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Facial Nerve Anatomy – Intracranial Segment

- The portion of the nerve from the brainstem to the internal auditory canal
- Made up of two components
  1. Motor root
  2. Nervus intermedius – carries preganglionic parasympathetic fibers and special afferent sensory fibers
    - Both join at the CPA/IAC to form the common facial nerve
Facial Nerve Anatomy – Intratemporal Segments

- **Meatal**
  - Portion of the facial nerve traveling from porus acusticus to the meatal foramen of IAC
  - Travels in the anterior superior portion of the IAC (7-UP, 8-Down)
    - Posterior superior – superior vestibular nerve
    - Posterior inferior – inferior vestibular nerve
    - Anterior inferior – cochlear nerve

- **Labyrinthine**
  - From fundus to the geniculate ganglion
  - Runs in the narrowest portion of the IAC (0.68mm in diameter)
  - Greater superficial petrosal nerve comes off at this point

- **Tympanic**
  - Runs from geniculate ganglion to the second genu
  - Highest incidence of dehiscence here (40-50% of population)

- **Mastoid**
  - From second genu to stylomastoid foramen
  - Gives off branches to the stapedius muscle and the chorda tympani
Cochlea
vestibule
LSC
PSC
Stapes
Pyramidal process
Stapedeal tendon
Cochlea
Round Window niche
PSC
S
Sinus tympani
Tensor tympani
Facial Nerve Anatomy – Extratemporal Segments

• Nerve exits stylomastoid foramen
  – Postauricular nerve - external auricular and occipitofrontalis muscles
  – Branches to the posterior belly of the digastric and stylohyoid muscles
• Enters parotid gland splitting it into a superficial and deep lobe
• Pes Anserinus
  – Branching point of the extratemporal segments in the parotid
    – To Zanzibar By Motor Car
      » Temporal
      » Zygomatic
      » Buccal
      » Marginal mandibular
      » Cervical
Facial Nerve Components

- Motor
  - Supplies muscles of facial expression
  - Stylohyoid muscle
  - Posterior belly of digastric
  - Stapedius muscle
  - Buccinator

- Sensory
  - Taste to anterior 2/3 of the tongue
  - Sensation to part of the TM, the wall of the EAC, postauricular skin, and concha

- Parasympathetic
  - Supplies secretory control to lacrimal gland and some of the seromucinous glands of the nasal and oral cavities
  - Chorda tympani carries parasympathetics to the submandibular and sublingual glands
Components of a Nerve

- **Endonerium**
  - Surrounds each nerve fiber
  - Provides endoneural tube for regeneration
  - Much poorer prognosis if disrupted

- **Perinerium**
  - Surrounds a group of nerve fibers
  - Provides tensile strength
  - Protects nerve from infection
  - Pressure regulation

- **Epinerium**
  - Surrounds the entire nerve
  - Provides nutrition to nerve
Sunderland Nerve Injury Classification

- Class I (Neuropraxia)
  - Conduction block caused by cessation of axoplasmic flow
  - What one experiences when their leg “falls asleep”
  - Full recovery
- Class II (Axonotmesis)
  - Axons are disrupted
  - Wallerian degeneration occurs distal to the site of injury
  - Endoneural tube still intact
  - Full recovery expected
- Class III (Neurotmesis)
  - Neural tube is disrupted
  - Poor prognosis
  - If regeneration occurs, high incidence of synkinesis (abnormal mass movement of muscles which do not normally contract together)
Sunderland Nerve Injury Classification

- **Class IV**
  - Epineurium remains intact
  - Perineurium, endoneurium, and axon disrupted
  - Poor functional outcome with higher risk for synkinesis

- **Class V**
  - Complete disruption
  - Little chance of regeneration
  - Risk of neuroma formation
Facial Nerve Trauma - Overview

- Second most common cause of FN paralysis behind Bell’s Palsy

- Represents 15% of all cases of FN paralysis

- Most common cause of traumatic facial nerve injury is temporal bone fracture
Temporal Bone Fracture

- 5% of trauma patients sustain a temporal bone fracture
- Three types
  » Longitudinal
    - Most common type – 70-80%
    - Fracture line parallel to long axis of petrous pyramid
    - Secondary to temporoparietal blunt force
    - Results in facial nerve paralysis in 25% of cases
  » Transverse
    - 10-20% of fractures
    - Fracture line perpendicular to long axis of petrous pyramid
    - Secondary to frontal or occipital blow
    - Results in facial nerve paralysis in 50% of cases
  » Mixed
    - 10% of temporal bone fractures
Temporal Bone Fracture

Chang and Cass (1999) reviewed facial nerve pathology of 67 longitudinal fractures and 11 transverse fractures where facial nerve paralysis was known

- **Longitudinal findings**
  - 76% of cases showed bony impingement or intraneural hematoma
  - 15% showed a transected nerve
  - 9% either had no pathologic findings or just neural edema

- **Transverse findings**
  - 92% of cases showed transection
  - 8% showed bony impingement or hematoma
Penetrating Trauma

- Typically results in FN injury in the extratemporal segments
- Gun shot wounds cause both intratemporal and extratemporal injuries
  - GS wounds to temporal bone result in FN paralysis in 50% of cases
  - Mixture of avulsion and blunt trauma to different portions of the nerve
  - Much worse outcome when comparing GS related paralysis to TB fracture related paralysis
Iatrogenic Trauma

- Surgical
  - Most common overall surgery with FN injury is parotidectomy
  - Most common otologic procedures with FN paralysis
    - Mastoidectomy – 55% of surgical related FN paralysis
    - Tympanoplasty – 14%
    - Exostoses removal – 14%
  - Mechanism - direct mechanical injury or heat generated from drilling
  - Most common area of injury - tympanic portion due to its high incidence of dehiscence in the this area, and its relation to the surgical field
  - Unrecognized injury during surgery in nearly 80% of cases

- Birth trauma
  - Forceps delivery with compression of the facial nerve against the spine
Work-up: History

- **History**
  - Mechanism – recent surgery, facial/head trauma
  - Timing – progressive loss of function or sudden loss
    - Transected nerve -> sudden loss
    - Intraneural hematoma or impingement -> progressive loss (better prognosis)
  - Associated symptoms – hearing loss or vertigo hint more toward a temporal bone injury
Work-up: Physical

- Physical
  - Perform a full head and neck examination
  - Facial asymmetry
  - Signs of facial injury (lacerations, hematomas, bruising)
  - Exam head/scalp for signs of injury to help guide you to vector of force if head trauma is involved
  - Otoscopic examination is a must
    - Canal lacerations or step-offs
    - Hemotympanum, TM perforation, drainage of blood or clear fluid from middle ear
    - Tunning fork tests (Weber/Rinne) with a 512 Hz fork can help determine if there is a conductive hearing loss
<table>
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<tr>
<th>Grade</th>
<th>Characteristics</th>
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<td>I.</td>
<td>Normal facial function in all areas</td>
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| II. Mild dysfunction | • Slight weakness noticeable on close inspection  
                   | • Forehead - Moderate-to-good function                                           |
|              | • Eye - Complete closure with minimal effort                                      |
|              | • Mouth - Slight asymmetry                                                        |
| III. Moderate dysfunction | • Obvious but not disfiguring difference between the two sides  
                   | • Forehead - Slight-to-moderate movement                                          |
|              | • Eye - Complete closure with maximum effort                                      |
|              | • Mouth - Slightly weak with maximum effort                                       |
| IV. Moderately severe dysfunction | • Obvious weakness and/or disfiguring asymmetry  
                   | • Forehead – No motion                                                           |
|              | • Eye - Incomplete closure                                                        |
|              | • Mouth - Asymmetric with maximum effort                                          |
| V. Severe dysfunction | • Only barely perceptible motion  
                   | • At rest, asymmetry                                                             |
|              | • Forehead – No movement                                                          |
|              | • Eye - Incomplete closure                                                        |
|              | • Mouth - Slight movement                                                         |
| VI. Total paralysis | No movement                                                                      |
Work-up: Radiologic Tests

- CT scans
  - Bony evaluation
  - Locate middle ear, mastoid, and temporal bone pathology
- Gadolinium enhanced MRI
  - Utilized for soft tissue detail and CPA pathology
Facial Nerve Testing

- Used to assess the degree of electrical dysfunction
- Can pinpoint the site of injury
- Helps determine treatment
- Can predict recovery of function – partial paralysis is a much better prognosis than total paralysis
- Divided into two categories
  - Topographic tests
    - Tests function of specific facial nerve branches
    - Do not predict potential recovery of function
    - Rarely utilized today
  - Electrodiagnostic tests
    - Utilize electrical stimulation to assess function
    - Most commonly used today
Nerve Excitability Test (NET)

• Compares amount of current required to illicit minimal muscle contraction - normal side vs. paralyzed side
• How it is performed
  • A stimulating electrode is applied over the stylomastoid foramen
  • DC current is applied percutaneously
  • Face monitored for movement
  • The electrode is then repositioned to the opposite side, and the test is performed again
• A difference of 3.5 mA or greater between the two sides is considered significant
• Drawback - relies on a **visual end point (subjective)**
Maximal Stimulation Test (MST)

- Similar to the NET, except it utilizes maximal stimulation rather than minimal
- The paralyzed side is compared to the contralateral side
- Comparison rated as equal, slightly decreased, markedly decreased, or absent
  - Equal or slightly decreased response = favorable for complete recovery
  - Markedly decreased or absent response = advanced degeneration with a poor prognosis
- Drawback - Subjective
Electroneurography (ENoG)

- Thought to be the most accurate of the electrodiagnostic tests
- How it works:
  - Bipolar electrodes deliver an impulse to the FN at the stylomastoid foramen
  - Summation potential is recorded by another device
  - The peak to peak amplitude is proportional to number of intact axons
  - The two sides are compared as a percentage of response
- 90% degeneration – surgical decompression should be performed
- Less than 90% degeneration within 3 weeks predicts 80 - 100% spontaneous recovery
- Disadvantages: discomfort, cost, and test-retest variability
Electromyography

- Determines the activity of the muscle itself
- How it works
  - Needle electrode is inserted into the muscle, and recordings are made during rest and voluntary contraction
- Normal = biphasic or triphasic potentials
- 10-21 days post injury - fibrillations
- 6-12 weeks prior to clinical return of facial function – polyphasic potentials are recordable
  - Considered the earliest evidence of nerve recovery
- Does not require comparison with normal side
Approach to Treatment and Treatment Options - Iatrogenic Injury

• If transected during surgery
  – Explore 5-10mm of the involved segment
  – Stimulate both proximally and distally
    • Response with 0.05mA = good prognosis; further exploration not required
    • If only responds distally = poor prognosis, and further exposure is warranted

• If loss of function is noted following surgery, wait 2-3 hours and then re-evaluate the patient. This should be ample time for an anesthetic to wear off
  – Waited time and still paralysis
    • Unsure of nerve integrity – re-explore as soon as possible
    • Integrity of nerve known to be intact
      – High dose steroids – prednisone at 1mg/kg/day x 10 days and then taper
      – 72 hours – ENoG to assess degree of degeneration
        » >90% degeneration – re-explore
        » <90% degeneration – monitor
          - if worsening paralysis occurs re-explore
          - if no regeneration, but no worsening, timing of exploration or whether to is controversial
Blunt Trauma with FN Paralysis

- Birth trauma and Extratemporal blunt trauma
  - Recommend no surgical exploration
  - >90% expected to regain normal/near normal recovery
- Complete paralysis following temporal bone fracture
  - Likely nerve transection
  - Surgical exploration
- Partial or delayed loss of function
  - Approach similar to iatrogenic partial or delayed loss
  - High dose steroids
  - ENoG 72 hours
    - >90% degeneration – explore
    - < 90% degeneration – can monitor and explore at later date depending on worsening or failure to regenerate
Penetrating Trauma with FN Paralysis

- High likelihood of transection – exploration warranted
- If extratemporal
  - Do not explore if injury occurs distal to the lateral canthus
    - Nerve endings are very small
    - Rich anastomotic network from other branches in this area
  - Exploration should occur within 3 days of injury
    - Distal branches can still be stimulated - easier to locate them
- Delayed exploration with gunshot wounds is recommended
  - GS results in extensive nerve damage
  - Waiting a little longer to identify the extent of injury can be beneficial in forming a surgical plan
Intratemporal Approaches to Decompression

• Nerve may be injured along multiple segments
  – localize injured site pre-operatively
  – Full exposure of the nerve from IAC to the stylomastoid foramen if can’t localize

• Approach to full exposure is based on patient’s auditory and vestibular status
  – Intact - Transmastoid/Middle cranial fossa approach
  – Absent – Transmastoid/Translabyrinthine approach

• Diamond burs and copious irrigation is utilized to prevent thermal injury

• Thin layer of bone overlying the nerve is bluntly removed

• Whether to perform neurolysis or not to open the nerve sheath is debateable
  – Recommended to drain hematoma if identified
Acute vs. Late Decompression - Controversial

- Quaranta et al (2001) examined results of 9 patients undergoing late nerve decompression (27-90 days post injury) who all had >90% degeneration
  - 7 patients achieved HB grade 1-2 after 1 year
  - 2 achieved HB grade 3
  - Concluded that patients may still have a benefit of decompression up to 3 months out

- Shapira et al (2006) performed a retrospective review looking at 33 patients who underwent nerve decompression. They found no significant difference in overall results between those undergoing early (<30 days post-injury) vs. late (>30 days post-injury) decompression

- Most studies like these have been very small, and lack control groups. Some studies have shown improvements with decompression occurring 6-12 months post-injury, but further evidence is needed
Nerve Repair - Overview

- Recovery of function begins around 4-6 months and can last up to 2 years following repair
- Nerve regrowth occurs at 1mm/day
- Goal is tension free, healthy anastomosis
- Rule is to repair earlier than later - controversial
  - After 12-18 months, muscle reinnervation becomes less efficient even with good neural anastomosis
  - Some authors have reported improvement with repairs as far out as 18-36 months
  - May and Bienstock recommend repair within 30 days, but others have found superior results if done up to 12 months out

- 2 weeks following injury -> collagen and scar tissue replace axons and myelin
  - Nerve endings must be excised prior to anastomosis for this reason if this far out
Primary Anastomosis

• Best overall results of any surgical intervention
• Done if defect is less than < 2cm
  – Mobilization of the nerve can give nearly 2cm of length
  – With more mobilization comes devascularization
• Endoneurial segments must match - promotes regeneration
• Ends should be sutured together using three to four 9-0 or 10-0 monofilament sutures to bring the epineurium or perineurium together (which one you bring together does not matter)
Grafting and Nerve Transfer - Overview

- Approach is based on availability of proximal nerve ending
- Performed for defects > 2cm
- Results in partial or complete loss of donor nerve function
Proximal and Distal Segments Available

• Great auricular nerve
  – Usually in surgical field
  – Located within an incision made from the mastoid tip to the angle of the mandible
  – Can only harvest 7-10cm of this nerve
  – Loss of sensation to lower auricle with use

• Sural nerve
  – Located 1 cm posterior to the lateral malleolus
  – Can provide 35cm of length
  – Very useful in cross facial anastomosis
  – Loss of sensation to lateral calf and foot

• Ansa Cervicalis
  – only utilized if neck dissection has been performed

• 92-95% of these patients have some return of facial function
  – 72-75% have good results (HB 3 or above)
Only Distal Segment Available

- Requires that the patient have an intact distal nerve segment and facial musculature suitable for reinnervation
  - Determined by EMG and/or muscle biopsy

- Hypoglossal nerve
  - Direct hypoglossal-to-facial graft
    - Distal branch of facial nerve is attached to hypoglossal nerve
    - 42-65% of patient’s expected to experience decent symmetry and tone
    - Complications – atrophy of ipsilateral tongue, difficulties with chewing, speaking, and swallowing
  - Partial hypoglossal-to-facial jump graft
    - Uses a nerve cable graft, usually the sural nerve, to connect the distal end of the facial nerve to a notch in the hypoglossal nerve
    - Much fewer complications, but increased time
    - May compared the results of direct VII-XII graft to the VII-XII jump graft
Comparison of Direct Hypoglossal Grafting vs. Jump Grafting

- **Jump graft**
  - 8% of patients experienced permanent complications
  - 41% obtained good movement with less synkinesis
  - Longer recovery time (9-12 months prior to some function)

- **Direct graft**
  - 100% permanent complications
  - Stronger motor function
  - Less recovery time
Only Distal Segment Available – Cont.

- **Facial-to-Facial Graft**
  - **Options**
    - Single contralateral branch to distal nerve anastomosis
    - Multiple anastomoses from segmental branches to segmental branches
  - Best described is the use of a sural nerve graft to connect the buccal branch on the contralateral side to the distal nerve stump
  - Most do not recommend this technique
    - Weakness caused to the contralateral facial nerve
    - Lack of power to control musculature resulting in poor results
Early Facial Nerve Monitors

- Early monitors relied on sensing muscle movement – pressure or strain gauge sensor
- Not used much now - large threshold must be reached to illicit movement
- Poorer response to facial nerve stimulation than electrophysiologic techniques
FN Monitors - Electromyography

- Electrodes detect differences in electrical potential associated with a depolarizing current
- Graphic signal and acoustic signal recorded
- 2 types of responses
  - Repetitive responses
    • Represent irritability of the nerve secondary to nerve injury
    • Used to warn the surgeon of injury or impending injury
  - Nonrepetitive responses
    • Single responses secondary to direct mechanical or electrical stimulation
    • Used to map the course of the nerve
Uses for Today’s Monitors

• Identify the nerve
  – Mechanical or electrical stimulation will produce nonrepetitive responses – how we find the nerve
  – Field should be free of fluids for electrical stimulation as fluid causes diversion of current

• Mapping
  – Once located, nerve can then be mapped by repeated stimulation
  – Bipolar stimulation
    • More precise
    • More false-negatives than monopolar technique

• Injury identification
  – Relies on repetitive responses
  – Allows surgeon to alter action
Uses Continued

- **Prognostic Information – Two different measures**
  - **Stimulated compound action potential**
    - Least used of the two
    - Hard to reproduce good results in studies due to variability in electrode placement
    - Utilizes a 0.4mA stimulus
    - If compound action potential is > 500-800 microvolts likely will have HB I-II
    - As drop below 500 microvolts, the outcome becomes poorer
  - **Nerve stimulus threshold**
    - Utilizes an electrical stimulus applied to the proximal end of the nerve
    - If nerve responds with a stimulus that is < 0.3mA, HB I-II is likely outcome
    - If > 0.3mA stimulus required to stimulate nerve, likely HB III-V
Does Monitoring Make A Difference? – CPA Tumors

- Dickinson and Graham - 1990
  - Reviewed CPA tumor cases
    - 38 cases done without monitoring
    - 29 cases with pressure or strain gauge sensor
    - 41 cases with EMG
  - Results – Poor outcome (HB V-VI)
    - Unmonitored – 37% of cases
    - Pressure or strain gauge sensor – 21%
    - EMG – 4%
  - Confounder – higher incidence of larger tumors in unmonitored group
Does Monitoring Make A Difference? – Middle Ear Surgery

- Pensak et al looked at 250 cases involving surgery on chronic middle ear disease - all were monitored
  - 100% of cases – facial nerve was grossly identified
  - 82% confirmed nerve with monitor stimulation
  - In cases where nerve was exposed
    - Monitor alerted surgeon to this in 93% of cases

- Silverstein and Rosenberg examined 500 cases in which facial nerve monitoring was used
  - No cases of facial nerve injury
  - Reported the monitor prevented injury in 20 cases
Does Monitoring Make A Difference? – Parotid Surgery

- Terrell et al. examined 117 cases – 56 with monitor and 61 without monitor
  - Statistically significant decrease in rate of post-operative paresis
  - No difference in long term outcome
  - Longer OR times associated with decreased rates of post-operative paresis

- Witt reviewed 53 cases – 33 with monitor and 20 without
  - No difference in paresis rates
  - No difference in long term outcome
Does Repetitive Stimulation Lead to Injury?

- Babin et al examined the use of pulsed current stimulation of cat facial nerves
  - Utilized pulse of 1mA applied to the nerve every 3 seconds for 1 hour
  - Noted a transient decrease in nerve sensitivity following cessation of stimulus
  - No permanent injury reported

- Hughes et al examined the use of pulsed and constant current models for stimulation of mouse sciatic nerve
  - In all cases in which pulsed current was utilized, no injury reported
  - In some cases in which constant current was utilized, mild injury and axonal degeneration occurred
  - Nearly all monitors now utilize pulsed currents
Sources