DIPLOPIA LOCALIZATION: EXAMINATION SKILLS

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INTRODUCTION

After a careful history has been obtained, the neuro-ophthalmological examination is pivotal in determining the etiology of diplopia. The motility of each eye is tested separately (ductions) and together (versions), but if necessary, additional tests can be done to detect more subtle misalignments of the eyes, including the cross cover test, Maddox rod testing and the Lancaster screen. Smooth pursuit, saccades and the vestibular ocular reflex (VOR) are examined to assess higher functional motility and better localize lesions.

Tests of Motility

DUCTIONS, VERSIONS AND VERGENCE

Ductions are tested when the motility of one eye is examined by itself, typically by asking the patient to follow a moving target, such as the examiner's finger. The target is moved in a broad H-pattern (not a plus sign) which allows the practitioner to examine the various recti and oblique muscles in relative isolation. Limitations in excursion can be described as a percentage of normal in each direction, as the number of degrees of excursion (normal being about 50 degrees for adduction, abduction, depression and 40 degrees for elevation, the latter decreasing with age) or using a number scale. It is important to examine each eye by itself, since milder limitations can be missed in the presence of more severe strabismus in the fellow eye if only versions are checked. Versions describe the action of testing both eyes simultaneously. This can help make a relative weakness more obvious in comparison to the fellow eye.

Following ductions and versions, vergences are tested. Following the broad-H, the clinician moves the target in towards the bridge of the nose, examining the convergence of the eyes, keeping in mind that this typically weakens with age. Divergence is then observed as the target recedes into the distance.

FORCED DUCTIONS

In order to confirm that an oculoparesis is due to a weak nerve or muscle, one may try to move the eye passively, typically by pulling the peri-limbal conjunctiva (following topical anesthesia). If the paresis is related to weakness, then the eye will move freely when tugged. If, on the other hand, the paresis is due to antagonist muscle restriction, then even passive force will not budge it.

Tests of Alignment

TROPIAS VS. PHORIAS

In some cases of diplopia, there is no frank limitation of motility in duction and version testing, but the eyes are misaligned during fixation. In some cases the misalignment manifests itself even when both eyes are uncovered, in which case, the patient is said to have a heterotropia or *tropia* for short. If the eyes are deviated outward, it is termed an exotropia, and if deviated inward, it is an esotropia. Hypertropia and hypertropia describe the situation where one eye sits higher than the other, depending on which eye one is referring to. Patients with tropias do not have binocular stereo fusion.

In other cases of diplopia, especially in the setting of congenital strabismus, the motility of each eye appears complete, and with both eyes uncovered, the misalignment does not manifest. However, when stereo vision is disrupted, either by covering one eye or changing the appearance of a target in one eye, the eyes become misaligned. This is termed a heterophoria or *phoria* for short. If the eye drifts out, it is an exophoria and if it drifts in, it is an esophoria. If it tends to drift upward, it is a hyperphoria and if downward, a hypophoria.

HIRSCHBERG AND KRIMSKY TESTS

In the Hirschberg test, a light is shined straight at the patient's eyes. The clinician notes where the light lands relative to center of each pupil. If an eye is deviated inward, the light will land on the outer half of the pupil, and so on. In the Krimsky test, a prism bar is then employed, and the prism strength needed to line up the reflection on both eyes is determined, thus quantifying the amplitude of the strabismus.

MADDOX ROD TESTING

The Maddox rod is a red prims lens that converts a point of light into a red line. By breaking stereo fusion, it is helpful in detecting and characterizing phorias. By convention, the Maddox rod is always placed in front of the right eye while the clinician shines a light (typically a small beam from a muscle light) toward the patient. The left eye will see the white light while the right eye sees a red line. The brain does not realize that these two disparate images are from the same source and should be in the same position in space. The eyes are thus permitted to drift in the direction of their phoria, producing a distance between where the patient sees the white light and red line. When held so that its gradations are horizontal, the Maddox rod will convert the white light into a vertical red line for the right eye. The patient is then asked to describe what he or she sees. If the left eye is adducted (drifted to the *right*) relative to the right eye, then the patient will see the white light to the *left* of the red line. (This might seem counterintuitive at first, but practice turning your eyes or head to the right and you will see that the images that were in front of you are now to the left of your visual world.) This esophoria says nothing about which eye is weaker, but this can be elucidated by rechecking the Maddox rod in different fields of gaze. For example, if the degree of separation between the white light and red line increases in left gaze, then the eye separation must be worsening in left gaze, and the esophoria is resulting from limitation of abduction of the left eye. (Possible causes include left lateral rectus or abducens nerve weakness or left medial rectus restriction)

The Maddox lens is then flipped over so that its gradations are vertical and the white light is converted to a horizontal red line but it is kept on the right eye. Now, the patient can be asked if the white light is above, below or directly on the red line. If the white light is higher, then the left eye must be lower and it is a left *hypo*phoria (or right *hyper*phoria; again, the culprit eye cannot yet be determined). If the problem is that the left eye cannot elevate well then the separation will be worse in upgaze. If the right eye cannot depress well, then the separation will worse in downgaze. Since the superior and inferior recti muscles are most active in the vertical plane in abduction while the oblique muscles are most active in the vertical pane in adduction, the relative separation of the white light from red line in left and right gaze can help determine which muscle is responsible for the deviation. More information is gathered by seeing if a vertical phoria changes in right or left head tilt. This is because a trochlear palsy is worse in ipsilateral head tilt and better in contralateral head tilt. When the degree of separation is equal in every direction of gaze, it is termed a commitant deviation, and it is suggestive of either a congenital strabismus or a skew deviation. The remaining cases in which the degree of misalignment changes in different directions of gaze are termed incommitant and suggest muscle or nerve weakness. One disadvantage of Maddox rod testing is that it is subjective, depending on the patient's description of what they observe.

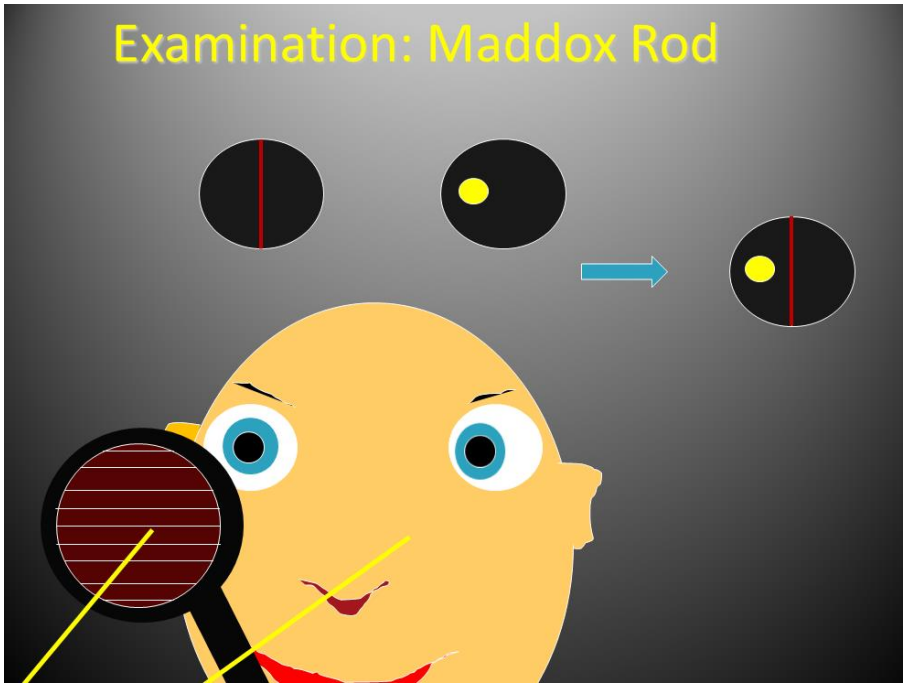

Figure 1. Maddox rod testing for horizontal phorias or tropias. Note that the left eye is esotropic and therefore deviated to the patient's right. The white light therefore appears more to the patient's left. The red line, which is what the right (non-paretic) eye sees, remains directly in the center, to the right of the white light. In summary, a "light-line" configuration signifies an esophoria while a "line-light" configuration reflects an exophoria.

A prism bar may be placed in front of one of the eyes and tuned to the prism strength needed to line up the light and line, again offering a semi-quantitative assessment of the degree of strabismus.

DOUBLE MADDOX ROD

In cases of torsional diplopia, one may perform the double Maddox rod test by placing a red Maddox over the right eye and a white Maddox over the left. This allows the examiner to measure the number of degrees of relative torsion between the two eyes. Typically, both are placed in a trial frame so that the patient may turn one of the lenses with a nob until the two lines are upon each other. The number of degrees from the vertical meridian is then measured – if the torsional offset is more than 10 degrees, than bilateral trochlear palsies are likely present, as unilateral trochlear weakness should not produce that much separation in the torsional plane by itself.

LANCASTER SCREEN

Similar to the Maddox rod, the Lancaster screen test is helpful in revealing phorias. The patient wears a pair of glasses with a red lens over the right eye and green over the left. They hold a green light pointer while the clinician holds a red one and they are asked to superimpose the red light on the green light on a screen. The relative placement of the red and green lights reflects the relative alignment of the right and left eye respectively. The test is repeated in the 9 cardinal fields of gaze and in head tilt, to deduce the pattern of the misalignment. The Lancaster screen test is useful in that lights are actually lines of light so that they can be turned to different axes to test vertical and horizontal deviations. Furthermore, the degree of torsional misalignment can be estimated based on the degree that the red and green lines are rotated from one another. Finally, in ocular myasthenia patients, the patient's light will tend to slide away from the other light after a few seconds, reflecting the fatigability with that disease.

COVER TESTING

There are three types of cover tests that can help elucidate a phoria.

- In the single cover test, each eye is covered individually and the movement of the non-covered eye is observed. If there is a tropia (where only one eye is fixating at a time due to the misalignment) then when the fixating eye is covered, the previously non-fixating eye will shift to pick up fixation. If the non-fixating

eye is covered, there will be no movement of the fixating eye. In this way, the "culprit" eye can be detected.

- The cover/uncover test is similar, except that the movement of the covered eye is observed when it is uncovered. Even if there is just a phoria, the eye will tend to drift away from the weak muscle once the eye is unneeded, and when it is uncovered again, it will be observed moving back in the direction of the weak muscle.

- If the cover/uncover test does not tease out the phoria, then the alternate cover test, which involves repeatedly covering one eye and then the other, may do so, as stereo vision is precluded. When the paretic eye is uncovered, it will move back toward fixation (for example, an exophoric eye will move back in). The angle of this movement is called the primary deviation. However, the force needed to keep the paretic eye fixating results in an equal force placed on the non-paretic eye (this is known as Herring's Law), moving it in the same direction while it's covered. This amplitude of this "secondary deviation" is larger than the primary deviation, probably because an equal force will move the non-paretic eye a greater distance than it will move the paretic eye in the direction of its paresis. When the non-paretic eye is then uncovered, it moves back into fixation. Because of the secondary deviation phenomenon, it is difficult to tell which eye is the paretic eye from the alternate cover test when tested in primary gaze. Therefore, the test is repeated in various fields of gaze and head tilt to elucidate which eye is responsible (similar to testing Maddox rod in various fields of gaze).

A prism bar can be utilized in the various cover tests to determine the amplitude needed to reverse the deviation. The strabismus can thus be quantified in every field of gaze.

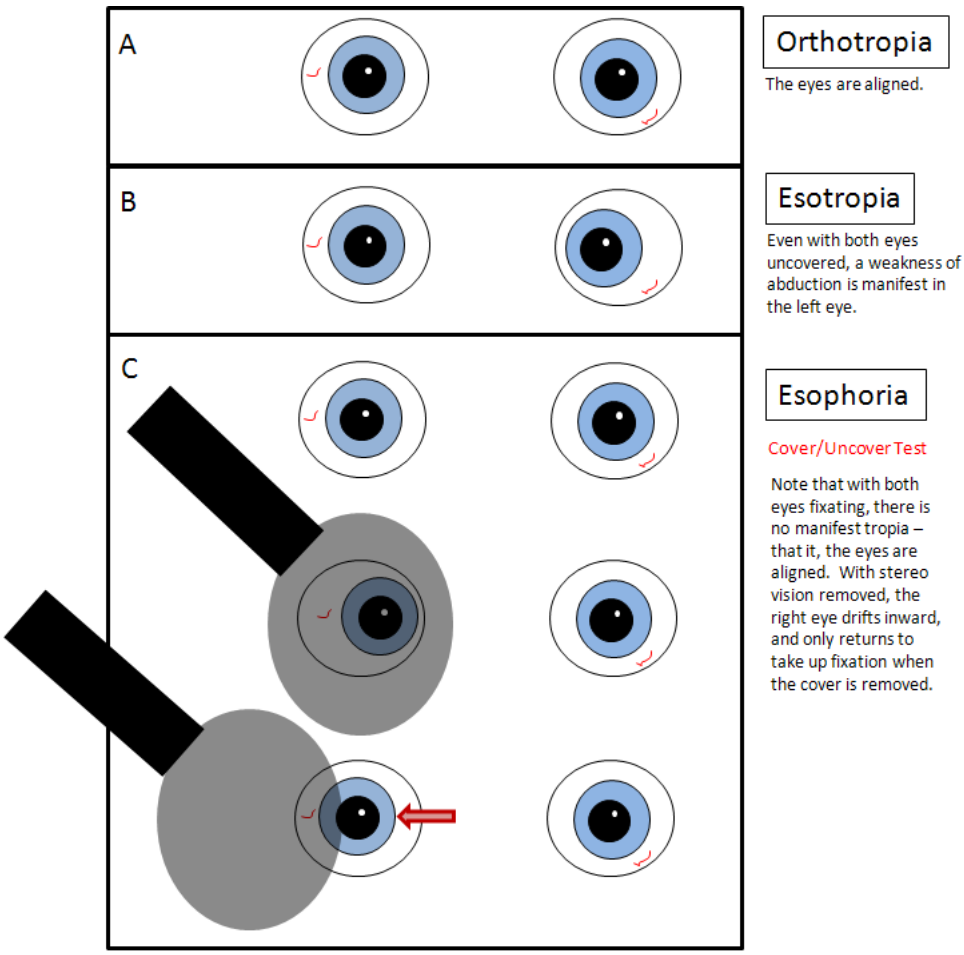

Figure 2. A. Orthotropia – the eyes are aligned. B. Esotropia – an example of a tropia, where the eyes are misaligned even with both eyes uncovered. C. Esophoria – an example of a phoria, where the misalignment is latent and only emerges when one eye is covered.

VESTIBULAR OCULAR REFLEX TESTING

Although a patient may have limitations of voluntary eye movement in one direction or another, sometimes, the eye can still move if stimulated to do so by the vestibule-ocular reflex (VOR). In such cases, the injury is neither in the muscle or nerve, but instead reflects injury to supranuclear pathways connecting cortical control with brainstem nuclei. Progressive supranuclear palsy and some strokes will result in such a supranuclear palsy that is overcome with vestibular stimulation.

SUGGESTED READING

1. Bouchert M, Principles and Techniques of the Examination of Ocular Motility and Alignment, Chapter 18 in Walsh and Hoyt's Neuro-ophthalmology, 6th edition, editors: Miller N and Newman N., Associate editors: Biousse V and Kerrison J.
2. Leigh J and Zee D, The Neurology of Eye Movements, 4th edition, 2006
3. Newman-Toker DE, Rizzo JF 3rd, Subjectively quantified Maddox rod testing improves diagnostic yield over alternate cover testing alone in patients with diplopia. J Clin Neurosci. 2010 Jun;17(6):727-30.