Cranial Nerves, Brain Stem Reflexes & Brain Stem Disorders

MHD – Neuroscience Module

Matthew McCoyd, MD
Associate Professor, SSOM
Department of Neurology, LUHS

Key Concepts

• In neuroanatomy, with few exceptions, motor is to the front and sensory is to the back, beginning with the neural tube in embryology (basal plate (motor) vs alar plate (sensory))
  – The motor strip is in front of the somatosensory strip
  – Anterior thalamus is involved in motor control, posterior thalamus in sensory pathways
  – Anterior horn cell is motor, dorsal root ganglion is sensory
• The sulcus limitans is the line that separates motor from sensory

Key Concepts

• The brainstem is “flattened” from behind (by the cerebellum), so motor is in the middle and sensory nuclei are on the sides
• The sulcus limitans is still the dividing line

CST: Corticospinal tract (motor pathway from the cortex (brain) to the spinal cord that crosses in the distal medulla
CN: Cranial Nerve
Key Concepts

- Cranial nerve nuclei medial to the sulcus limitans are motor
  - GSE: start in the midline, exit via midline
    - CNs 3, 4, 6, 12
    - Fun fact: all divide into 12 (and no other brainstem nuclei do)
  - SVE: motor nuclei in a “special place”: start anterior-lateral & exit anterior lateral
    - CNs 5, 7, 8, 10, 11
- Though not a cranial nerve, the CST runs down the front of the brainstem on both sides of the midline

For the curious: the term “SVE” is derived from these CN nuclei roles in fish viscera; they have no visceral role in humans, the name just stuck.

Key Concepts

I totally remember what the corticospinal tract is from M1 year and how it runs, but my friend doesn’t... could you remind him?

- The corticospinal tract is the pathway from the motor cortex (upper motor neuron), down through the internal capsule, then cerebral peduncle, and then the anterior brainstem, crossing in the distal medulla (pyramidal decussation) and then going down the lateral spinal cord where it synapses with anterior horn cells (lower motor neuron)

Key Concepts

- Cranial nerve nuclei lateral to the sulcus limitans are sensory
  - GSA:
    - Incoming sensory information related to touch for the face
    - CN 5: two major nuclei—Spinal Tract of V (pin/temp) and Main Sensory Nucleus (vibration/position sense)
    - CNs 7, 9, 10 (carry minor contributions from the ear—but information is sent to the Spinal Tract of V)
  - SSA
    - CN 8 (vestibulocochlear)
    - CN 1 is also SSA but not in the brainstem

GSA: General Somatic Afferent, SSA: Special Somatic Afferent
GSE: General Somatic Efferent, SVE: Special Visceral Efferent
GV: General Visceral Efferent, GVA: General Visceral Afferent
GV/A: General Visceral Afferent
Autonomic nuclei (GVE, GVA, SVA) are not discussed—but the same principles apply. The “Tractus Solitarius”—the only GVA/SVA nucleus—receives sensory information including taste.

GV nuclei are preganglionic parasympathetic in function.
Key Concepts

- "Cranial Nerves" and "Cranial Nuclei" are not perfectly synonymous.
- Some cranial nuclei are discrete cells that are present at one level and give rise to only one cranial nerve: 3, 4, 6, 7 examples.
- Some cranial nuclei are columns of cells that span multiple levels and can receive input from or give rise to one or multiple cranial nerves:
  - Spinal tract of V (receives sensory input from 5, 7, 9, 10).
  - Nucleus Ambiguus (gives rise to motor components of 9, 10, 11).
  - Hypoglossal nucleus (12) to multiple levels through only one tract or one nerve.
- Some cranial nerves receive contributions from multiple nuclei:
  - 5, 7, 8, 9, 10 are examples where a nerve is a "road" with many off-ramps (nuclei).

Everything in neuroanatomy crosses:
- The right side of the brain controls the left side of the body.
- Pathways to motor cranial nuclei (upper motor neurons) decussate just above the level of the associated nucleus.
- Motor cranial nuclei & nerves are ipsilateral to the muscles they control (they are the lower motor neurons) or the structures they receive sensation from for sensory nuclei.
- CST does not cross until the very lower medulla (pyramidal decussation).
- Spinal cord sensory pathways cross immediately (SpTh) or in the lower medulla (DC/ML).
- Brainstem lesions often cause "cross-brain findings":
  - Symptoms on one side of the face (cranial nerve), opposite side of the body (sensory or motor).

In the brainstem, the SpTh Tract has a mostly lateral location (near the sulcus limitans), much like in the spinal cord. The Dorsal Columns synapse in the lower medulla (Nucleus Gracilis/ Nucleus Cuneatus) and ascend to become the Medial Lemniscus (a thin medial ribbon behind the corticospinal tract) and slowly work their way dorsally with the SpTh tract as they rise to enter the posterior thalamus (VPM/VPL).

Spinothalamic Tract: carries pin/temperature sensation.
- Crosses almost immediately after entering the spinal cord and ascends in the anterior lateral spinal cord & lateral brainstem.
- DC/ML is a procrastinator—crosses late, wanders to the front, slowly works its way to the back where it's supposed to go.
Cases: Medulla

Case

• A 27 year old male falls from a ladder hitting the back of his head. He then develops weakness of both arms and legs. All cranial nerve function is normal as is sensation of the face and body. A causative lesion would be expected where?

Just for fun (future neuro-anatomists, not to be tested): where would the lesion be if the patient had weakness of the right arm and left leg (with normal cranial nerve and sensory findings)?

Localizing the Lesion

Putting it All Together

• Need something that affects:
  – CST (both of them/bilateral)
• Yet also spares:
  – GSE (cranial motor nuclei)
  – SVE (“special” cranial motor nuclei)
  – GSA (sensory nuclei (spinal tract of V))
  – Dorsal columns/medial lemniscus
  – Spinothalamic tract
Answer: Pyramidal Decussation/Lower Medulla

• Taking what you just learned:
• CST is involved so the anterior-medial brainstem has to be involved
  – And it spares everything else—so must be only the anterior-medial brainstem

Case

• A 57 year old male presents with **right** arm and **right** leg weakness. Pin sensation is normal. The following is noted when he attempts to protrude his tongue. Where is the lesion?

Localizing the Lesion

Putting it All Together

• Need something that affects:
  – CN 12 (fascicles) or the nucleus (hypoglossal)—which is GSE (starts midline, exits close to midline)
  – CST

• Yet also spares:
  – Medial Lemniscus
  – SVE cranial nuclei (9, 10, 11)
  – Sensory nuclei (spinal tract of V)
  – Spinothalamic tract
Answer: Lower Medulla

- Tongue deviates to the left: LEFT CN 12
  - Motor CN (GSE): starts midline/exits midline
  - Tongue pushes to the OPPOSITE side; usually deviates TOWARDS the lesion ("lick your wounds")
- Right arm & leg are weak: LEFT CST rostral to the pyramidal decussation
  - "Crossed Brain Finding"
- Hemiplegia alterans infirma (Jackson's syndrome): lesion leads to palsy of the tongue on the ipsilateral side & hemiplegia on the contralateral side with predominant upper limb
  - The medial lemniscus (which has already crossed) can be involved leading to ataxia & sensory loss (either unilateral or bilateral)
  - DO NOT worry about the name of the syndrome!

Key Concept

Where is the Medial Lemniscus in the last case?

Key Concepts

Fibers from the Nucleus Gracilis & Cuneatus move forward & cross the midline to form a thin ribbon in the medial brainstem behind the corticospinal tract ("Medial Lemniscus")
**Question**

- A 28 year old male presents for sudden onset dizziness. Symptoms developed over a few minutes while lifting weights. His examination is notable for a hoarse voice/dysarthric speech, decreased pin sensation over the **right** face, mild weakness of **right** palatal elevation, and decreased pin sensation of the **left** arm. There is incoordination of the right arm. The remainder of the cranial nerve examination, motor examination, and vibratory sensation are normal.
- Can you localize the lesion?

**Localizing the Lesion**

**Things to Know for this Case**

- The trigeminal nerve (Cranial Nerve 5) mediates sensation for the face (both pin sensation and vibratory sense)
  - 7, 9 and 10 bring in minor contributions for sensation from the ear—though the information is “dropped off” in the spinal tract of V
- The trigeminal nerve enters the brainstem in the upper pons
  - Fibers carrying vibration sense cross the midline almost immediately to join the contralateral medial lemniscus
  - Fibers carrying pin/temp sensation join the “spinal tract of V”
- What is the pathway of the spinal tract of V upon in the brainstem?

**Localizing the Lesion**

**Things to Know**

- The spinal tract *descends* (lateral to the sulcus limitans) to around C3-C4 (where it occupies the posterior horn of the spinal grey) before decussating and ascending (eventually merging with the spinothalamic tract and entering the posterior thalamus (VPM))
Imagine the Spinal Tract/Nucleus of V is a Packers fan from Eau Claire, WI coming home from vacation:

1. Arrives from vacation at O’Hare (pons)
2. Drives his car south to southern Illinois (cervical spinal cord)
3. Passes multiple landmarks along the way (including other brainstem/cranial nuclei)
4. Turns and drives all the way north to Madison (thalamus)
5. Finishes his journey to Eau Claire (somatosensory strip)
6. Is this a smart route to take? Are Packers fans smart?

Trigeminal nerve (CN V) carries sensory information from the face into the pons. Pin sensation is conveyed via spinal tract of V all the way down to the cervical spinal cord (C3-C4) The pathway crosses the midline and heads north (rostral) after reaching the cervical cord. The pathway targets the contralateral VPM of the thalamus. Information is routed to the somatosensory strip.

This is for you Joe Bergman. You still owe me for our last round of Golden Tee. Go Bears.

The case has a hoarse voice and right sided palatal droop. This picture is of left palatal droop, though illustrative of a palatal droop.

- CN 9 (Glossopharyngeal) which elevates the larynx and pharynx during swallowing & talking
- CN 10 (Vagus) innervates the pharynx, larynx and soft palate
- The cranial nerves derive from the Nucleus Ambiguus (SVE), a column of cells in the anterior-lateral brainstem

CN 11 (Spinal Accessory): debatably is part of the Nucleus Ambiguus—fibers to the larynx briefly run on CN XI; it major nucleus is in the very distal medulla/cervical cord.
Localizing the Lesion

Things to Know for this Case

• There is decreased pin sensation of the right face and decreased pin sensation of the left arm
• How is that possible?

Localizing the Lesion

Things to Know for this Case

• The spinothalamic tract is responsible for pin/temperature sensation
• It crosses from left-to-right shortly after entering the spinal cord (contralateral to its origin)
• It ascends in the anterior-lateral spinal cord, and anterior-lateral brainstem, slowly working its way dorsally in the brainstem as it moves rostrally (upwards)
• Spinal tract of V runs ipsilaterally down the brainstem before decussating in the cervical cord & then ascending
• Medial lemniscus runs close to the midline in the brainstem, behind the CST

Localizing the Lesion

Putting it All Together

• Need something that affects:
  – SVE: CN 9, 10, the motor components of which arise from Nucleus Ambiguus
  – GSA: Spinal Tract of V
  – Ascending Spinothalamic tract (SpTh)
• Yet also spares:
  – Corticospinal tract (CST)
  – Medial lemniscus (ML)
Localizing the Lesion: Lateral Medulla

What Could Do That?

Vertebral Artery Dissection (which in turns occludes the PICA)

NORMAL  ABNORMAL
Localizing the Lesion

• The patient likely had a vertebral artery dissection, which occluded the Posterior Inferior Cerebellar Artery (PICA), leading to a Lateral Medullary infarction
• Referred to as a “Wallenberg Syndrome”
• Key finding: there are “crossed brain” findings

Adolf Wallenberg (1862-1949) was a German neurologist who described the syndrome clinically (1895) and at autopsy (1901). He moved to the US in 1940 and lived in Chicago, IL until he died.

Localizing the Lesion

Why is there Ataxia (Incoordination) of the Right Arm?

• The olivocerebellar fibers from the left olive cross the midline and enter the right cerebellum (headed to the Dentate Nucleus) through the inferior cerebellar peduncle—which is also in the area just described
• Cerebellar lesions cause ipsilateral symptoms
  - Right cerebellar lesion causes right-sided symptoms
  - Cerebellar hemisphere communicates with the contralateral thalamus/Red nucleus
• Knocking out the olivocerebellar fibers can have an effect similar to knocking out a cerebellar hemisphere

Just for fun: there is a stroke syndrome in which patients develop ipsilateral ataxia and hemiparesis (ie, weakness and ataxia of the same limb). Where and why would that occur?

Cases: Pons
Three Cases to Consider

Case 1

• A 63 year old male presents for slurred speech. He first noticed symptoms after he woke up in the morning and had difficulty drinking coffee. When you examine the patient you notice the following: there is facial asymmetry with a decreased right nasolabial fold and asymmetric smile with normal movement of the forehead.
• Where is the lesion?

Three Cases to Consider

Case 2

• A 63 year old male presents for slurred speech. He first noticed symptoms after he woke up in the morning and had difficulty drinking coffee, and could not taste the flavor. He also noticed loud sounds have been bothering him. When you examine the patient you notice the following: there is facial asymmetry with a decreased right nasolabial fold and asymmetric smile with no movement of the forehead. There are no eye movement abnormalities noted, sensory abnormalities, or other focal findings (ie, weakness, ataxia, etc).
• Where is the lesion?

Case 1 and 2

Upper vs Lower Motor Neuron 7th

• The upper face has bilateral upper motor neuron innervation
  – Unilateral cortical lesions cause lower facial weakness only, sparing the forehead (Case 1)
• Lower motor neuron lesions cause upper and lower facial weakness, usually more severe (Case 2)
  – The facial nerve also innervates the stapedius muscle so sound is not muffled (“hyperacusis”)
  – The facial nerve is responsible for taste of the anterior 2/3rds of the tongue so taste can be involved
  – Referred to as “Bell’s Palsy” (isolated 7th nerve palsy, often idiopathic)
Case 3

What's Wrong Now?

- A 63 year old male presents for slurred speech. He first noticed symptoms after he woke up in the morning and had difficulty drinking coffee. When you examine the patient you notice the following: there is facial asymmetry with a decreased right nasolabial fold, asymmetric smile, and reduced movement of the forehead.
- When you ask him to look to the right & left the following is noted:
  - The remainder of the exam is normal.
- Where is the lesion?

Localizing the Lesion

Putting it All Together

- Need something that affects:
  - SVE: CN 7 (lower motor neuron facial weakness)
  - GSE: CN 6 (impaired lateral gaze to the right)
- Yet also spares:
  - Corticospinal tract (CST)
  - Medial lemniscus (ML)
  - Spinal tract of V

Localizing the Lesion: Pons

Things to Know in This Case

- Cranial nerves 6 and 7 share a “special” relationship: 7 starts anterior-lateral, wraps around 6, and then turns back to exit anterior-laterally.
- The 7th nerve exits the brainstem in the cerebellopontine angle (CPA), in close proximity to the 8th CN, and then enters the facial canal.
Localizing the Lesion

Things to Know in This Case

- Also, look closely: the medial lemniscus “slid” down (from “standing up” to a “laying down” position)
- It maintains somatotopic distribution (Face-Arm-Leg)
- It will start to move back (dorsally) as it rises (rostrally) towards the thalamus


Localizing the Lesion

Things to Know in This Case

- Case as presented can occur with small strokes or demyelinating conditions
- Additional symptoms can occur if the lesion is larger
  - Facial paralysis, lateral rectus paralysis, and weakness of the contralateral tongue and limbs (Foville Syndrome)
  - Just consider what else is in the area
- Blood supply by the Basilar Artery (middle) and Anterior Inferior Cerebellar Artery (AICA)

Blumenfeld H. Neuroanatomy through Clinical Cases.

Blood Supply: Pons

Localizing the Lesion

Things To Know in This Case

- In the last case, when the patient was asked to look right, neither eye moved. When he has was asked to look left, both eyes moved. Why?

“Look left”

“Look right”
Localizing the Lesion

Medial Longitudinal Fasciculus/Paramedian Pontine Reticular Formation

- Simplistically:
  - Frontal eye fields “decide” to turn the eyes contralaterally
  - Message is sent to the contralateral 6th Nerve Nucleus/Paramedian Pontine Reticular Formation (PPRF)
  - Message is sent via 6th Cranial Nerve to the Lateral Rectus to abduct the ipsilateral eye
  - Message is sent up the MLF to the contralateral 3rd Nerve Nucleus
  - 3rd Cranial Nerve sends message to the Medial Rectus to adduct the contralateral eye concurrently
  - If the Abducens Nucleus (6)/PPRF is knocked out, neither eye will move!

- MLF is involved in turning the head and eyes to quickly react to sounds/lights (the Vestibulocochlear Nerve is close by too! More on both at a later date…)

---

Cases: Midbrain

- A 68 year old male presents to the ER after falling. On examination he is noted to have right arm and right leg weakness. He has normal sensation of the face, arm and legs bilaterally. The following is noted on his eye examination:
  - Where is the lesion?
Localizing the Lesion
Putting it All Together

• Need something that affects:
  – GSE: CN 3 (there is complete ptosis, the eye is deviated down and out, and the pupil is enlarged)
  – Corticospinal tract (that is uncrossed/pre-decussation)
  – “Crossed-brain findings”: left eye findings and right-sided weakness

• Yet also spares:
  – Sensory pathways

Localizing the Lesion: Midbrain

Things to Know for this Case

• 3rd Cranial Nerve originates in the midbrain (“Mickey Mouse’s Head”)
• Corticospinal Tract (uncrossed) is found in the Cerebral Peduncle with a somatotopic distribution
• Referred to as the “Weber Syndrome”
  – Patients can have additional features such as tremor (Red Nucleus involvement) or cerebellar dysfunction (Decussation of the Superior Cerebellar Peduncles)

Sir Hermann David Weber described the syndrome in 1863 while practicing in England

Just for fun: would there be mild lower facial weakness?

Likely yes—the fibers to the face do not cross until the pons; cranial nerve motor nuclei cross close to the lower motor neuron

Localizing the Lesion

Things to Know for this Case

• Blood supply to the area is mostly by the Posterior Cerebral Arteries (with contributions from other vessels)
• Can be multiple causes including small strokes

Midbrain Blood Supply

Haymaker W. Bings Local Diagnosis in Neurological Diseases

1/23/2019
Localize the Lesion

Why are there no sensory symptoms in this case?

- The Medial Lemniscus and Spinothalamic tract have continued to work back (dorsally) as they rise (rostrally).
- Eventually they will enter the posterior aspect of the thalamus.
  - They continue to maintain a somatotopic orientation: face/arm/leg...just as they do in the VPM (face) & VPL (arm/leg) of the thalamus.
- Sensory always (eventually) ends up in the back!

Localize the Lesion

What's different about these two patients?

- Oculomotor Dysfunction (CN III)
  - Parasympathetic innervation constricts the pupil.
    - When injured, the pupil enlarge (unopposed sympathetic).
    - Fibers ride on the outer aspect of the oculomotor nerve.
    - Affected early in compressive lesions (“blown pupil”)
  - Innervates the levator palpebrae (main elevator of the lid).
  - Dysfunction causes significant ptosis.
  - Eye deviates down and out (unopposed action of the superior oblique (CN IV) and lateral rectus (CN VI)).
Localize the Lesion

What’s different about these two patients?

- Sympathetic Dysfunction
  - Horner’s Syndrome: ptosis, miosis and anhydrosis (the last part does not always occur; depends on where the lesion is)
  - Ptosis is due to weakness of the superior tarsal muscle (Müller’s muscle—which assists in elevating the lid) and is usually milder
  - Miosis is due to unopposed parasympathetics

Localize the Lesion

Things to Know for this Case

- The sympathetic pathway to the eye is long
  - Starts in the [ipsilateral] hypothalamus
  - Works down the lateral aspect of the brainstem (can be affected in lateral medullary syndromes/Wallenberg) into the lateral spinal cord
  - Exit the spinal cord around C8/T1 (can be affected by Pancoast tumors/apical lung tumors)
  - Ascends along the cervical ganglion
  - Rides on the outer aspect of the carotid artery into the Cavernous Sinus (CS)
  - Jumps onto CN 6 in the CS, then rides along CN 5, then the Long Ciliary Nerve

Fun fact: remember almost everything crosses? The sympathetic pathway does not.

Supplemental

This is supplemental that I think may help understand the function of different cranial nerves
Cranial Nerve I: Olfactory

• SSA: sense of smell
  – Fibers remain ipsilateral & decussate (bilateral innervation)
  – Only sensory pathway that does not reach the thalamus—reaches the piriform lobe, amygdala, hypothalamus, and septal nuclei
• Most common cause of dysfunction: common cold, head trauma (shearing of the cribriform plate); dysfunction can occur in Alzheimer’s & Parkinson Disease

Foster-Kennedy Syndrome: olfactory groove mass (such as a meningioma) leads to anosmia (direct pressure on the olfactory bulbs), ipsilateral optic atrophy (direct injury to the optic nerve), and contralateral papilledema due to raised intracranial pressure.

Cranial Nerve III: Oculomotor

• GSE: 4 subnuclei innervate 5 ocular muscles
  – Lesion leads to weakness of most eye movements (causing double vision) and ptosis
• GVE: Edinger-Westphal Nucleus (single unpaired nucleus for pupil control)
  – Lesion can lead to mydriasis (enlarged pupil; bilateral if the lesion is nuclear, unilateral if fascicular)

Fun facts: fibers for the superior rectus arise from the contralateral subnucleus (medial subnucleus); a single lesion can affect both sides (since the fascicles cross through the opposite subnucleus).

Cranial Nerve IV: Trochlear

• GSE: innervates the contralateral superior oblique
  – Depression of the eyeball (e.g., when the eye is adducted) & intorsion of the eyeball (e.g., when the eye is abducted)
  – Lesion causes the affected eye to drift upwards
  – Everything about this cranial nerve is wrong: the lower motor neuron crosses the midline, it exits the back of the brainstem, it goes a long way (75mm) to do just one thing, it has a function I can never understand. This is my least favorite cranial nerve.
Cranial Nerve IV: Trochlear

Hypertropia (elevated eye) occurs on the side of the palsied nerve. “Bielschowsky Test” - patients often unconsciously tilt their head away from the palsy (E).

Most common causes are congenital and trauma. James Buchanan (pictured) was accused of attempted hanging during his presidential campaign as the reason for his head tilt.

Cranial Nerve VI: Abducens

• GSE: Innervates the lateral rectus (abducts the eye)
  - Works in conjunction with the Oculomotor N. (VI and III), and medial rectus (III) - both eyes are affected by nuclear lesions (contralateral lateral rectus (VI) and contralateral medial rectus (III), ipsilateral eye (lateral rectus) only by fascicular lesions
  - Takes long course:
    - Passes forward through the pons through the medial lemniscus & corticospinal tract
    - Enters the lateral medullary nucleus
    - Exits the brainstem & enters the clival dura
    - Turns rostrally up the clivus into Dorello’s Canal
    - Enters the Cavernous Sinus (only cranial nerve actually in the sinus: III, IV and V1 are in the wall of the sinus)
    - Passes through the Superior Orbital Fissure to the Lateral Rectus

• Look at this case: there is impaired right eye abduction
  - The lesion does not affect the Abducens nucleus
  - The left eye adducts—so a message must have been sent from the right Abducens Nucleus/PPRF up the MLF to the left Oculomotor nucleus
  - The lesion must affect the Abducens Nerve somewhere along its pathway from the brainstem to the muscle
  - Other findings may help better localize the exact location
Cranial Nerve V: Trigeminal

- One nerve, 4 nuclei, 3 major branches, 3 foramina
  - V1: Superior Orbital Fissure (with CNs III, IV, VI)
  - V2: Foramen Rotundum
  - V3: Foramen Ovalis

- GSA: sensory innervation for most of the head
  - 1. Spinal Tract of V: pin/temb sensation
  - 2. Main (principal) Nucleus: sensory nucleus (vibra/position sense)
  - 3. Mesencephalic Nucleus: involved in the jaw jerk reflex pathway

- SVE: muscles of mastication
  - 4. Motor Nucleus; muscles have bilateral upper motor neuron innervation (so there may be mild weakness but jaw deviation is rare; lower motor neuron lesions can cause jaw deviation)

Cranial Nerve VII: Facial Nerve

- One nerve that receives from/contributes to 4 nuclei
  - GSE (Facial Nucleus): Almost all muscles of facial expression & stupedian
  - GVE (Superior Salivatory Nucleus): parasympathetic fibers that innervate lacrimal, palatine and nasal glands as well as submandibular & sublingual glands
  - GSA (Spinal Tract of V): sensory innervation from the ear
  - SVA (Tractus Solitarius): taste from the anterior 2/3s of the tongue

Fun Fact: emotional (involuntary) movements and voluntary movements are dissociated—emotional movements do not descend in the internal capsule. Patients with cortical strokes (UMN) may still laugh symmetrically.
Cranial Nerve VIII: Vestibulocochlear

- SSA (hearing)
- One nerve: 6 nuclei
  - 2 Cochlear nuclei (Ventral & Dorsal): convey sound bilaterally
    - Cross the midline in the trapezoid body
  - 4 Vestibular Nuclei: closely associated with cerebellar pathways, head and eye movements for balance & posture
    - Vestibulo-Ocular Reflex (to be discussed)

Where & What Do the Cochlear Nuclei Project

- Dorsal cochlear nuclei fibers (14) pass dorsal to the inferior cerebellar peduncle, cross the pontine tegmentum, and ascend in the contralateral lateral lemniscus
- Ventral cochlear nuclei fibers (11) pass ventral to the inferior cerebellar peduncle & synapse bilaterally in the superior olivary nuclear complex (9)
  - Superior olivary nucleus is involved in localizing sounds horizontally
  - Crossing auditory fibers form the trapezoid body (12)

Cranial Nerves VII and VIII are closely related in the cerebellopontine angle and internal auditory canal—a tumor (schwannoma) can cause facial weakness and hearing loss
Cranial Nerve IX: Glossopharyngeal

- SVE (Nucleus Ambiguus): Innervates the stylopharyngeus muscle
- GVE (Inferior Salivatory Nucleus): Innervates the otic ganglion and the parotid gland
- GSA (Spinal Tract of V): Sensory innervation from the ear
- SVA (Nucleus Solitarius): Taste from the posterior 1/3rd of the tongue
- GVA (Nucleus Solitarius): Caudal portion receivesafferents from the carotid and aortic bodies.

Vagal Nucleus Class: Functions

- Dorsal Motor Nucleus of the Vagus
  - Preganglionic parasympathetic fibers that innervate the pharynx, esophagus, heart, stomach, liver, and pancreas
  - Forms the vagal trigone on the floor of the 4th ventricle, near the obex and hypoglossal trigone
  - Causes bronchoconstriction, slowing of peristalsis, slowing the cardiac cycle, increasing secretions (bronchi, stomach, pancreas, intestines)
  - Motor to the smooth muscle of the trachea, bronchi, esophagus, and GI tract except the lower part of the large intestine

- Nucleus Ambiguus
  - Supply all striated musculature of the soft palate, pharynx, and larynx (except tensor veli palatini and stylopharyngeus muscles of the tongue)
  - Cortical centers are in the lower precentral gyri, predominantly crossed but bilateral

- Nucleus Solitarius
  - The Nucleus Solitarius is really the only neuron for GVA and SVA, which is why the two are “on top of” each other in most diagrams.
  - Taste sensation from the epiglottis, hard & soft palate, and pharynx (rostral nucleus solitarius)
  - General visceral sensations from the oropharynx, larynx, linings of thoracic & abdominal viscera (nucleus parasolitarius), including chemoreceptors & baroreceptors from the aortic arch sensing changes in blood pressure and pH status (caudal nucleus solitarius)

- Spinal Tract V
  - Somatic sensory fibers from the pharynx, larynx, meninges/dura mater of the posterior fossa, small region near the external auditory meatus (caudal nucleus solitarius)

"Vagus" means "wandering" in Latin, so named for the wandering course it takes providing innervation to various organs.

Keeping Track: Nucleus Ambiguus

- Branchial efferent fibers (SVE) from CN IX (to the stylopharyngeus, which elevates the soft palate) and CN X (to the other laryngeal, pharyngeal muscles & upper esophageal muscles except tensor veli palatini (V))
- There is not universal agreement as to the contribution of CN IX to the nucleus ambiguus, some including it, others not.
- Fibers for the recurrent laryngeal nerve travel briefly with CN XI after exiting the brainstem before joining CN X.
- Probably scattered cells and not a “discrete” nucleus.
- Probably not preganglionic parasympathetic fibers to the heart (true in rodents).
- Source: The name is difficult to choose the nucleus as conventional named cranial nerves (V-X).
Tractus Solitarius & Nucleus Solitarius

- Visceral sensory fibers from CN VII, IX, & X
  - Forms a discrete bundle (the "solitary tract")
  - The nucleus appears isolated in cross section ("solitary")
  - Rostral portion receives afferents from visceral structures & taste buds (gustatory region) (SVA)
    - VII (Nervus Intermedius)
    - IX
    - Taste buds on epiglottis: X
  - Caudal portion receives afferents from cardiopulmonary receptors, chemoreceptors, and baroreceptors (IX, X) (GVA)
    - Near the Area Postrema at the caudal region of the 4th ventricle
  - Somatic (general) sensation from the pharynx/larynx, posterior fossa meninges, and ear (VII, IX, X) (GSA) likely terminate on the trigeminal nucleus

Gustatory: relating to taste or tasting

Solitary Nucleus is the only GVA and SVA nucleus, hence the two are "on top of" each other on the diagram

Keeping Track of the Tracks

Cranial Nerve Contributions

- Nucleus Ambiguus
  - SVA: Branchial Motor
  - Glossopharyngeal
  - Palate (except tensor veli palatini: CN V)
  - Pharynx (except stylopharyngeus)
  - Larynx: Glossopharyngeal
  - Palatine: Facial

- Dorsal Motor Nucleus of the Vagus (GVE)

Cranial Nerve XI: Spinal Accessory

- GSE: innervates the trapezius and sternocleidomastoid
  - Not a true cranial nerve (in my opinion)
  - Originates from the medulla (cranial portion; SVE) and the spinal cord (1-6th cervical cord)
  - Fibers unite & ascend in the subarachnoid space, entering the skull through the foramen magnum
  - Within the skull is joined by the rootlets of CN X (cranial portion works with the vagus to supply the pharynx & larynx)
  - Exit the skull via the jugular foramen
  - Supplies the sternocleidomastoid (along with fibers from C2) and trapezius (along with fibers from C3-C4, which supply mostly the lower trapezius)
  - There is some debate as to whether CN 11 may receive some contribution from the Nucleus Ambiguus (I’m sure the debate is exhilarating….)

Fun fact: CNs 9, 10, and 11 all exit via the foramen magnum, and a mass lesion there can cause palatal droop, hoarseness, and shoulder droop (Vernet Syndrome)
Cranial Nerve XI: Spinal Accessory

- Can be associated with trapezius atrophy, mild scapular winging, and inability to abduct the arm >90°
- The trapezius (spinal accessory n. and 3rd and 4th cervical segments)
  - Upper fibers elevate, retract & rotate the scapula
  - Middle fibers rotate & retract the scapula
  - Lower fibers depress & draw it towards the midline
- With weakness, the shoulder should sag, the upper scapula falls laterally the vertebral border flares and the inferior angle is drawn medially
- Shoulder abduction enhances the winging
- Can occur with ENT surgery to remove lymph nodes (nerve is "sacrificed")

Cranial Nerve XII: Hypoglossal

- GSE: innervates the tongue
- UMN lesions do not usually cause weakness
- LMN lesion cause ipsilateral weakness and the tongue deviates towards the weak side
Cranial Nerve XII: Hypoglossal

GSE: midline nuclei that innervate skeletal muscle derived from somites (III, IV, VI, XII)
Cranial Nerve Organization: Motor

SVE: ventrolateral nuclei derived from the branchial arches; supply skeletal muscle
- Functionally & histologically similar to ordinary skeletal muscle
- Distinctive “special” location ventrolaterally in the brainstem
- “Visceral” is based on the fact that in less developed animals (fish) the branchial arches are associated with nerves that synapse on postganglionic neurons that innervate smooth muscle or glands
- Mostly associated with muscles of the larynx, pharynx, jaw and face

SVE: ventrolateral nuclei derived from the branchial arches; supply skeletal muscle

• First Arch: Trigeminal (V)
  - Muscles of mastication, anterior belly of the digastric, mylohyoid, tensor tympani, tensor veli palatini
• Second Arch: Facial nerve (VII)
  - Facial expression, posterior belly of the digastric, stylohyoid, stapedius
• Third Arch: Glossopharyngeal (IX)
  - Stylopharynx
• Fourth & Sixth: Vagus (X) & Spinal Accessory (XI)
  - Muscles of the palate, pharynx, larynx
  - Trapezius & SCM

There are 6 arches, but the 5th disappears; no structures result from it.

GVE: immediately medial to the sulcus limitans; preganglionic parasympathetic fibers that innervate smooth muscle & glands

- III: Edinger-Westphal Nucleus
- VII: Superior Salivatory Nucleus: innervates submandibular, submaxillary & pterygoal pain ganglia; mediates lacrimation, salivation and vasodilation
- IX: Inferior Salivatory Nucleus: innervates otic ganglion (in turn the parotid gland)
- X: Dorsal Motor Nucleus of X: no discrete ganglion (only diffuse ganglia in organ walls)

Cranial Nerve Organization: Sensory

GVA: immediately lateral to the sulcus limitans; receive afferent from visceral organs (ie, changes in blood pressure)
- Glossopharyngeal
- Vagus

SVA: superimposed on GVA; involved in “special senses” & utilize chemoreceptors
- Taste: Facial, Glossopharyngeal, Vagus
Cranial Nerve Organization: Sensory

GSA: General Sensation: pseudounipolar cell body lies outside the CNS; innervates skin, muscle spindles, tendons/joints

- V: main player
- VII, IX, X: largely involved in sensation around the ear and mouth
  - Central processes enter the brain via the respective cranial nerve, travel in the trigeminal spinal tract, and end in the trigeminal spinal nucleus
  - Reaches the contralateral thalamus via the trigeminothalamic tract

Cranial Nerve Organization

SSA: highly specialized somatic receptors

- VIII
  - Very laterally located—placing the nuclei close to the cerebellar nuclei with which they are the most intimately involved
- Cranial nerves I and II are also SSA—but not located in the brainstem

Cranial Nerve Organization

<table>
<thead>
<tr>
<th></th>
<th>SSA</th>
<th>GSA</th>
<th>SYA</th>
<th>GVA</th>
<th>GVE</th>
<th>SVE</th>
<th>GSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIII</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IX</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XI</td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>XII</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

LATERAL    MIDLINE