Visual Evoked Potential Testing

- Office-based electrodiagnostic testing – “VEP”
- Based on the principles of neural electrophysiology
- A VEP testing device uses a patterned-stimulus to generate visual evoked potentials
- Parameters of visual evoked potentials are sensitive to abnormalities in the visual system
- By measuring the speed and strength of the evoked response along the visual pathway, VEP testing evaluates the integrity of the afferent visual sensory system

Clinical Applications of VEP Testing

- As with all ancillary tests, VEP testing may be considered reasonable and medically necessary based upon the following:
  - Patient symptoms
  - Clinical signs of illness
  - Clinical signs of injury
- In diseases that affect the structure and function of the afferent visual sensory system, visual evoked potential testing is performed to assess the integrity of the visual pathways

Clinical Indications for VEP Testing

- Evaluate diseases of the optic nerve, such as:
  - Optic nerve atrophy
    - Primary optic atrophy – 371.11
    - Glaucomatous optic atrophy – 377.14
    - Partial optic atrophy – 377.15
  - Ischemic optic neuropathy
  - Papilledema
  - Optic disc drusen
- Identification and follow-up for conversion disorder
  - To evaluate persons reporting subjective blindness or loss of vision with no known physiological cause

Clinical Indications for VEP Testing

- Evaluate visual disturbances, such as:
  - Amblyopia
  - Subjective visual disturbances
    - Subjective visual disturbance, unspecified – 368.10
    - Visual discomfort – 368.13
  - Diplopia and other disorders of binocular vision
  - Visual field defects
    - Visual field defect, unspecified – 368.40
    - Paracentral scotomas – 368.41
  - Color vision deficiencies
  - Night blindness

Clinical Indications for VEP Testing

- Identification and/or follow-up for multiple sclerosis
  - Helps to identify the demyelination process
- Diagnosis and treatment for neoplasm compressing the optic nerve
  - Optic nerve glioma
  - Meningioma
  - Cranioopharyngioma
  - Pituitary tumor
  - Giant aneurysm
Clinical Indications for VEP Testing

- Detect optic neuritis at an early, subclinical stage
  - Optic neuritis, unspecified – 377.30
  - Optic papillitis – 377.31
  - Retrobulbar neuritis – 377.32
  - Nutritional optic neuropathy – 377.33
  - Toxic optic neuropathy – 377.34
- Ocular Injury
  - Intracranial injury – 850.4
  - Injury to the optic nerve and visual pathways – 950.0
- Dystrophies involving the retinal pigment epithelium

Visual Evoked Potentials

- The optic nerve transmits sensory information through the neurons of the visual pathway to the occipital cortex of the brain
- Exposure to light stimulus results in a measurable electrical action potential in the neurons within the visual pathways – this is called the visual evoked potential (VEP)
- The VEP is extracted, amplified, filtered, and then displayed as a characteristic VEP waveform

Neural Response of the Visual Pathway

- Receptors
  - Rod cells in the retina
  - Cone cells in the retina
- Transmitters
  - Optic nerve
  - Optic chiasm
  - Optic tract
  - Lateral geniculate nucleus
  - Optic radiations
- VEP Generator Site
  - Primary visual cortex
  - Extrastriate visual cortex

Structures involved in the transmission of sensory information along the pathway

VEP Waveform Interpretation

- The time from stimulus onset to the maximum positive deflection of the VEP waveform of referred to as the peak time
- Most constant VEP wave is the N75-P100-N135 Wave Complex and it peaks about 100 milliseconds after stimulation

Parallel Neural Conduction Channels

- Parvocellular pathway starts with specific retinal ganglion cells called P cells
  - P cells are sensitive to color and show a preference for high spatial-frequency stimuli
  - 80% of total fibers
  - High redundancy
- Magnocellular pathway starts with specific retinal ganglion cells called M cells
  - M cells are sensitive to motion and show a preference for low spatial-frequency stimuli
  - 5-10% of total fibers
  - Low redundancy
VEP Waveform Interpretation

- Hc = High-contrast visual stimulus tests the integrity of the parvocellular neural pathway
- Lc = Low-contrast visual stimulus tests the integrity of the magnocellular neural pathway

Superimposed VEP waveforms

Medical Decision-Making

- Clinical Diagnosis
  Malingering – Fabricating or exaggerating the symptoms of decreased vision for a variety of motives.

- Treatment Plan
  (1) Order retinal laser scans
  (2) Order Full 120 visual field examination
  (3) Order VEP testing

Optical Coherence Tomography

- Mild fallout of the RNFL in the superotemporal region of the right eye
- Macula scan is normal in each eye
- No apparent RNFL or macular pathology sufficient to cause the patient’s decreased vision

Visual Field Examination

Case 1

- 56-year-old Black man with a chief complaint of decreased vision
- Wants to know if eyeglasses will improve his vision
- Temporal history is significant for a previous eye examination 10 months earlier that produced no Rx
- Refraction is – 0.25 in each eye
  - Right eye = 20/60
  - Left eye = 20/60
- Patient has a history of mental disease

Superimposed VEP waveforms

Diopsys NOVA-LX

Visual Field Exam: 2011-01-20
Exam Time: 09:59:30

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Remarks: Normal
Medical Decision-Making

- Patient with pre-existing mental disease
- Unreliable subjective refraction
- Unreliable/abnormal subjective visual field exam
- Retinal laser scan excludes structural damage to the retinal nerve fiber layer and the macula
- Normal visual evoked potential testing in each eye
- Patient does not appear to be deceptive
- Patient is cooperative during diagnostic testing
- No medico-legal context for the exam's presentation

Medical Decision-Making

- Physical Diagnosis
  - Conversion Disorder – A mental disease that presents as a loss of physical function suggestive of a physical disorder

- Treatment Plan
  - (1) Treatment of depression or anxiety, if present
  - (2) Suggestive therapy may be effective for short-term treatment
  - “This problem usually goes away in a few weeks”

Glaucoma Population Studies

- The Baltimore Eye Study proved that glaucoma can be hard to diagnose
- 50% of all people found to have glaucoma during the study had seen an eye doctor within the past year and were unaware that they had glaucoma
- The Early Manifest Glaucoma Trial demonstrated that 50% of patients with glaucoma, even if they had elevated IOPs most of the time, had screening IOPs below 22 mm Hg

Open-Angle Glaucoma: Risk Factors

- Vertically elongated cup-to-disc ratios
- Asymmetric cup-to-disc ratios
- IOPs greater than 21 mm Hg, risk begins to increase at IOPs above 16 mm Hg
- Intraocular pressure asymmetry > 5 mm Hg
- Advancing age
- Black or Hispanic race
- Thin corneas, if IOP is elevated
- Family history
- Medical history (e.g., metabolic syndrome)

Clinical Evaluation of Glaucoma

- Ophthalmoscopy
- Retinal laser scan
- Intraocular pressure
- Electrodiagnostics
- Pupil reactivity exam
- Race/Age
- Fundus photography
- Visual field examination
- Anterior chamber exam
- Central corneal thickness
- Patient history
- Visual acuity

Natural History of Glaucoma

- Electrophysiological studies suggest that glaucoma must not be considered as a disease exclusively involving ocular structures, but is a pathology in which brain structures are also damaged
- First indication involves the early impairment of the ganglion cells of the outer retina
- Second indication involves the impairment of the brain’s postretinal visual pathways secondary to transsynaptic degeneration
- Third indication involves impairment of brain function at the level of the lateral geniculate nucleus

Glaucomatous Optic Atrophy

- Retinal Nerve Fiber Layer
  - Ganglion cell complex
  - Arcuate bundles
  - Papillomacular bundle
- Optic Nerve
- Optic Tract
- LGN
- Optic Radiations
- Occipital Lobe
  - Primary visual cortex
  - Extrastriate visual cortex

Case Report 2

- 58-year-old black woman presenting for doctor recommended eye examination (VSP)

  - Previous examination 19 months earlier in our office
    - IOP in the right eye = 12 mm Hg
    - IOP in the left eye = 13 mm Hg

  - Patient wants to know if new eyeglasses will improve her vision

  - Intraocular pressure measurements are “normal”
    - Right eye = 13 mm Hg
    - Left eye = 14 mm Hg

RAPDx Expanded Pupil Diagnostics

- Automated pupillography
- Goal of pupillary light reflex testing is to determine if there is a defect in either neural light reflex pathway
- Designed to detect a relative afferent pupillary defect (RAPD)
- Assessment of differential amplitudes and latencies

RAPDx Pupillary Testing

Fundus Photography

CD ratio = .40/.40
Distinct optic disc margins
Healthy neuroretinal rim tissue
Glaucoma Risk Factors
(1) Black race

CD ratio = .45/.50
Distinct optic disc margins
Pallor of the neuroretinal rim tissue from 12:00 – 3:00
Glaucoma Risk Factors
(1) Black race
(2) Abnormal disc appearance
Optic Disc Evaluation

Right Eye

Left Eye

Changes in Coloration of the Optic Disc

- Pallor of the temporal neuroretinal rim tissue
- Pallor is indicative of ischemia
- Pallor of the neuroretinal rim alone is not indicative of glaucoma
- Pallor of the temporal rim in combination with increased cupping is suspicious for glaucoma

Medical Decision-Making

- **Clinical Diagnosis**
  - Normal-tension glaucoma

- **Treatment Plan**
  1. Order laser scan of the retinal nerve fiber layer
  2. Order 30-2 threshold visual field examination

Optical Coherence Tomography

- Abnormal retinal nerve fiber layer thickness in both eyes
- Loss of superotemporal retinal nerve fiber layer bundle in the left eye
- Clinically significant asymmetry between the eyes

Visual Field Examination

Early inferior paracentral scotomas in each eye

Medical Decision-Making

- IOP measurements within the “normal” range
- Relative afferent pupillary defect in the left eye
- Abnormal optic nerve appearance in the left eye
- Visual field defect in the left eye
- Fallout of an entire RNFL bundle in the left eye

**Physical Diagnosis**

Normal-tension glaucoma. No treatment today. RTC for confirmatory visual field exam, visual evoked potential testing, color vision exam.
Reporting Medical Services

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Visual Field Exam – 3 day later

- Normal visual field
- Inferior paracentral scotoma

VEP Waveform in Glaucoma

- Delayed P100 peak time of the low-contrast VEP response is the usual finding in patients with glaucoma
- Decreased P100 amplitude of the low-contrast and/or high-contrast VEP response and wave shape perturbation may be found in patients with glaucoma
- Ocular hypertensives who develop glaucoma do not consistently have abnormal VEP waveforms
- Recent research suggests that glaucomatous changes can be detected with VEP testing before measurable visual field defects are detected

Visual Evoked Potential Testing

- Normal VEP waveform shape in each eye
- Normal N75-P100-N135 wave complex in the right eye
- Delayed P100 peak time in the left eye’s high-contrast VEP response
- Clinically significant asymmetry between the eyes

Visual Evoked Potential Testing

- Right eye’s VEP response
  - High-contrast 113.2 ms
  - Low-contrast 118.2 ms
- Left eye’s VEP response
  - High-contrast 127.9 ms
  - Low-contrast 123.0 ms
- 14.7 ms difference between the high-contrast VEP responses

Medical Decision-Making

- IOP measurements within the “normal” range
- Relative afferent pupillary defect in the left eye
- Abnormal optic nerve appearance in the left eye
- Repeatable visual field defect in the left eye
- Fallout of an entire RNFL bundle in the left eye
- Abnormal visual evoked potential in the left eye
- Normal color vision in each eye

Diagnosis is confirmed. Differential diagnoses are excluded. Begin the treatment of normal-tension glaucoma. Prescribe Combigan 2x per day.
## Reporting Medical Services

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## Medical Decision-Making

- VEP testing helps to confirm the clinical diagnosis of normal-tension glaucoma
- Abnormal VEP test results correlates with abnormal OCT scans, abnormal visual fields, abnormal pupils
- VEP testing becomes more important in the presence of unreliable visual fields or unexpected OCT results
- Abnormal VEP test results may lead to additional diagnostic testing (e.g., extended color vision, MRI of the brain, repeat VEP testing to confirm results)

## Case Report 3

- 38-year-old black woman returning for eye exam in Nov 2012, previous exam by me 18 months earlier
- Temporal history revealed two episodes of dizzy spells described as “spinning”
- Initial episode was August 2012 which was accompanied by blurred vision to the right periphery, lasting 1 day
- The other episode was 2 weeks ago which she states she awakened with dizziness and then had vomiting
- Both episodes lasted approximately 10 minutes

## Patient History

- Patient states that she saw visual scotomas and halos in daytime light with the last episode while driving
- Occasional mild headaches and denies any history of seizures
- Intermittent tingling pain to both arms and legs for many years
- Approximately 20 episodes in 2012, but had worsening symptoms of tingling pain this summer
- Episodes last for many hours and is relieved by Hydrocodone as prescribed by her PCP

## Medical Decision-Making

- **Refraction**
  1. Plano – 0.50 x 090 in each eye
  2. 20/20 acuity in each eye
  3. Wants tinted contact lenses on VSP insurance
- **Clinical Diagnosis**
  Subjective visual disturbances
- **Treatment Plan**
  1. Order retinal laser scans
  2. Order 30-2 visual field examination
  3. Order VEP testing

## Optical Coherence Tomography

- Cirrus OCT scan of the retinal nerve fiber layer
  - Cup-to-disc ratio
    - Right eye = .65/.65
    - Left eye = .65/.65
  - Mild focal defects of the retinal nerve fiber layer
    - Right eye @ 5:00
    - Left eye @ 11:00
Visual Field Examination

- **Inferior paracentral scotoma**
- **Dense, inferior sector field defect**

Visual Evoked Potential Testing

- Normal VEP waveform shape in the right eye
- Normal N75-P100-N135 wave complex in the right eye
- Normal VEP waveform shape of the high-contrast response in the right eye
- Abnormal VEP waveform shape of the low-contrast response in the left eye

NOVA-LX Test Report

- Diopsys NOVA-LX will display on the report: “N75-P100 complex not found”
- Even if you don’t know what you are seeing – you know it’s not normal
- Be suspicious
- Trust the technology

Medical Decision-Making

- Normal visual acuity
- Normal basic sensorimotor examination
- Normal ophthalmoscopy
- Normal color vision exam with D-15 panel
- Normal OCT retinal nerve fiber layer scan
- Abnormal medical history – several years
- Abnormal ocular history – 3 months
- Abnormal visual field examination – today
- Abnormal VEP testing – today

Differential Diagnoses with Abnormal VEP

- Major uncorrected refractive error
- Lens and media opacities
- Retinopathies
- Compressive lesions of the optic nerve
- Demyelinating disease
- Glaucoma
- Diffuse central nervous system disease
- Other acquired optic nerve diseases

Acquired Optic Nerve Diseases

- Optic Neuritis – Inflammation of the optic nerve
- NAAION – An ischemic process in older patients that affects the blood flow from the short posterior ciliary arteries
- AAION – An inflammatory disorder of the arteries that supply the optic nerve
- Papilledema – Optic disc swelling in response to increased intracranial pressure
- Toxic Optic Neuropathy – Patients have a personal history of malnutrition and alcohol abuse

*McCann AL. Identify Acquired Optic Nerve Disease. Review of Optometry. 2006 Jun 15; 65(80).*
Optic Neuritis

- Most common cause is a demyelinating event on the optic nerve – hallmark sign of multiple sclerosis
- Second most common cause is from a systemic inflammatory process or infection
- Unilateral vision loss in younger (under 50), mostly female patients
- Other clinical signs and symptoms include pain that increases with eye movement, afferent pupillary defect, decreased color vision in the involved eye, abnormal VEP waveform, and variable visual field defects

Multiple Sclerosis

- Most common demyelinating disorder of the central nervous system
- More than 350,000 people in the United States
- Prevalence of multiple sclerosis is increasing
- Almost half present with ocular findings as the initial manifestation of the disease
- Early diagnosis and treatment with disease-modifying therapies can delay the development of overall disease progression of multiple sclerosis

Medical Decision-Making

- **Physical Diagnosis**
  - Retrobulbar optic neuritis
  - Identify and exclude differential diagnoses
    - Optic neuritis secondary to multiple sclerosis
    - Optic neuritis, unspecified
    - Neurovisual disturbance secondary to vascular obstruction
    - Brain tumor
  - Schedule MRI of head with and without contrast
  - Schedule doppler ultrasound of the carotid arteries

- **Medical Decision-Making**
  - VEP testing helps to refine the initial diagnosis of visual field defect
  - Abnormal VEP test results correlates with abnormal visual field examination and abnormal symptoms
  - VEP testing becomes more important in the presence of unexpected OCT results
  - Abnormal VEP test results may lead to additional diagnostic testing (e.g., extended color vision, MRI of the brain, repeat VEP testing to confirm results)

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Diagnosis and Treatment Program

- Review MRI and doppler ultrasound results
  - Multiple abnormal lesions involving the left side of the splenium of the corpus callosum, the medial left parietal cortex, the medial left occipital cortex and the inferior left cerebellum
  - Given the patient’s age and the involvement of the corpus callosum, demyelinating diseases such as multiple sclerosis must be highly considered
  - Bilateral ultrasound of the carotids was negative
- Schedule consultation with local neurologist
- Follow-up with emotional support
- Schedule next visit in six months
Case Report 4

- 28-year-old woman referred by her neurologist for an initial VEP test
- Patient has abnormal MRI of the head and abnormal physical symptoms
- No current ocular symptoms
- Previous episode of severe optic neuritis in the left eye seven years earlier

Optical Coherence Tomography

- Abnormal RNFL scan in each eye
- Artifact in the left eye’s scan affects the OCT’s analysis of the RNFL
- Superior and inferior RNFL bundle defects in the right eye
- Clinically significant asymmetry

Retinal Nerve Fiber Layer Analysis

- Repeat the scan, left eye
- Slope and modulation of the TSNIT curve profile is normal
- Deviation map reveals significant fallout of the RNFL
- History of optic neuritis in the left eye suggests this finding may be a retrograde degeneration of the retinal nerve fiber layer

Visual Field Examination

Mild loss of sensitivity
Isolated central scotoma

VEP Interpretation & Report

- VEP report to referring neurologist
- Normal VEP response in both eyes
- No evidence of the demyelination process
- Re-assure patient
- Good for the patient
- Good for the neurologist
- Good for me

Reporting Medical Services

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