Evaluation of Diplopia:
An Anatomic and Systematic Approach

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Double vision, or *diplopia*, is a symptom with many potential causes that can involve many different structures. An anatomic and systematic approach to the clinical evaluation of diplopia can lead to an accurate diagnosis without extensive laboratory investigation. The goal of this review is to provide the reader with a practical guide to the historical assessment as well as physical examination of a patient with double vision and to review the most common associated features that help localize the cause of the problem. **Table 1** defines terms commonly used to describe ocular movements and misalignment. **Figure 1** illustrates the extraocular muscles.

MECHANISMS OF DIPLOPIA

The two most common mechanisms for diplopia are ocular misalignment and ophthalmic aberrations (ie, defects of the cornea, lens, iris, or retina). The most important clue to the identification of the mechanism is whether the patient has *monocular* or *binocular* diplopia. Ocular misalignment in a patient with normal binocular vision results in binocular diplopia, defined as diplopia that resolves when either eye is occluded. If the image of an object that is being viewed does not fall on the fovea of both retinas, then the image appears to be in 2 different spatial locations and diplopia occurs.

Monocular diplopia is defined as double vision that is present in the affected eye while the other eye is occluded. In nearly all circumstances, monocular diplopia is the result of a local ocular aberration of the cornea, iris, lens, or, rarely, the retina. Monocular diplopia is never caused by misalignment of the eyes.

A third, rare mechanism of diplopia is dysfunction of the primary or secondary visual cortex. This results in bilateral monocular diplopia and should be considered in the appropriate setting when the patient has no ocular aberration.

Finally, diplopia that occurs without any pathologic cause may be termed *functional*; patients whose diplopia is functional often complain of multiple other somatic or neurologic symptoms in addition to double vision. Historical clues should be gathered to help define one of these four mechanisms before embarking on the examination.

HISTORICAL ASSESSMENT

Every effort should be made to ascertain whether the diplopia is monocular or binocular because this is critical in determining the mechanism and cause. For patients with binocular diplopia, the examiner can evaluate for causes of ocular misalignment due to neurologic or orbital disease, whereas for patients with monocular diplopia, the examiner can focus on disorders of the eye. If a patient is uncertain whether the diplopia is monocular or binocular, he or she should be asked during the history to look at an object in the examining room that appears doubled and determine whether the double vision remains if the right eye is occluded and whether it remains if the left eye is occluded. Note that monocular diplopia can occur in both eyes simultaneously (ie, bilateral monocular diplopia).

The history elicited should include elements to aid in the localizing the source of the problem. As is customary, the examiner should gather information regarding onset, duration, frequency, associated symptoms, and exacerbating or relieving factors. Patients should be asked specifically about vision loss, trauma, childhood strabismus, amblyopia, and prior ocular or strabismus surgery. It is essential to perform a full neurologic and ophthalmic review of systems.

Historical Assessment of Monocular Diplopia

Clues to ophthalmic causes. The most common ophthalmic causes of monocular diplopia are uncorrected refractive error and other defects of the cornea (**Table 2**).[1] Certain descriptions of the diplopia can help the examiner determine the cause. Patients with corneal defects often experience double vision as a

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Table 1. Common Terms Used in Describing Ocular Movement and Misalignment

Binocular vision: sight resulting from processing vision from both eyes simultaneously

Pursuits: slow, smooth, eye movements that track a moving target

Saccade: fast eye movement that moves the eye(s) directly from one target to another

Duction: the movement of *one* eye tested monocularly

  Abduction: horizontal eye movement toward the lateral position

  Adduction: horizontal eye movement toward the medial position

  Supraduction: vertical eye movement toward the superior position

  Infraduction: vertical eye movement toward the inferior position

Version: the simultaneous movement of both eyes in the same direction

Strabismus: misalignment of one eye relative to the other

Phoria: misalignment of one eye relative to the other that occurs when binocular viewing is interrupted (ie, interruption of simultaneous fixation with both eyes)

Tropia: misalignment of one eye relative to the other during binocular viewing

Exodeviation: one eye aligned outward relative to the other eye; *exotropia, exophoria*

Esodeviation: one eye aligned inward relative to the other eye; *esophoria, esotropia*

Amblyopia: the lack of development of normal sight in one eye during childhood because the unaffected eye is "favored" by the brain; strabismus is the most common cause

Front of left eye

Figure 1. Extraocular muscles.

"shadow" image or a second image that "surrounds" an object; they also may complain of a "haze" or "blur" to their vision. Common cornea problems in otherwise healthy patients include irregular astigmatism, corneal scars, and corneal defects induced by laser eye surgery (ie, LASIK).[2] Cataract formation usually results in loss of visual acuity and glare, but occasionally, patients report diplopia due to a "ghost" image that is much lighter and less defined. Retinal defects involving the macula result in distortions of images that appear to be bent or warped. Some macular defects (eg, subretinal neovascular membrane) result in diplopia that typically is monocular but can be binocular.[3,4] Skilled ophthalmoscopy allows one to easily recognize macular disease and should be performed when retinal disease is sus-
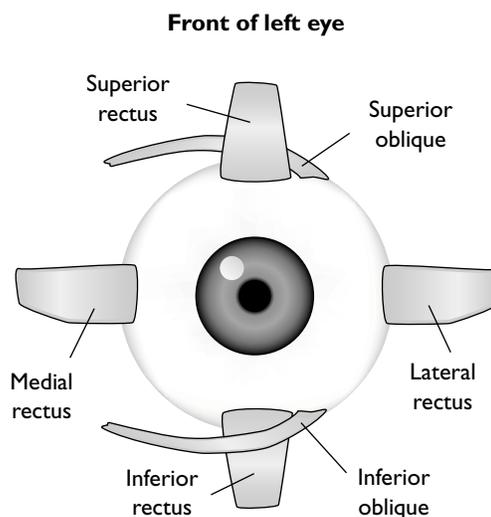
pected. Prior to the examination, the patient can be asked to draw and describe what he or she sees, and the characteristic distortions of macular disease might become apparent (**Figure 2**).

Clues to neurologic causes. A rare manifestation of disease involving the primary or secondary visual cortex is the visual perception of multiple images, which is a bilateral monocular phenomenon because it is present with either eye closed. Cerebral polyopia (ie, seeing 3 or more images) and cerebral diplopia are rare presentations of cortical disease.[5] Palinopsia, another type of cortical disturbance, refers to seeing multiple images of an object immediately after turning away from the object or after the object is removed from sight. Patients often use the term "strobe effect" or "after image" to describe palinopsia. Discrete lesions within the occipitoparietal or occipitotemporal cortex, seizures, drugs, and migraines can cause cerebral diplopia, cerebral polyopia, or palinopsia.[5,6] Homonymous visual field defects (ie, deficits on the same side for both eyes) often are associated with these types of cortical visual illusions. However, patients are not always aware of the visual field loss.

Clues to nonpathologic causes. Patients whose diplopia is functional generally have numerous other vague complaints about their vision. Patients should never be labeled as "functional" unless comprehensive ophthalmologic and neurologic examinations and work-up indicate no pathologic cause. A second visit may be necessary to be certain that an etiology with a relapsing and remitting course is not the origin of the diplopia.

Table 2. Causes of Monocular Diplopia

Refractive error

Corneal defect (eg, irregular astigmatism)

Iris injury

Cataract

Macular defects (eg, epiretinal membrane, choroidal folds)

Media opacities

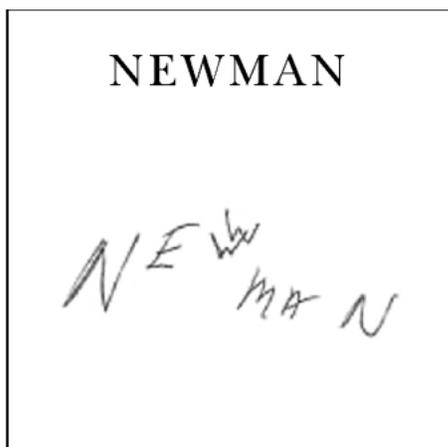Cerebral cortical dysfunction (bilateral monocular diplopia)

Figure 2. Drawing by a patient with diplopia due to macular disease. As the patient reads the word "NEWMAN," only the portion of the word that he is focused upon appears doubled and distorted (the W and E), whereas the adjacent letters appear normal.

Historical Assessment of Binocular Diplopia

From the eye to the brain, the following 7 mechanisms and their associated locations should be kept in mind while gathering historical information regarding binocular diplopia (**Table 3**): (1) orbital or ocular displacement; (2) extraocular muscle restriction; (3) extraocular muscle weakness; (4) neuromuscular junction dysfunction; (5) dysfunction of the third, fourth, or sixth cranial nerves; (6) cranial nerve nuclear dysfunction in the brain stem; and (7) supranuclear dysfunction involving the pathways to and between the nuclei of the third, fourth, or sixth cranial nerves.

Patients should routinely be asked if the diplopia is horizontal, vertical, or oblique. Horizontal diplopia is related to the control and movement of the medial rectus muscle, the lateral rectus muscle, or both (**Figure 3**). Vertical diplopia is related to the control and movement of the inferior rectus muscle, the superior rectus

Table 3. Common Causes of Binocular Diplopia

Orbital disorders

Trauma, mass or tumor, infection, thyroid-associated ophthalmopathy

Extraocular muscle restriction

Thyroid-associated ophthalmopathy, mass or tumor, extraocular muscle entrapment, extraocular muscle injury or hematoma due to ocular surgery

Extraocular muscle weakness

Congenital myopathies, mitochondrial myopathies, muscular dystrophy

Neuromuscular junction dysfunction

Myasthenia gravis, botulism

Palsies of the third, fourth, or sixth cranial nerves (any location)

Ischemia, hemorrhage, tumor or mass, vascular malformation, aneurysm, trauma, meningitis, multiple sclerosis

Brain stem injury to cranial nerve nuclei

Stroke, hemorrhage, tumor or mass, trauma, vascular malformation

Supranuclear injury (pathways to and between cranial nerve nuclei)

Stroke, hemorrhage, tumor or mass, trauma, multiple sclerosis, hydrocephalus, syphilis, Wernicke's encephalopathy, neurodegenerative disease

muscle, the inferior oblique muscle, the superior oblique muscle, or a combination of these muscles.

The direction of gaze that results in diplopia or increases the separation of the images can help determine which structures are involved in the cause of diplopia. For instance, if a horizontal, binocular diplopia is worse in left gaze, then either the left eye cannot fully abduct (eg, from a left sixth nerve palsy) or the right eye cannot fully adduct (eg, from a right intranuclear ophthalmoplegia). Knowledge of the actions of each extraocular muscle is essential to direct and utilize historical information to localize the causative structures (Figure 3).

Orbital disease or extraocular muscle restriction. Most patients with orbital disease or extraocular muscle restrictive processes will have conspicuous signs of periorbital or orbital abnormalities on examination. Nonetheless, patients must be questioned about changes in appearance because early or symmetric changes can be subtle and difficult to detect by the examiner. For example, signs such as eyelid retraction and periorbital edema fluctuate in diseases such as
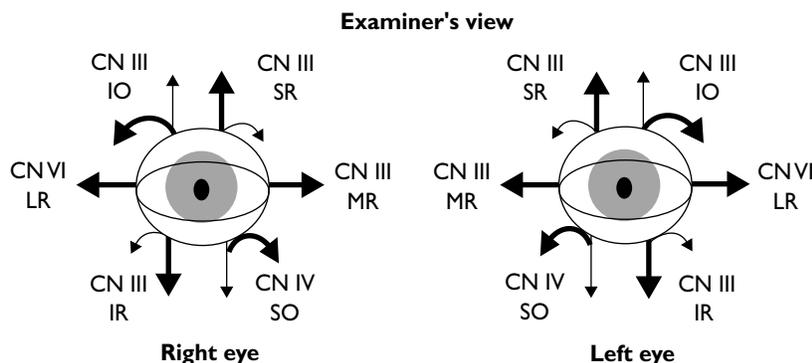
Examiner's view

Right eye / Left eye

Figure 3. Actions of extraocular muscles and cranial nerve control from the examiner's view. The *wide arrows* represent the primary action by the muscle, and the *narrow arrows* represent the secondary action. Of note, the superior rectus and the superior oblique muscles intort (twist inward) the eye, and the inferior rectus and the inferior oblique muscles extort (twist outward) the eye; this is represented by *curved arrows*. CN = cranial nerve; IO = inferior oblique muscle; IR = inferior rectus muscle; LR = lateral rectus muscle; MR = medial rectus muscle; SO = superior oblique muscle; SR = superior rectus muscle.

thyroid-associated ophthalmopathy and can be less evident in early or mild stages of disease. Old photographs or a driver's license photo are extremely useful for detection of subtle changes. Patients also should be asked about recent ocular surgery, trauma, and eye pain. Orbital processes such as cellulitis, mass lesions, and inflammatory disorders of orbital tissues (eg, orbital pseudotumor) can begin with eye pain and diplopia.

Extraocular myopathic weakness. Mitochondrial myopathies, some congenital myopathies, and muscular dystrophies such as oculopharyngeal dystrophy, can present with diplopia due to significant extraocular muscle weakness.[7] If a myopathy is suspected, symptoms denoting weakness of other cranial or skeletal muscles should be elicited. Inquiries about family history as well as a history of muscle weakness in childhood should be made. Of note, inflammatory myopathies, such as dermatomyositis, polymyositis, and steroid-induced myopathies, arguably never involve weakness of the extraocular muscles.[7,8] Alternative explanations for diplopia in these disorders should be sought.

Neuromuscular junction dysfunction. Fluctuating weakness is the historical hallmark of a neuromuscular junction dysfunction, and patients with diplopia should be routinely questioned about diurnal variation of diplopia. For example, diplopia that is absent in the morning and progressively worsens throughout the day or worsens with reading is common in neuromuscular junction disorders that affect the extraocular muscles. More than 50% of patients with myasthenia gravis, which is the most common disorder of the neuromuscular junction, present with ptosis (eyelid drooping) and diplopia without other symptoms or signs of weakness.[9]

Third, fourth, and sixth cranial nerve palsies. Historical information is best gathered with a clear under-

standing of the pathways of the third, fourth, and sixth cranial nerves as they traverse from the brain stem to the orbit. (*See* review by Bennett and Pelak, 2001.[10]) The cranial nerves that innervate the extraocular muscles can be injured in the following locations from the eye to the brain: (1) orbit, (2) superior orbital fissure, (3) cavernous sinus, (4) subarachnoid space, and (5) brain stem. Characterization of associated historical and examination features are vital to localizing the site of injury, and localization leads to an accurate differential diagnosis (**Table 4**). For example, a 65-year-old patient with severe headache and an isolated third cranial nerve palsy with a mydriatic (ie, dilated) and paralyzed pupil implicates a compressive injury of the third cranial nerve in the subarachnoid space, and the most likely cause would be an intracranial aneurysm involving the posterior communicating artery.[11]

When cranial nerve palsies occur in isolation, patients should be questioned about vascular risk factors and diabetes because microvascular ischemic infarct of the third, fourth, or sixth cranial nerve can occur. Systemic vasculitides, such as temporal arteritis, can present with a cranial nerve palsy; symptoms of jaw claudication, headache, scalp tenderness, and arthralgias should be inquired about in older patients with diplopia due to a cranial nerve palsy.[12]

A third cranial nerve palsy typically presents with vertical and horizontal diplopia that improves when the affected eye is abducted because the lateral rectus muscle and the sixth cranial nerve abduct the eye. Fourth cranial nerve palsies result in vertical diplopia that is worse or only present with near vision and downward gaze in the opposite direction of the affected eye. Because the superior oblique muscle intorts the eye (Figure 3), patients with fourth nerve palsies

Table 4. Localization of Third, Fourth, and Sixth Cranial Nerve Palsies: History and Examination

Location of Injury	Cause	History	Examination Findings
Superior orbital fissure	Cellulitis, tumor or mass, TAO	Eye pain, change in appearance of orbit	Proptosis, combination of 3rd, 4th, and 6th n. palsies
Cavernous sinus	Infection, carotid artery aneurysm, cavernous carotid arterial venous fistula, inflammation, tumor, mass	Same as orbit	Same as orbit with or without proptosis, plus Horner's syndrome*; 6th n. commonly first involved
Subarachnoid space	Aneurysm, hemorrhage, meningitis due to infection or cancer, hydrocephalus	Headache, nausea and vomiting, recent trauma, constitutional symptoms, hearing loss	Isolated palsies are often localized here; if 3rd n. palsy due to compression, then pupil typically involved; 6th n. palsy with IL hearing loss
Brain stem	Stroke, hemorrhage, tumor or mass, trauma, vascular malformation, inflammation, multiple sclerosis	Rapid onset, dysarthria, vertigo nausea, facial and extremity weakness or numbness, hearing loss, dysmetria, ataxia, altered mentation	3rd n./midbrain: CL extremity weakness, CL tremor, CL dysmetria 4th n./midbrain: IL or CL (dependent on nuclear or fascicular injury) APD, INO, Horner's syndrome. 6th n./pons: IL 7th n. palsy, IL INO, IL horizontal gaze palsy

APD = afferent pupillary defect; CL = contralateral; IL = ipsilateral; INO = intranuclear ophthalmoplegia; n = nerve; TAO = thyroid-associated ophthalmopathy.

*Horner's syndrome refers to ptosis and miosis.

also may report that one of the images is tilted. Patients with a sixth nerve palsy experience horizontal double vision that is worse when the affected eye is abducted (ie, in lateral gaze toward the side of the affected eye) or when viewing objects at distance, because the eyes must diverge.

Brain stem injury. Injury within the brain stem to the supranuclear pathways, the cranial nerve nuclei, or the cranial nerve fascicles rarely results in *isolated* diplopia. Instead, most patients experience diplopia associated with additional neurologic symptoms because the anatomic structures that control sensory, motor, coordination, and gait functions are in close proximity to the structures that control eye movements. Familiarity with the structures within the midbrain, pons, and medulla is necessary to localize the lesion using historical information. Patients should be asked about facial numbness or weakness, hearing loss, dysphagia, dysarthria, vertigo, and imbalance, as well as incoordination, numbness, or weakness of the extremities. (*See* review by Brazis et al.[13])

Supranuclear pathways. Supranuclear pathways make connections to and between the cranial nerve nuclei and originate in the cortex, brain stem, cerebellum, and the peripheral vestibular structures.[14] Supranuclear dysfunction can result in *conjugate* or *dysconjugate* gaze abnormalities. If both eyes are equally paretic in the same direction of gaze due to a supranuclear lesion, then the deficit is conjugate and patients will not have diplopia. Deficits can be congenital or aquired.[15]

Supranuclear gaze palsies can be either horizontal or vertical. In most cases, conjugate horizontal gaze palsies localize to the pons or frontal cortex and conjugate vertical gaze palsies localize to the midbrain. Dysconjugate gaze palsies have various localizations. An example of a dysconjugate supranuclear horizontal gaze palsy is an intranuclear ophthalmoplegia. An intranuclear ophthalmoplegia is characterized by an adduction deficit in the eye on the same side as the lesion with simultaneous nystagmus of the abducting eye during lateral gaze, and it is commonly associated with multiple sclerosis or stroke. An example of a dysconjugate supranuclear vertical palsy is skew deviation. It localizes to the brain stem, cerebellum, or the peripheral vestibular system.[14,16]

Table 5. Supranuclear Gaze Palsies

Gaze Palsy	Common Causes	Location and Associated Features
Horizontal	Stroke, tumor, trauma, Wernicke's encephalopathy	Frontal cortex: CL saccade impairment, CL extremity weakness Pons (PPRF or 6th nerve nucleus): IL conjugate gaze paresis, IL INO, IL facial palsy
Vertical: up	Stroke, tumor, hydrocephalus, syphilis	BL dorsal midbrain: light–near pupil dissociation, lid retraction, C-R nystagmus
Vertical: down	Stroke, tumor, PSP, spinocerebellar ataxia	BL anterior midbrain: extremity weakness, tremor Also with PSP: gait imbalance, axial rigidity, lid retraction

Skew deviation	Stroke, tumor, increased intracranial pressure	Midbrain: INO, lid retraction, head tilt
		Medulla: vertigo, nausea, vomiting, dysphagia, dysarthria
		  IL: palatal weakness, facial anesthesia, ataxia, Horner's syndrome
		  CL: extremity anesthesia

INO	Stroke, multiple sclerosis	Pons: IL 6th cranial nerve palsy, IL horizontal gaze palsy

BL = bilateral; CL = contralateral; C-R = convergence-retraction; IL = ipsilateral; INO = intranuclear ophthalmoplegia; PPRF = paramedian pontine reticular formation; PSP = progressive supranuclear palsy.

Unlike conjugate gaze palsies, dysconjugate gaze palsies result in diplopia because ocular misalignment occurs in 1 or many directions of gaze.[17]

As with injury to the cranial nerves and their nuclei, supranuclear pathway injuries are often accompanied by other neurologic signs and symptoms. The numerous structures and etiologies that are commonly associated with lesions of the supranuclear pathways are shown in **Table 5**.[18] Patients should be asked about symptoms of weakness, numbness, cognitive impairment, imbalance, incoordination, dysphagia, dysarthria, vertigo, nausea, and vomiting.

EXAMINATION FOR ANATOMIC LOCALIZATION

Examination of all basic visual sensory and ocular motor functions is necessary in the evaluation of diplopia. Best-corrected visual acuity, visual fields to confrontation, pupil appearance and reaction to light, and posterior fundi should be examined in every patient. In addition, if the pupil light response is abnormal for either eye, then the pupil response to viewing a near target should be recorded (ie, part of the accommodation reflex). Alignment should be noted while the patient is fixating on distant and near targets in all directions of gaze, and evaluation of ductions, versions, saccades, and pursuits should be performed (Table 1). An invaluable tool for measuring visual acuity is a handheld pinhole device that allows a patient to have a monocular view of an eye chart through small holes. Pinholes can eliminate refractive error and eliminate

monocular diplopia caused by many types of refractive error.

Examination for Monocular Diplopia

To determine the specific ocular cause of monocular diplopia, a complete ophthalmologic examination, including a slit lamp examination, is necessary. If expertise or equipment is inadequate, a formal ophthalmologic consultation should be obtained for refraction and examination of the cornea, iris, lens, ocular media, and retina for every patient who complains of monocular diplopia. If pinholes correct the diplopia, then the cause likely involves the cornea or lens. Macular disorders of the retina do not improve with pinholes. An Amsler chart (**Figure 4**) can be used to identify macular disease, which should be verified by direct ophthalmoscopy.

Examination for Binocular Diplopia

The examination of a patient with ocular misalignment involves more than the evaluation of the movement of the eyes. The examiner should measure or note ocular alignment in various directions of gaze, periorbital swelling, orbital abnormalities such as forward or backward displacement of the globe (ie, exophthalmos/proptosis or enophthalmos), injection of the ocular conjunctiva or sclera, eyelid position, and fatigable weakness of the extraocular muscles or levator palpebrae muscles of the eyelids. A complete general neurologic examination also is necessary.
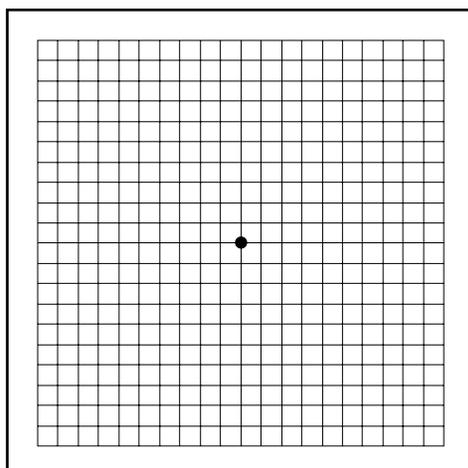
Figure 4. Example of an Amsler grid chart to test central vision. Patients with macular disease often see a bent or warped appearance of the grid lines (distortion not shown). The patient should be tested monocularly (ie, with one eye closed).

Globe, orbit, and eyelid examination. An exophthalmometer is used to detect and measure proptosis or enophthalmos, and readings greater than 21 mm for either eye or differences greater than 2 mm between each eye indicates proptosis or enophthalmos. Some people (eg, some African American women) have shallow orbits and readings that range from 23 mm to 25 mm can be normal.[19] If an exophthalmometer is not available, one should view the eyes in a side profile or from above the patient to evaluate for asymmetry.

Eyelid function and eyelid position should be examined. The upper eyelid position should be just slightly below the top of the iris. When the upper eyelid is above the iris and sclera is showing, *lid retraction* is diagnosed (**Figure 5**), and if the eyelid "lags" behind the eye with downward eye pursuits, then *lid lag* is present. These two signs are very common in patients with thyroid-associated ophthalmopathy. Dorsal midbrain disease can result in eyelid retraction but not lid lag. *Ptosis* is present if there is less than 4 mm between the corneal light reflex on the center of the pupil (seen when the patient fixates on a light projected toward him or her) and the upper eyelid. Neurologic causes of ptosis result from dysfunction of the levator palpebrae muscle, controlled by the third cranial nerve, or from dysfunction of Müller's muscle, which is controlled by sympathetic innervation.[20] Ptosis from Müller's muscle weakness caused by Horner's syndrome is always minimal and often the lower lid is slightly elevated.[17] Old photographs help to differentiate acute versus chronic processes involving the globe, orbit, and eyelids.

Figure 5. Photo of a patient with thyroid-associated ophthalmopathy demonstrating bilateral eyelid retraction with the lids above the iris with sclera showing (*arrow*). Note also the periorbital edema.

Extraocular muscle movement examination. The cardinal positions of gaze (Figure 3) are examined by asking the patient to follow a target or the examiner's finger held at approximately 12 to 14 inches away from the patient's eyes. If ductions or versions are limited, one must determine whether the limitation is caused by a restrictive process, muscle weakness, neuromuscular junction dysfunction, cranial nerve palsy, or a supranuclear process. Forced duction testing is useful to detect mechanical limitation for patients with substantial extraocular muscle limitation. Following topical anesthesia of the cornea and conjunctiva, the tip of a cotton swab applicator or a fine-toothed forceps is used to attempt to move or "force" the eye into the direction of limitation. If no resistance is encountered, mechanical restriction is not present.

The gross examination may be insensitive to the cause of binocular diplopia, especially when dealing with a partial third or fourth nerve palsy. A *Maddox rod*—a red lens with ridges (**Figure 6**)—or a red lens without ridges can be used to determine the presence and degree of ocular misalignment. The red lens is held over the right eye (by convention) while the patient views a pinpoint white light from a transilluminator on the body of an ophthalmoscope or another light source held by the examiner. The location of the red bar seen by the patient using Maddox rod, or the red light seen by the patient using a red lens without ridges, in relation to the white light indicates how the eyes are misaligned. Ocular torsion can be measured with use of a double Maddox rod.[21]

Neuromuscular junction examination. Evaluation for signs of fatigable extraocular muscle and fatigable eyelid weakness with recovery of strength is accomplished with techniques such as sustained gaze or repetitive eye closure. Extraocular muscle fatigue is somewhat difficult to observe, but an attempt at maintaining eccentric positions of gaze by a patient with neuromuscular junction dysfunction might reveal increasing strabismus, even in patients without initial evidence of ocular misalignment.[22] Repeat extraocular
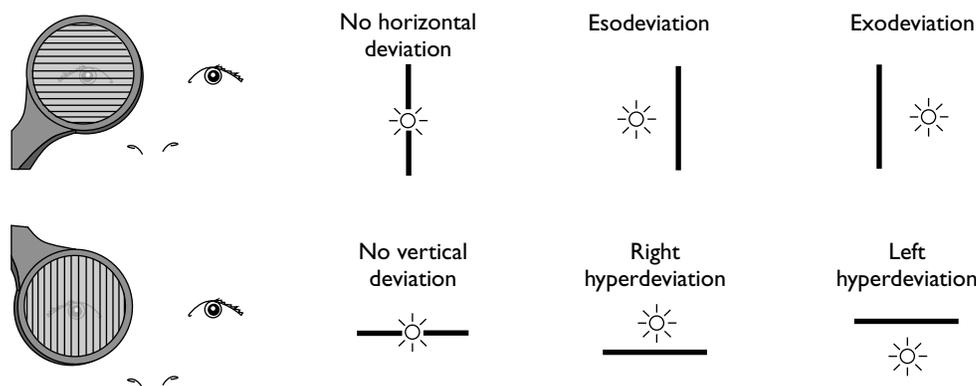
Figure 6. Maddox rod assessment of ocular misalignment. The ridges are placed in the horizontal direction to evaluate for horizontal misalignment and in the vertical direction to evaluate for vertical misalignment. The patient focuses on a distant, pinpoint light source, and the relationship of the line to the light that the patient sees determines the type of misalignment. The red line seen by the patient is oriented vertically when the ridges are placed horizontally over the right eye; the line is oriented horizontally when the ridges are positioned vertically. The light and line positions shown are drawn from the patient's view. (Adapted with permission from Liu GT, Volpe NJ, Galetta SL. Neuro-ophthalmology: diagnosis and management. 1st ed. Philadelphia: WB Saunders; 2001:31.)

muscle duction and version testing if no rest or recovery is allowed after sustained gaze might reveal increased ophthalmoplegia from baseline. Weakness of the levator palpebrae muscle results in ptosis. Ptosis that is characterized by recovery after rest is referred to as *Cogan's lid twitch.* It is observed by having the patient maintain fixation in downgaze for 10 to 20 seconds; the patient then should refixate with a saccade (ie, a fast eye movement) on a target in primary (straight ahead) gaze. If upon return to primary gaze, the ptotic lid rises and then falls quickly, Cogan's lid twitch is present. The triad of fatigable ptosis, fatigable extraocular muscle weakness, and weakness of the orbicularis oculi muscles is highly suspicious for myasthenia.

Third, fourth, and sixth cranial nerve examination. Examination of the range of extraocular muscle movement as well as the determination of the degree of horizontal or vertical misalignment in all positions of gaze, and with a right or left head tilt, allows one to diagnose whether a cranial nerve is responsible for the deficit.[10] The greatest misalignment of the eyes will occur in the direction of the action(s) of the weak muscle(s) (Figure 3).

The third cranial nerve innervates the superior, inferior, and medial recti muscles; the inferior oblique muscle; the pupillary sphincter muscle; and the levator palpebrae superioris muscle of the eyelid. Injury to the third nerve results in the following signs: limited supraduction, infraduction, and adduction; pupil mydriasis and partial or complete pupil paralysis to light; and partial or complete ptosis of the affected eye. When the unaffected eye is fixating on a distant target in primary

gaze, the affected eye usually is positioned *down* and *out* because of the unopposed action of the superior oblique and lateral rectus muscles, which are innervated by the fourth and sixth cranial nerves, respectively (**Figure 7A**). Complete paralysis of the extraocular muscle and eyelid without involvement of the pupil (ie, complete pupil-sparing third nerve palsy) is most often due to ischemia of the third nerve. In cases of partial third nerve palsies, a Maddox rod or red glass test often is needed to verify the diagnosis (Figure 6). The Maddox rod typically reveals a hyperdeviation of the *affected* eye in downgaze and a hyperdeviation of the *unaffected* eye in upgaze, referred to as an *alternating hyperdeviation.* There also will be an exodeviation that worsens when the affected eye is adducted.

The fourth cranial nerve innervates the superior oblique muscle, which infraducts and intorts the eye. When the unaffected eye is fixating on a distant target in primary gaze, a misalignment may not be present; for this reason, and because limitations in downgaze can be difficult to directly observe, fourth nerve palsies often are poorly recognized (**Figure 7B**).[23] If no limitation with infraduction and adduction is obvious to the examiner, the patient can be asked to view a straight line on paper placed near and below the eyes to the right and left. If double vision is present, the patient can draw the false second image. The false image should be below the line and tilted in cases of fourth nerve palsies such that it forms an arrow that points to the side of the palsy (**Figure 8**). Due to the intorsion action of the superior oblique muscle, the separation of the doubled images increases when the head is tilted toward the side of the
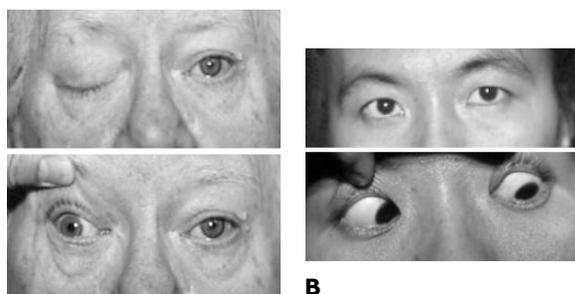
Figure 7. (**A**) Photo of a patient with an ischemic, right third cranial nerve palsy. The patient has complete ptosis (*top panel*). When the eyelid is manually opened (*bottom panel*), the right eye is deviated downward and outward. (Note that the corneal light reflex in the right eye is medial and higher than the light reflex of the left eye.) (**B**) Photo of a patient with bilateral fourth cranial nerve palsies due to trauma that was worse on the left than the right. Note in the top panel that the head is slightly tilted to the right (to prevent diplopia from the left fourth nerve palsy), and that the misalignment is difficult to note in primary gaze. In the bottom panel, the eyes are directed down and to the left and the right eye is unable to fully infraduct the eye. Double Maddox rod measurements revealed that both eyes are excyclotorted (twisted outward).
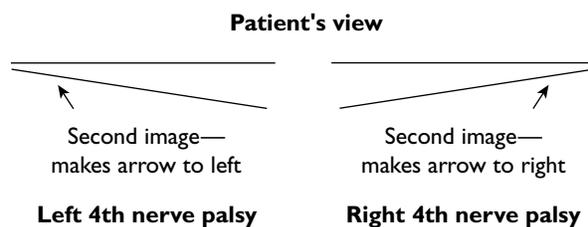

Figure 8. The "arrow test" to examine for a fourth cranial nerve palsy. With fixation by the unaffected eye, a straight line appears doubled and tilted due to weakness of the superior oblique muscle in the affected eye, which normally *depresses* and *intorts* the eye. The doubled image and the straight line together form an arrow that points to the side of the fourth nerve palsy.

fourth nerve palsy and the deficit improves when the head is tilted to the side opposite the fourth nerve palsy. Thus, a right fourth nerve palsy is made worse by a right head tilt. For this reason, patients may unconsciously hold their head slightly tilted to the opposite side of the fourth nerve palsy (Figure 8). A Maddox rod test will show a hyperdeviation of the affected eye when it is infraducted while in adduction.

The sixth cranial nerve innervates the lateral rectus muscle, which abducts the eye. When the unaffected eye is fixating on a distant target in primary gaze, the affected eye is often deviated inward (esotropia). The Maddox rod will reveal an esotropia that is greatest when the affected eye is abducted.

Brain stem examination. In order to assess brain stem function, the third, fourth, and sixth cranial nerves—as well as all other cranial nerves—must be tested. Testing of facial strength and sensation, corneal sensation, masseter strength, hearing, elevation of the palate and the uvula, sternocleidomastoid and trapezius muscle strength, gag reflex, and position and strength of the tongue will complete the cranial nerve examination. Characteristic stroke syndromes within the brain stem are well defined and can be recognized by the combination of signs and symptoms that result because of distinctive vascular territories of penetrating small vessels.[24]

Supranuclear pathway examination. The most im-

portant examination feature of a supranuclear motility deficit is the ability to overcome the ocular motility limitation with an oculocephalic maneuver. In cases of supranuclear injury, the nuclei that control the third, fourth, and sixth cranial nerves are still intact and the cranial nerve fascicles are functioning normally. Therefore, stimulation of the nuclei with head movements should result in full ocular ductions. To perform the oculocephalic maneuver, the patient should fixate on an object 14 to 16 inches away, such as the patient's thumb or the examiner's nose. Then, while the patient continues to fixate, the patient's head is turned slowly to the right and left and up and down. This head movement during fixation should overcome any limitation of ductions or versions due to supranuclear pathway dysfunction.

Patients with a grossly normal ocular motility examination. A neuro-ophthalmic consultation is prudent for any patient with binocular diplopia and examination results that appear normal on gross inspection. The Maddox rod can be used in conjunction with variable degrees of prism lenses to quantify the misalignment in all directions of gaze. From these measurements, a pattern will emerge that allows for localization.

WORK-UP AND TREATMENT

Work-up and treatment depends on the suspected cause of the diplopia. In cases of monocular diplopia, refraction may be all that is needed. For orbital disorders, a computed tomography scan or magnetic resonance imaging scan of the orbits is indicated. In cases of chronic, binocular diplopia, magnetic resonance imaging of the brain is indicated unless the etiology is well understood. If myasthenia gravis is suspected, anti-acetylcholine receptor antibodies and electromyography

should be performed. Surgical or medical treatment or the use of prism lenses can relieve symptoms of diplopia once the cause has been determined and the patient has a stable deficit.[25,26]

SUMMARY

Evaluation of diplopia can be daunting without a basic understanding of the mechanisms and anatomy involved in ocular motility. A systematic approach is necessary to uncover the mechanism of diplopia and to appropriately direct the work-up and management. With an understanding of the important historical clues that help one guide and execute the examination, the challenge of evaluating diplopia can be uncomplicated and rewarding.   **HP**

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