Audiologists and the Facial Nerve

Greg Mannarelli, AuD, BCS-IOM, CCC/A, FAA
Life as an Audiologist

I have no financial or non-financial disclosures other than being employed by the Regents of the University of Michigan.

Lab Section: I have no financial relationships with the vendors who have brought the equipment for the lab section.
Index Patient

- Normal functioning 5 year old.
- Falls backwards and hits his head on a sharp knife sticking out of the silverware bin of an open dishwasher.
- Posterior to anterior injury.
Index Patient

- Taken to the ER and had the lesion sutured up.
- As they are leaving, mom notices that his smile seems uneven.
Index Patient

• ER physician tells the family that it is likely Bell’s Palsy and that he would recover on his own.
• Thoughts?
Index Patient

- Pictures posted to Facebook.
- Co-worker called the parents.
- This is a facial nerve injury, likely at the main trunk as it exits the skull.
- FN injuries should be evaluated by specialist (otolaryngologist)
- What can an audiologist do?
What does the Facial Nerve do for us?

Anatomy and Physiology
So…What does the Facial Nerve do for ya?

• Face
• Taste
• Ear
• Tear
Facial Nerve Anatomy

• The “Facial Nerve” is really comprised of two nerves, the Facial Nerve (Efferent) and the Nervus Intermedius (Afferent).
Facial Nerve Anatomy

• Black = Nervous Intermedius Sensory and Parasympathetic – (Afferent and Efferent)

• White = Motor Facial Function
Facial Nerve Cranial Nerve Nuclei

Keep in Mind:
The Facial Nerve originates from multiple points on the brainstem.
Facial Nerve Anatomy

- Motor nucleus originates in Pons in the Cerebellopontine Angle (CPA)
Facial Nerve Anatomy

• Motor nucleus
  Originates in Pons in the Cerebellopontine Angle (CPA)
Root Entry Zone (REZ)

• The Redlich–Obersteiner's zone is the boundary between the CNS and the PNS, most frequently called the REZ. It is the point where the nerves enter/exit the brainstem.

• The technical boundary is where the makeup of the myelin sheath changes
  – In PNS Myelin is from Schwann Cells
Basic Nerve Diagram

- Cell Bodies in the Brainstem form Cranial Nerve Nuclei
- Axon Bundles form a nerve fiber extending out into body
  - Sensory System: First Order Neuron
  - Motor System: Lower Motor Neuron

Course of the Facial Nerve

• The facial nerve can then be viewed as a series of straight “segments”
• Divided by a complex series of sharp bends the nerve is required take as it courses around other important structures in the skull
• Exit point at the stylomastoid foramen.
Course of brachial motor segment of CN VII

• The motor nucleus of the Facial Nerve is located within the pons.
• The nerve exits the pons and travels around the abducens nerve (CN VI) entering the internal auditory canal (IAC) along with CN VIII.
• The **IAC** is situated at the level where the pons and cerebellum meet (CP Angle)
Course of brachial motor segment of CN VII

- **Meatal (or intracanalaricular or IAC) segment:** the facial nerve runs through the anterior/superior quadrant of the IAC.

- In the IAC the Facial and Auditory nerves are Anterior
- Vestibular nerves are posterior
- Facial is superior to Auditory (7 up/coke down)
Cisternal and IAC Facial Nerve

1.8 mm vestibular schwannoma  
Tumor Removed
Labyrinthine Segment
Geniculate Ganglion

Coronal CT

Floor of Brain

Superior
Tympanic Segment

Labyrinthine

Geniculate

Tympanic
Tympanic Segment
Descending Facial Nerve (in Bone)
Translabyrinthine Approach to AN

Descending Segment of CN VII (encased in bone)
Facial Recess and Mastoid Segment
(Cochlear Implant)

Facial Recess
Facial Nerve
Horizontal Canal
Descending Segment VII
Coronal CT
Main Trunk and Peripheral Branches
Mimetic Muscles of the Face
When a peripheral nerve gets injured

Anatomy, Physiology and Classification of an injured peripheral nerve
When a nerve is injured

- We need to NOT think of the facial nerve as a single unit....
When a Nerve is Injured

• ...But rather as a bundle of discrete and dedicated connections from the brainstem system to an organ with a specific function.
Classification of Nerve Injuries

- Let's take a look down the barrel of our nerve tunnel.

**AXON**
- Each nerve fiber is an axon
  - contains cytoplasm, (aptly named axoplasm.)
- It is the axoplasm that conducts the electrical impulses.
ENDONEURIUM
The axon is surrounded by a myelin sheath, Schwann layer, and other connective tissues.

- This sheath is called:
  - **Endoneurium** or,
  - neural tubule or
  - endoneural tube.
Several “neural tubes” are then bundled together (by connective tissue) to form the funiculus or fascicle.

In Latin, Funiculus means “Cord”
Classification of Nerve Injuries

**EPINEURRIUM**
- Finally, the bundles are held together by more connective tissue.
- This more compressed connective layer is the epineurium.
Key things to remember

1) **Axon** does the neurotransmission
2) For our purposes, think of every thing else as a series of **protective layers** around the axon
Protective Layers are Key!
Classification of Nerve Injuries

• Sunderland's 5 degrees of nerve injury
  – based on the extent of damage to various functional anatomical components and layers of the nerve.
  – A summary of nerve injury classification based on the works of Seddon and Sunderland
Five Degrees of Nerve Injury

- Ascending order of the severity from 1<sup>st</sup> to 5<sup>th</sup>
  - 1) conduction in the axon
  - 2) damage to axon structure
  - 3) damage to endoneural tubular structure
  - 4) the funiculus and its contents
  - 5) the entire nerve

- Classification is based on the effect, not the cause
1st degree injury

- Neuropraxia
- It’s the kinked hose
- The nerve does not depolarize
2\textsuperscript{nd} degree injury

- The subway tunnel is intact but the rails are broken
3rd degree injury

- Neurotemesis (3+)
- Your tunnel has collapsed and the tracks partially regrow down the wrong tunnel
- Endoneural tubes disrupted and internal components of the Funiculus is disorganized

Photo: REUTERS/CHINA DAILY
4th Degree injury

- Your entire transportation grid is disrupted and disorganized
5 degrees of nerve injury

• **Fifth-degree injury**
  – involves transection of the entire nerve trunk.
  – The majority of regenerating axons do not reach their designated funiculi or endoneural tubule because of the separation of the nerve ends and scarring.
  – Recovery will not occur without surgical intervention, and complete restoration of function is impossible even if the nerve ends are repaired.
  – Often a traumatic injury
Mixed Nerve Injuries

- The degree of injury can be unevenly distributed across a nerve fiber.
- Fifth-degree injuries by definition cannot coexist with lesser degree injuries.
  - It is possible to have a partial transection, although injuries severe enough to partially transect a nerve will most likely leave a significant injury in any non-transected fibers.
- **Mixed injuries can muddy the diagnostic waters** and make it difficult for any objective measure to make a clear and definitive differentiation regarding the specific degree of injury.
Degree of Spontaneous Recovery by Degree of Injury

<table>
<thead>
<tr>
<th>1st</th>
<th>Complete recovery within 2 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>Complete recovery or mild deficit</td>
</tr>
<tr>
<td>3rd</td>
<td>Residual deficit is typical</td>
</tr>
<tr>
<td>4th</td>
<td>Spontaneous recovery is scant and rarely useful</td>
</tr>
<tr>
<td>5th</td>
<td>No recovery without intervention. Early reanimation is indicated</td>
</tr>
</tbody>
</table>
Bedside Examination of Facial Weakness

• Step 1: Examine the Face at Rest
  – **Spasticity**: Any Muscle stiffness (associated with spastic muscles secondary to upper motor neuron lesion)
  – **Contracture**: Permanent shortening of a muscle due to hypertonic muscle activity (UMN and LMN)
    • Sustained contraction on affected side can give false appearance of paralysis on the normal side.
      – Look for: narrow palpebral fissure (space btn eyelids), elevated corner of mouth, naso-labial fold deepened.
  – **Tone**: Loss of muscle mass secondary to long term denervation
    • Muscle tone is evaluated by looking to see if expected creases in the facial profile are present.
  – **Hemifacial Spasm**: Involuntary facial twitches
Bedside Examination of Facial Weakness

• Step 2: Examination of the Face in Motion
  – **Volitional Movements**: Pt is asked to independently move muscle groups innervated by the upper for peripheral branches of the facial nerve
    • “Raise your Eyebrow”
    • “Close your Eye”
    • “Scrunch up your nose”
    • “Smile”
    • “Make a sour or pouty face”
  – **Synkinesis**: Observation for unintended movement at sites distant from the current target muscle group.
  – **House-Brackmann Scale** (1-6) – See chart in appendix
Synkinesis

Watch her right eye when she scrunches her nose
Now we can finally talk about our Electrophysiology Tests! (yay!)

Non-Stimulated: Electromyography (EMG)

Stimulated: Electroneuronography (ENOG) or Stimulated EMG
Stimulated EMG / ENOG

Clinical Use
- Determine the patient’s prognosis for recovery by determining the extent of the Wallerian Degeneration that has occurred

Intraoperative
1. Anatomical identification
2. Evaluate nerve function
3. Intraoperative Guidance (hemifacial spasm surgery)
More on Wallerian Degeneration, Please!

• This phenomenon was first described by Augustus Waller in 1950.
• It is a self-induced deterioration of the axon that is separate from apoptosis.
• 3 days to 3 weeks.

Image Credit: https://mmcneuro.wordpress.com/2013/06/
ENOG

– What is ENOG
  • **CMAP Recordings, using normal side as your control!**
– ENOG is a Wallerian Degeneration Detector.
  • **You are stimulating distal to the lesion**
  • **Looking to see if there is a distal axon to conduct the signal**
– Stimulation
  • Location: Stylomastoid Foramen
  • Cathode/Anode placement
  • Supramaximal Stimulation
  • **Requires Neural Synchronization**
• **Compound Muscle Action Potential (CMAP)**
  
  - Near-synchronous firing of all the muscle fibers innervated by the stimulated nerve.
  - It is Real Time (not averaged like an ABR)
### Symmetrical ENOG

<table>
<thead>
<tr>
<th>Trace</th>
<th>Site</th>
<th>Lat 1 (ms)</th>
<th>Amp (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Nasalis (Left)</td>
<td>5.4</td>
<td>0.4</td>
</tr>
<tr>
<td>B6</td>
<td>Nasalis (Right)</td>
<td>5.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Absent ENOG

- Electroneuronography responses 1 month post-injury from patient with bilateral temporal bone fracture.
- Bilateral Facial Weakness, worse on the right.
- Responses demonstrated a large compound muscle action potential response from the left (top)
- No response (100% degeneration) on the right (bottom)
Asymmetric ENOG

• Compound muscle action potential amplitudes were reduced on the left side by 44%.
• These results indicate a moderate type I injury, with some distal degeneration. These results represent a good prognosis for recovery.
• Results are from a 34-year-old male with a history and diagnosis of Ramsey Hunt syndrome.
• He was evaluated 4 days after his onset.
• He was a HB Grade V at the time of evaluation.
ENOG Interpretation

ENOG Criteria

- Remember you can only check for Wallerian Degeneration, which occurs within 3 days to 3 weeks of injury.
- ENOG will always be normal if you test too early.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present/Absent</td>
<td>Type 1 injures (neuropraxia): there is never any deterioration of the ENOG and recovery is complete within 2 weeks.</td>
</tr>
<tr>
<td>Amplitude Reduction</td>
<td>&lt;90% Criteria (previous proposals for 75%)</td>
</tr>
<tr>
<td></td>
<td>= &gt;50% chance of incomplete recovery</td>
</tr>
<tr>
<td>Velocity of Denervation</td>
<td>The Faster the deterioration, the more severe the injury.</td>
</tr>
</tbody>
</table>
Typical timeframes for onset of Wallerian Degeneration

Fisch, Ugo
Stimulated EMG: Intraoperative Applications
Intraoperative Stimulated EMG

• Direct electrical stimulation of the nerve
  – Probing for the presence/absence of the nerve
  – Confirmation of nerve function
  – Prognosis
    • Threshold
    • Proximal vs distal stimulations
Intraoperative CMAP
Stimulated Facial EMG – Video Example
Intraoperative Guidance

Stimulated EMG can actually be used to guide surgical maneuvers.
Hemifacial Spasm Overview

- A.K.A. “Tic Convulsif”
- Symptom: unintended facial twitch
- Cause:
  - Artery wrapped around CNVII
  - Results in a hyperactive facial motor nucleus in the Brainstem
- Objective Diagnosis: Lateral Spread Response
  - Hyperactive FN “over reacts” to stimulation resulting in atypical response patterns
- Treatment: Get the vascular loop off the nerve
  - Surgery is called a “Microvascular Decompression”
Hemifacial spasm
Abnormal Stimulation Pattern

Normal

Lateral Spread
Lateral Spread Response (LSR)

Obligatory Orbicularis Oculi CMAP

Lateral Spread on Mentalis
(This should not happen)

<table>
<thead>
<tr>
<th>Trace</th>
<th>Site</th>
<th>Lat 1 (ms)</th>
<th>Amp (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Orbicularis oculi</td>
<td>3.4</td>
<td>2.3</td>
</tr>
<tr>
<td>A2</td>
<td>Mentails</td>
<td>12.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

LSR = Approx. 9 ms delay
Hemifacial Spasm – OR Recordings

Free RUN EMG
Burst like EMG from hemifacial spasm

Zygomatic Stimulation
Normal Orbic Oculi Resp.
Lateral Spread Response approx threshold 6.0 mA
Photo of CN V and VII

Posterior

Inferior

CN V

CN VII
Placing Superior Teflon on V (video)
Decompression Complete, LSR is absent at levels > baseline threshold (9.6 mA)
During Closing, we see a return of the LSR but at significantly higher thresholds.

**LSR – OR Recordings**

![Graph showing LSR recordings during closing, with thresholds indicated.](image)
Stimulation 30 mA

Stim is high enough that lower channel is picking up Eye CMAP creating “shadow curve” but LSR is absent.
Electromyography (EMG)

Caution: Information here is related to assessing peripheral nerves, not central motor control or muscular pathology.
Electromyography

• Origins of EMG
  – Study of the electrical potentials of muscles has its origins from biologists studying electrical eels in the 1600s. (Redi)
  – What is EMG
    • Motor unit action potential (MUAP)
    • Electrical (and/or acoustical) representation of electrical innervation of the target muscle.
Motor Unit Action Potentials

• MUAP components
  – The nerve action potential and muscle fiber generate a summated potential that is recorded by the electrode. The specific components that contribute to this summated response include:
    – Lower Motor neuron soma (facial nerve nuclei)
    – Afferent axon
    – Synaptic Cleft
    – Motor end plate
    – Muscle fibers
EMG electrodes

Three types of needle electrodes
• Left: standard concentric needle with single wire filament in shaft,
• Middle: bipolar concentric needle with paired wire filaments
• Right: monopolar electrode
Clinical EMG: Spontaneous Activity

• Unintended EMG is a sign of abnormal regeneration
  – Why? Skeletal muscles become more irritable if they are denervated!
    • (it’s a complicated neurotransmitter thing)
    • Found in Grade 3 and higher lesions

• Two Types:
  – Positive Sharp Waves: prolonged insertional activity
  – Fibrillation Activity: Motor units from a single muscle fire. No interference pattern. Inverted from normal EMG pattern
Normal vs Abnormal MUAP

- Normal MUAP
- Fibrillation Potential
- Positive Sharp Wave

200 µV
10 msec
Abnormal Resting Potentials

• Abnormal resting potentials appear as early as 7 days (Mills 2005),

• Frequently occur after 10 to 17 days. (Sittel, 2001; Grosheva, 2008)
  – Fibrillation potentials are not exclusive to neural disease, the can also be found in inflamed muscles as well as dystrophic muscle disease. (Mills)

• Abnormal Resting potentials will first be seen between 7 and 17 days.
Spontaneous EMG
Evaluating Volitional EMG

• Patient is asked to fully contract the muscle being recorded
  – the examiner is observing for the presence of any volitional EMG.
• Normal volitional movements will demonstrate:
  – A initial low-amplitude positive component followed by a larger negative component.
  – Two to Four phases (or turns)
  – Normal interference pattern. (Recruitment Pattern)
• EMG signal (frequency & amplitude & overlap) should be proportional to effort of attempted movement. The signals should start to overlap or interfere with each other.
Volitional EMG Left facial weakness

Right Frontalis (Control)

Left Frontalis (Affected side)
Volitional EMG

Left Orbicularis Oculi (Volitional, Major effort)

Left Zygomaticus (Volitional w/ major effort)
EMG Recording Locations
Evaluating Volitional EMG

- Timing: Volitional can be completed at any time post injury
- Presence or Absence of EMG is primary finding
- Number of sites with volitional EMG
  - Granger 1967 found that the higher number of sites with volitional EMG the better the outcome for Bell’s Palsy

<table>
<thead>
<tr>
<th># Sites</th>
<th>Good Outcome %</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>91%</td>
</tr>
<tr>
<td>2-3</td>
<td>87%</td>
</tr>
<tr>
<td>0-1</td>
<td>11%</td>
</tr>
</tbody>
</table>

- Weitt (unpublished data) EMG from eye indicates better outcomes
Intraoperative Uses of EMG

American Audiology Board of Intraoperative Monitoring

What is the Value of Specialty Board Certification in IOM for an Audiologist?

Surgeons, patients, credentialing bodies, health care facilities and employers can be assured that the audiologist who has achieved AABIM board certification in IOM possesses specialized education, training and experience beyond that required for entry into the general profession (e.g., Ph.D., Au.D.) as well as the Certificate of Clinical Competence in Audiology (CCC-A). Board certified audiologists in IOM possess an advanced understanding in this sub-specialty in audiology. They have met rigorous educational, practice and examination requirements and are required to maintain their board certification by demonstration of ongoing continuing education, ethical professional standing and valid licensure to practice.
Free Run EMG – Spasm

• “Trains” that are provoked by irritation or injury of the nerve.

• Repetitive action potential (MUAP) activity
  – Spasm that has a normal recruitment (overlapping) pattern may be a precursor to patient movement.
  – “A Train” or “Dive bomber” pattern
    • High frequency/High pitch w/o recruitment—very concerning for nerve injury


Medtronic Paired Subdermal Needle Electrodes
Mechanical Activation of EMG Intraoperatively
Facial EMG Example – Mechanical
Putting the two Tests Together

Bells Palsy Criteria
Idiopathic Facial Weakness

- Gantz et al. Criteria:
  - ≥90% degeneration on ENOG and no EMG indicates surgical decompression of the facial nerve.
    - No intervention = 58% chance of significant weakness
    - 100% not meeting surgery criteria returned to normal (or near normal).

- Good surgical outcomes are tied to the time of intervention.
  - 93% recovery if intervention by day 12, and was 82% by day 14.
  - No benefit from surgery after 14 days (When spontaneous EMG appears)

- Patients should be evaluated early (day 3) and then monitored (day 6, 10-12)

- Despite the best efforts, there will be some patients who do not recover acceptable facial function or show up after the intervention window.
# Good Vs Bad Outcome Indicators

<table>
<thead>
<tr>
<th>Good Outcome Indicators</th>
<th>Bad Outcome Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal ENOG after 14-21 days</td>
<td>Weakness at time of trauma</td>
</tr>
<tr>
<td>Late onset of Wallerian Degeneration (Decreased Enog) &gt; 14 days</td>
<td>Early onset Wallerian (Decreased EnoG ) (3-5 days is worse than 6-14)</td>
</tr>
<tr>
<td>Normal Resting Potentials on EMG after 14-21 days</td>
<td>Progressive decay of ENOG</td>
</tr>
<tr>
<td>Polyphasic motor units on EMG (Regeneration)</td>
<td>Abnormal spontaneous activity on EMG after 10-21 days</td>
</tr>
<tr>
<td>Early volitional motor units &lt;4 days</td>
<td>Delayed Recovery &gt; 3 months (bells palsy) functional &amp; EMG</td>
</tr>
<tr>
<td>Improving volitional EMG</td>
<td>No Volitional EMG or Volitional EMG only at 1 recording site</td>
</tr>
<tr>
<td>Volitional EMG recorded at 2+ sites (4-5 better). Especially Eye/Zygomatic</td>
<td></td>
</tr>
</tbody>
</table>
Facial Nerve Injury Timeline

- **Facial Weakness at time of trauma concerning for severe FNI**
  - **Onset**
    - Volitional EMG to rule out 5th degree injury.
    - Always Normal ENOG/Prior to Onset of Wallerian Degeneration
    - Early Degeneration of ENOG is concerning for 5th degree FNI

- **Day 3**
  - EMG can be assessed for Spontaneous activity
  - Cutoff for decompression in Bell's Palsy

- **Day 6**
  - Degeneration of ENOG concerning for 3-4th degree injury

- **Day 12**
  - Later degeneration of ENOG is concerning for 2nd degree injury

- **Day 21**
  - Monitor EMG for improvement in volitional responses to help determine candidacy for reanimation

- **Day 24**
  - 8 Months

- **24 Months**
How to Apply

A cover letter is required for consideration for this position and should be attached as the first page of your resume. The cover letter should address your specific interest in the position and outline skills and experience that directly relate to this position.

Responsibilities*

- Learn to provide intraoperative neurophysiologic monitoring for head and neck, otology, pediatric otolaryngology and neurosurgery at University Hospital, Mott Children's Hospital, East Ann Arbor Ambulatory Surgical Center, Livonia Ambulatory Surgical Center and affiliated settings (3-4 days per week).
Live Demonstrations
Demonstration: Recording Locations

- Standard ENOG
- Lateral Spread
- EMG

[Diagram of facial muscles]
Directors Cut

• Here are the slides that did not make the theatrical release.
Classification

**Efferent**
- **Somatic motor neurons (General Somatic Efferent-GSE)**, which originate in the central nervous system, project their axons to the target tissues, which are always skeletal muscles developed from somite cells. Skeletal muscles are involved in locomotion (such as the muscles of the limbs, abdominal, and intercostal muscles). This includes skeletal muscles, extraocular, and glosso-muscles.
- **Visceral Motor Neurons (General Visceral Efferent-GVE)**: Afferent activity from parasympathetic nerves. This includes glands and smooth muscle, pupil constriction (CN III), gland secretion (CN VII), muscles of the heart (CN X), the trachea, bronchi, esophagus, and thoracic and abdominal organs.
- **Branchial Motor Neurons (Special Visceral Efferent-SVE)**, also called *branchial motor neurons*, which directly innervate branchial muscles. These are the branchial muscles that develop from the branchial arches instead of coming from somite cells. These include muscles of mastication (CN V), facial expression (CN VII), pharynx (CNX)

**Afferent**
- **General Sensory (Special Somatic Afferent-SSA)** these mediate touch, pain, temperature, pressure, vibration and proprioceptive sensation.
- **General Visceral Sensory (GVS)** viscera, glands, and blood vessels to the central nervous system.
- **Special Visceral Sensory (SVS)**: smell, vision, taste, hearing, and balance
Facial Cranial Nuclei

<table>
<thead>
<tr>
<th><strong>Facial Motor Nucleus</strong></th>
<th>Deep pons near CPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Brachial Motor</td>
<td></td>
</tr>
</tbody>
</table>

**Superior Salivatory Nucleus**
- Nervus Intermedius to greater petrosal nerve: lacrimal, submandibular, sublingual. Mucous glands of mouth, pharynx, and nose
- Pontine tegmentum, dorsomedial to facial nucleus

**Gustatory Nucleus (Solitary Nucleus)**
- Taste from tongue (CN V and VII)
- Part of solitary nucleus in medulla oblongata

**Trigeminal Nucleus**
- Fine Touch/Pain concha bowl
- Largest nuclei it extends through the midbrain, pons, and medulla
# Organization of the Facial Nerve

<table>
<thead>
<tr>
<th></th>
<th>General</th>
<th>General Visceral</th>
<th>Special Visceral</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor (Efferent)</strong></td>
<td>None</td>
<td>Tear Ducts</td>
<td>Brachial Motor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Facial and Stapedius</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Muscles</td>
</tr>
<tr>
<td><strong>Sensory (Afferent)</strong></td>
<td>Touch: sensation from concha bowl and Auricle</td>
<td>None</td>
<td>Taste from Tongue</td>
</tr>
</tbody>
</table>
## Classification of Cranial Nerve Function

- Cranial Nerve Function can be divided into six distinct modalities
  - 3 efferent (“motor”) and 3 afferent (sensory)
  - General vs Visceral (involuntary)
    - Visceral is subdivided into General Visceral and Special Visceral

<table>
<thead>
<tr>
<th>Motor (Efferent)</th>
<th>General</th>
<th>General Visceral</th>
<th>Special Visceral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatic Motor</td>
<td>Somatic Motor</td>
<td>Visceral Motor</td>
<td>Branchial Motor</td>
</tr>
<tr>
<td>General Sensory</td>
<td>General Sensory</td>
<td>Visceral Sensory</td>
<td>Special Sensory</td>
</tr>
</tbody>
</table>
The course of the facial nerve

- **Labyrinthine segment**: After leaving the IAC, the facial nerve enters the *facial canal (or Fallopian canal)* traveling above the vestibule to form the Geniculate.

- The nerve then bends abruptly at the *geniculation ganglion* where the cell bodies for the general sensory neurons synapse, giving off the petrosal nerve branches.

- **Tympanic Segment**: The main portion of the facial nerve forms the *tympanic segment* continuing through the antrum of the mastoid.
Course of the Facial Nerve

- **The mastoid (or descending) segment:**
  - facial nerve bends under the horizontal vestibular canal and continue between the posterior wall of the tympanic cavity and the mastoid air cells to the stylomastoid foramen.
  - The mastoid segment gives off two tributary branches
    - Stapedius muscle (acoustic reflexes)
    - chorda tympani (taste)
  - Exits skull through the stylomastoid foramen

- **The Facial Recess**
  - The space between the corda tympani and descending segment
  - Access to the middle ear for CI surgery and cholesteatoma removal
The Course of the Facial Nerve

- The extracranial segment (commonly referred to as the “main trunk”) travels through the parotid gland.
- The peripheral branches include the:
  - Temporal branch (frontalis muscle),
  - Zygomatic branch (orbicularis oculi),
  - Buccal branch (zygomaticus major, buccinators, orbicularis oris muscles),
  - Marginal mandibular branch (mentalis),
  - Cervical branch (platysma muscle).
5 degrees of nerve injury

• **First-degree injury (neuropraxia):**
  – result of a conduction block
  – typically secondary to nerve compression or ischemia.
  – **No axonal degeneration** so that the axonoplasmic continuity remains intact distal to the lesion.
  – Neuropraxic injuries will continue to conduct a neural impulse if an electrical stimulus is delivered at a point distal to the site of lesion.
  • This is the basic premise on which ENOG testing is based. Recovery from this type of injury is spontaneous and complete.
5 degrees of nerve injury

- **Second-degree injury (axonotmesis):**
  - Complete interruption of both the axon and the axoplasm contained within the axon.
  - Preservation of the endoneural tubule.
  - The peripheral end organ being isolated from its corresponding neuron.
  - Loss of nerve supply to the end organ is referred to as denervation.
  - Because the endoneurium remains intact, the axon can regenerate toward its original end organ through the intact tubule. This leads to a better prognosis in terms of recovering motor function following the injury.
  - **Anterograde axonal degeneration (called Wallerian degeneration) occurs.**
5 degrees of nerve injury

- **Third-degree injury (neurotmesis):**
  - Damage to the endoneural tube and its contents
  - Regeneration can now occur across disrupted endoneural tubules.
  - Axons may reach intended end organs or they may enter totally *foreign* tubes.
    - Distorted and less efficient firing pattern
    - Synkinesis
    - Contracture.
5 degrees of nerve injury

- **Fourth-degree injury (neurotmesis):**
  - Involved damage to the perineural boundaries of the funiculus.
  - All bundles are breached.
  - Funicular bundles become so disorganized that they are no longer distinguishable from the surrounding connective tissues of the epineurium.
  - Large numbers of regenerating axons escape and infiltrate foreign tubes.
    - Some spontaneous recovery can occur, but it is of little functional value.
Facial Nerve Grading Scales

House-Brackmann Facial Nerve Grading System

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal function in all areas of the face</td>
</tr>
<tr>
<td>II</td>
<td>Slight weakness or synkinesis on close inspection</td>
</tr>
<tr>
<td>III</td>
<td>Obvious but not disfiguring weakness, synkinesis or contracture; complete eye closure with effort</td>
</tr>
<tr>
<td>IV</td>
<td>Obvious or disfiguring asymmetry with movement but normal tone and symmetry at rest; incomplete eye closure</td>
</tr>
<tr>
<td>V</td>
<td>Barely perceptible movement and asymmetric at rest</td>
</tr>
<tr>
<td>VI</td>
<td>No Movement</td>
</tr>
</tbody>
</table>
## Facial Nerve Grading System 2.0

<table>
<thead>
<tr>
<th>Score</th>
<th>Brow</th>
<th>Eye</th>
<th>NLF</th>
<th>Oral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>2</td>
<td>Slight weakness, &gt;75% normal</td>
<td>Slight weakness, &gt;75% normal, Complete close with mild effort</td>
<td>Slight weakness, &gt;75% normal</td>
<td>Slight weakness, &gt;75% normal</td>
</tr>
<tr>
<td>3</td>
<td>Obvious weakness, &gt;50% Normal, Symmetry at rest</td>
<td>Obvious weakness, &gt;50% Normal, Closure with maximum effort</td>
<td>Obvious weakness, &gt;50% Normal, Symmetry at rest</td>
<td>Obvious weakness, &gt;50% Normal, Symmetry at rest</td>
</tr>
<tr>
<td>4</td>
<td>Asymmetry at rest, &lt;50% normal</td>
<td>Asymmetry at rest, &lt;50% normal, Cannot close completely</td>
<td>Asymmetry at rest, &lt;50% normal</td>
<td>Asymmetry at rest, &lt;50% normal</td>
</tr>
<tr>
<td>5</td>
<td>Trace movement</td>
<td>Trace movement</td>
<td>Trace movement</td>
<td>Trace movement</td>
</tr>
<tr>
<td>6</td>
<td>No movement</td>
<td>No movement</td>
<td>No movement</td>
<td>No movement</td>
</tr>
</tbody>
</table>

### Degree of Abnormal Movements

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Slight synkinesis; minimal contracture</td>
</tr>
<tr>
<td>2</td>
<td>Obvious synkinesis; mild to moderate contracture</td>
</tr>
<tr>
<td>3</td>
<td>Disfiguring synkinesis; severe contracture</td>
</tr>
</tbody>
</table>

### Scoring

<table>
<thead>
<tr>
<th>Total Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>I</td>
</tr>
<tr>
<td>5-9</td>
<td>II</td>
</tr>
<tr>
<td>10-14</td>
<td>III</td>
</tr>
<tr>
<td>15-19</td>
<td>IV</td>
</tr>
<tr>
<td>20-23</td>
<td>V</td>
</tr>
<tr>
<td>24</td>
<td>VI</td>
</tr>
</tbody>
</table>
Wallerian Degeneration

• Degeneration occurs in three not well understood phases.
  – (1) **Acute injury phase**: As soon as a few minutes after axotomy, a quick degeneration at both end of the injury,
  – (2) **Latency Phase**: The distal axon remains structurally and functionally stable. Theorize that there is latent “survival factor” that is responsible for cell maintenance. It gets blocked and eventual deterioration.
    • *(Minimum 3 days to start)*
  – (3) **Granular Fragmentation**: an abrupt and asynchronous fragmentation of the entire axon. “The whole thing goes”
    • **Complete by 21 Days**
Lateral Spread – Clinical Equipment Screen Shot

Stimulus Site A: Zygomatic
Stimulus Site B: Mandibular

<table>
<thead>
<tr>
<th>Recording Site</th>
<th>Lat (ms)</th>
<th>Dur (ms)</th>
<th>Amp (mV)</th>
<th>Area (mVms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1: Orbicularis oc</td>
<td>3.7</td>
<td>20.2</td>
<td>0.1</td>
<td>5.0</td>
</tr>
<tr>
<td>A2: Mentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3: Orbicularis oc</td>
<td>6.8</td>
<td>5.3</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>A4: Mentalis</td>
<td>15.8</td>
<td>4.5</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>B5: Orbicularis oc</td>
<td>6.4</td>
<td>4.9</td>
<td>0.1</td>
<td>1.2</td>
</tr>
<tr>
<td>B6: Mentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B7: Orbicularis oc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B8: Mentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Segment
Zygomatic-Orbicularis oculi
Facial Nerve with Cable Graft
Delayed polyphasic CMAP
Fibrillation vs Fasciculation

• Skeletal muscle fibrillations are not visually observable on the skin, they are always pathological. Fasciculations are visible contraction of muscle fibers. They are not always pathologic but can certainly be seen in LMN injuries.
Prognostic Value of ENOG

• Prognostic Value
  – A literature review indicated that, depending on the criteria used
  – Electroneuronography was 50-91% accuracy (Positive Predictive Value or PPV) in identifying individuals requiring intervention and
  – 80-100% accurate in predicting those who recover spontaneously (Negative Predictive Value or NPV).
Prognostic Value of EMG

- Electromyography can be used to assess both volitional movements (PPV 75-91% and NPV 62-89%) and for spontaneous activity (PPV 80-100% and NPV 92-96%). Mannarelli, 2012

- Largest Variability is “Good Outcome Criteria” (Some count HB Grade II as a Good outcome, some do not).
- Varability in the facial nerve grading scale that was used
References/Recommended Reading

- Waller A. Experiments on the section of the glossopharyngeal and hypoglossal nerves of the frog, and observations of the alterations produced thereby in the structure of their primitive fibres. *Philosophical Transactions of the Royal Society of London* 1850;140:423-429.
Reference/Recommended Reading

Operative Techniques in Otolaryngology-Head and Neck Surgery
Management of Patients With Chronic Facial Nerve Injury

Electrophysiological measures in facial paresis and paralysis
Greg Mannarelli, AuD, Garrett R. Griffin, MD, Paul Kileny, PhD, Bruce Edwards, AuD

7. Advances Facial Nerve Testing In and Out of the Operating Room
Gregory R Mannarelli, Paul R Kileny
- Anatomy 111
- ENoG 119
- EMG 124
- Protocols 130
- Future Directions 135
- Future Research 135
References/Recommended Reading

- Adrian ED, Bronk DW. The discharge of impulses in motor nerve fibers. Part II. The frequency of discharge in reflex and voluntary contractions. J Physiol (Lond)1929; 67(2):119-151.