the legend for each case. In all 10 cases presented, Park’s 3-step gave no diagnosis as completion of the 3-steps was not possible.
Figure 7(i) Case #1 (DG): Diagnosis matched as a bilateral IO underaction/bilateral SR overaction. No significant vertical deviation was noted using the novel 3-step test. Unable to complete Park’s 3-step test due to no vertical element being detected. “Area of plot” was 79% and 85% right and left respectively.

Figure 7(ii) Case #2 (DG): Diagnosis matched as a bilateral SO underaction/bilateral IR overaction. No significant vertical deviation was noted using the novel 3-step test. Unable to complete Park’s 3-step test due to no vertical element being detected. “Area of plot” was 92% and 95% right and left respectively.

Figure 7(iii) Case #3 (IM): Diagnosis matched as a left SO underaction and a right IR overaction. If no vertical deviation is considered, then a bilateral SO underaction/IR overaction would be noted. There is likely some MR underaction also in each eye. Unable to complete Park’s as no significant change in vertical from left gaze to right gaze was found. “Area of plot” was 104% and 93% right and left respectively.
Figure 7(iv) Case #4 (CC): Diagnosis matched to an underacting right IR and left SO overaction. The vertical deviation was subtle on Hess but was picked up on the 3-step test. If “no vertical deviation”, then both IR EOMs would be deemed underacting and both SO EOMs as overacting which would not necessarily be an “incorrect” conclusion. Unable to complete Park’s as no significant change in vertical from left gaze to right gaze was found. “Area of plot” is 90% and 114% right and left respectively.

Figure 7(v) Case #5 (SS): Diagnosis matched to underacting left SO and overacting right IR. There may also be some MR involvement L>R also. Unable to complete Park’s as no significant change in vertical from left gaze to right gaze was found. “Area of plot” was 101% and 34% right and left respectively.

Figure 7(vi) Case #6 (MS): Diagnosis matched to an underacting right SO and an overacting left IR (left MR did overact the greatest extent however with a mild hypo-component). Unable to complete Park’s as no significant change in vertical from left gaze to right gaze was found. “Area of plot” was 70% and 120% right and left respectively.
**Question 1:** Does the patient have exo or eso-deviation?

**EXO**

**ESO**

**V-pattern**

**A-pattern**

**R/L**

**L/R**

**LSR**

**RSR**

**LIR**

**RIR**

**LSO**

**RSO**

**LIO**

**RIO**

**Question 2:** Does the patient have a V-pattern or an A-pattern?

**Question 3:** Does the patient have a R/L or a L/R deviation?

Underacting and overacting EOM candidates in ISOLATION (Figure 5B)

EOMs implied on Hess as eyes move out of primary position (Figure 5A)

**Figure 7(vii) Case #7 (MS):** Diagnosis matched to a left SR underaction and a right IO overaction. Park’s could not be completed as no result was attained on step 3 (head tilt section). “Area of plot” was 99% and 89% right and left respectively.

**Figure 7(viii) Case #8 (TS):** Diagnosis matched to a left SO underaction and a right IR overaction. Unable to complete Park’s as no significant change in vertical from left gaze to right gaze was found. “Area of plot” was 106% and 85% right and left respectively.

**Figure 7(ix) Case #9 (RP):** Diagnosis matched to right IR underaction and a left SO overaction. Vertical element was picked up on the novel 3-step phi motion. Unable to complete Park’s as no change in vertical from left gaze to right gaze was found. “Area of the plot” was 96% and 100% right and left respectively.
Discussion

The results presented in this paper illustrate that the proposed novel 3-step test predicts EOM dysfunction in a manner consistent with computerized Hess analysis. Thus, in the absence of Hess testing facilities, the practitioner can use this test to predict the EOM anomaly responsible for a given deviation in a manner comparable to Hess testing, even in longstanding bilateral deviations that have experienced a spread of comitance. The proposed novel 3-step test also appears to predict EOM dysfunction correctly in the absence of a significant vertical deviation and is thus also effective in cases of bilateral EOM dysfunction. This is important as Park’s 3-step test was not designed for such EOM anomalies, yet these are common presentations in the clinical setting.

The high level of agreement between the predicted results using the anatomy based flowchart and computerized Hess analysis confirms that we can use the anatomical EOM model (i.e., Figure 5B) with the “translational step” to predict functional results on Hess testing (i.e., Figure 5A). The difficulty in accurately diagnosing EOM dysfunction is highlighted if we consider that in one study using Park’s 3-step, a higher incidence of vertical recti muscle issues were found when using prism bar neutralization in the nine positions of gaze compared to the results from Park’s test.4 The reason proposed was that there is less difference in the magnitude of the vertical deviation between the two head positions when tilting the head to the left and right with paretic vertical recti muscles as opposed to paretic oblique muscles.8,9 This is because the vertical strength of the oblique EOMs is thought to be less than that of the vertical recti muscles.4 As there is no head tilt step involved in the proposed novel 3-step test, this issue is avoided. In addition, if no vertical deviation is present one cannot complete Park’s 3-step test (step 1, Figure 1). The observation that Park’s was not useful in the presented cases is not particularly surprising as arguably Park’s 3-step test was never designed for dealing with cyclovertical deviations which have no significant vertical component (i.e., due to being bilateral or having experienced a spread of comitance).

Although figures 5A and 5B show EOM function both in isolation and when the eyes are abducted and adducted by specified amounts respectively, the difficulty in diagnosing EOM dysfunction is that in any position of gaze the resultant eye position is a product of a myriad of EOM forces. These forces include those exerted by both the ipsilateral and contralateral agonist and antagonist EOMs, which will change their relative contribution in different eye positions, not to mention check ligament forces. Thus, it is very difficult when using any tool in longstanding deviations to “backtrack” to the actual muscles initially at fault. The flowchart used in the proposed novel 3-step test attempts to at least isolate the primary underacting and overacting EOM or EOM pair responsible for the ocular deviation. It should be mentioned that the...
Figure 8: Patient (left) was initially thought to have a right 4th nerve palsy prior to referral. The novel 3-step test did not indicate the right SO however. Hess analysis on this patient (top left) may indicate a right SO weakness, but there is a spread of comitance to the point where the primary affected EOM is difficult to ascertain. The drooping upper lid in the left eye towards the end of the day in addition to the left Hess plot being in the “down and out position” lends weight to the diagnosis of longstanding left partial 3rd nerve palsy. In addition, Park’s 3-step test shows no result on the head tilt test (Figure 9). The Hess on the upper right shows another Hess plot from a confirmed recent onset 3rd nerve patient. This patient’s Hess pattern has a similar pattern to the Hess on the left, albeit with a lesser spread of comitance. The EOMs indicated by the novel 3-step in this case (assuming a basic exo-deviation with R/L deviation) do not appear to match the Hess results. Thus it appears that the novel 3-step test is not very predictive in CN III palsy cases.

![Figure 8](image)

Figure 9: Decision tree and motility pattern for patient discussed in Figure 8. It can be seen that the spread of comitance makes it very difficult to determine the primary defective position of gaze (white X indicates positions of mis-alignment detected by observation only). The marked positions of gaze (the positions of maximum diplopia) were measured using a prism cover test and did not aid in pinning down a position of maximum deviation. This agrees with the Hess pattern which has clearly undergone a spread of comitance (Figure 8). Adding weight to the 3rd nerve palsy diagnosis is the finding that the head tilt test was negative (Maddox rod used) making a right SO palsy (the previous diagnosis) unlikely. This case highlights the difficulty clinicians face when dealing with longstanding deviations in practice. In this particular case, both Parks and the novel 3-step test (not surprisingly) failed to give a concrete diagnosis. In this case Hess analysis was the best diagnostic tool, but even this failed to give a concrete diagnosis.

<table>
<thead>
<tr>
<th>Question 1: Does the patient have exo or eso-deviation?</th>
</tr>
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<tbody>
<tr>
<td>EXO</td>
</tr>
<tr>
<td>ESO</td>
</tr>
<tr>
<td>Question 2: Does the patient have a V-pattern or an A-pattern?</td>
</tr>
<tr>
<td>V-pattern</td>
</tr>
<tr>
<td>A-pattern</td>
</tr>
<tr>
<td>Question 3: Does the patient have a R/L or a L/R deviation?</td>
</tr>
<tr>
<td>R/L</td>
</tr>
<tr>
<td>L/R</td>
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</tbody>
</table>

proposed 3-step test has been tried in the primary author’s clinic with multiple EOM dysfunction cases (i.e., CN III palsies) and has not been very predictive. This is illustrated in the case below (see Hess plots in Figure 8 and the decision tree and photos in Figure 9) in which a patient presented with longstanding diplopia and a progressively drooping left upper lid towards the end of the day. It can be seen that the flow chart does not correctly indicate the underacting and overacting muscles on
the Hess screen, but clearly there are other EOMs involved. Thus, the novel test (like Park’s 3-step test) is not very useful in cases of nerve palsies affecting multiple EOMs.

There appears to be some ambiguity as to whether Figure 5A or 5B is being used when referring to A and V patterns. For example, V-pattern exo-deviations are commonly quoted as being due to an “inferior oblique overaction”, an EOM anomaly which is likely the most common deviation seen in practice. Looking at Figure 5A however, which is the same template as used on Hess analysis (see all plots in paper), an “inferior oblique overaction” would appear to cause an over-adduction or eso-deviation in upgaze. Of course, given that Figure 5A should only be used (strictly speaking) when the eye adducted or abducted, one could say that Figure 5A should not be applied in any Hess plot when looking for A and V patterns. One must then ask the question as to why the layout in Figure 5A is applied to Hess analysis at all given that in addition to adduction and abduction, both pure elevation and depression (i.e., A and V patterns) are being assessed. This is why the translational step is required as this step essentially converts the Hess pattern to the pattern used in Figure 5B which is arguably the most appropriate in any case as for upgaze and downgaze Figure A should not be applied strictly speaking.

It is therefore interesting to note that when one looks at Figure 5B, the notion that an inferior oblique overaction causing a V-pattern exo-deviation seems more logical as the inferior oblique (in isolation) causes elevation, abduction and excyclorotation (as indicated by the three vectors of this EOM in Figure 5B). So it is very apparent that when we refer to an EOM being responsible for a given EOM dysfunction pattern, we must be very careful to specify whether we are talking about what one would see on a Hess screen test (i.e., Figure 5A) or whether we are referring to the actual EOM affected in isolation (i.e., Figure 5B). The importance of this distinction is apparent if one looks at a Hess plot of a V-pattern exo-deviation and follows the rules of Hess interpretation (for example see Hess in Figure 7i). In the case of a V-pattern exo-deviation it is an inferior oblique underaction and not an overaction that appears to be the diagnosis on Hess analysis. This “disjoint” in terminology has likely caused much confusion as the apparent EOM at fault on Hess testing does not match with the predicted EOM at fault when considering muscle actions in isolation. This “disjoint” can be resolved if one simply acknowledges that Figure 5A should not be applied to Hess when looking at upgaze and downgaze as this layout is only appropriate when the eye is adducted or abducted away from the primary position.

In summary, this research has shown that using an anatomical model (i.e., Figure 5B) and a “translational step” to predict the Hess result is very useful to confirm the diagnosis in cases of primarily single or bilateral EOM dysfunction, even in longstanding cases with a spread of comitance. This research has important ramifications, as it appears that this anatomical model could be used to aid in the construction of simulations of most motility defects. These simulations could then be compared to the actual patient motility observations (or Hess results) to confirm the primary affected EOM(s). The novel 3-step test used in this paper to predict Hess defects thus has potential both in the diagnostic realm and in the realm of EOM modelling/simulations.

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References


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