Laryngeal Innervation

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The nerve of Galli-Curci

- Celebrated opera soprano
- Underwent surgery in 1935 for a thyroid goiter- done under local to prevent injury
- The “amazing voice is gone forever; instead of cream velvet there is a sad quivering ghost”
- Many argue that SLN injury ended her career (though this is highly controversial)
Laryngeal Anatomy

- Hyoid Bone
- Epiglottis
- Thyrohyoid Membrane
- Aryepiglottic Fold
- Cuneiform Tubercle
- Transverse Arytenoid
- Thyroid Cartilage
- Thyrohyoid Membrane
- Cricoid Cartilage
- Oblique Arytenoid
- Cricothyroid Ligament
- Cricothyroid Muscles
- Trachea
Laryngeal Anatomy 2

Hyoid Bone
Epiglottis
Thyrohyoid Membrane
False Vocal Cords
True Vocal Cords
Thyroid Cartilage
Ventricle
Vocalis Muscle
Cricoid Cartilage
Trachea

FORAMEN FOR SUPERIOR LARYNGEAL VESSELS AND NERVE (INTERNAL BRANCH)

OBlique and TRANSVERSE ARYtenoid MUScLES

POSTerior CRICO-ARYtenoid MUSCLE

VERTICAL PART
CRICO-THyroid MUSCLe
OBQuE PART

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Nerves to the larynx

- Recurrent laryngeal nerve
  - Branch of vagus - arises at the level of the arch of aorta - travels up the side of the trachea to the larynx (left loops under the arch)
  - Innervates all muscles except cricothyroid
  - Sensation to larynx below vocal cords
  - First documented by Galen
- Galen cut pigs’ recurrent laryngeal nerves while awake
- Pigs stopped squealing but continued to struggle and breathe.
Recurrent Laryngeal Nerve

- Somatic fibers in the nucleus ambiguous and emerge from the medulla in the cranial root of the accessory nerve
- Fibers cross to join the vagus in the jugular foramen
- Sensory cell bodies are in the inferior jugular ganglion and fibers terminate in the solitary nucleus
- Parasympathetic fibers to segments of the trachea and esophagus in the neck originate in the dorsal nucleus of the vagus
Pharyngeal Arches

- **1st** – mandibular arch
  - V2 and V3
  - Muscles of mastication, anterior belly of the digastric, mylohyoid, tensor tympani, tensor veli palatini
  - Maxilla, mandible, incus, malleus, Meckel’s cartilage
  - Maxillary artery, external carotid
Pharyngeal Arches

- 2\textsuperscript{nd} – hyoid arch
  - Facial nerve
  - Muscles of facial expression, buccinator, platysma, stapedius, stylohyoid, posterior belly of digastric
  - Stapes, temporal styloid process, lesser horn and upper part of body of hyoid, Reichert’s cartilage
  - Stapedial artery, hyoid artery

- 3\textsuperscript{rd}
  - Glossopharyngeal nerve
  - Stylopharyngeus
  - Greater horn and lower part of body of hyoid, thymus, inferior parathyroids
  - Common Carotid, internal carotid
Pharyngeal arches

- 4th
  - superior laryngeal nerve
  - cricothyroid muscle, intrinsic muscles of soft palate
  - thyroid and epiglottic cartilage, superior parathyroids
  - right-subclavian, left aortic arch

- 6th
  - recurrent laryngeal nerve
  - cricoid cartilage
  - all intrinsic muscles of larynx except cricothyroid
  - right pulmonary artery
  - left pulmonary artery and ductus arteriosus
RLN embryology

- RLN forms a loop around the sixth aortic arch
- On the left, the sixth arch forms the ductus arteriosus
- On the right, the sixth aortic arch disappears and the nerve loops around the more superior right subclavian artery
Giraffes - 15 feet

- Nervus laryngeus inferior
  - Inferior laryngeal nerve
- Nervus vagus
  - Vagus nerve
- Aorta dorsalis
  - Dorsal aorta
- Arteria pulmonalis
  - Pulmonary artery
- Cerebrum
- Brain
- Nervus laryngeus superior
  - Superior laryngeal nerve
- Nervus laryngeus recurrent
  - Recurrent laryngeal nerve
- Arteria corotis
  - Carotid artery
- Arcus aortae
  - Aortic arch
- Ductus arteriosus Botalli
  - Botalli’s duct
- Cor
  - Heart
RLN paralysis

- Injury to RLN resulting in temporary palsy of vocal cord reported at 0.2-5.8% of thyroidectomies
- Permanent paralysis 0.1-3.9% of cases
- Right RLN damaged more commonly because the left travels closer in the tracheo-esophageal groove (and non-recurrent inferior laryngeal nerves occur on right)
Variation

- Extralaryngeal bifurcations or trifurcations of the terminal division of the nerve before it enters the larynx have been reported.

- Anastomotic branches with sympathetic chain have also been reported.

- Anatomic displacements, differing relationships to the inferior thyroid artery.
Non recurrent inferior Laryngeal nerve

- Less than 1% of surgical reports (1-2% in anatomic studies)
- Typically on the right, Associated with a right subclavian artery arising from the left side of the aorta usually crossing behind the trachea and esophagus.
Non recurrent inferior laryngeal nerve

- Branches off the vagus
- May loop around inferior thyroid artery or come directly from vagus
- Left nonrecurrent 0.04%- situs inversus AND anomalous left-sided subclavian artery
More variation...

- Nonlocalizing parathyroid adenoma
- Intrathyroidal
- RLN identified and dissected superiorly, a second nerve of equal size was encountered originating in the region of the right carotid sheath
- Merged with previously identified RLN to enter larynx
- Normal vascular anatomy
<table>
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No embryologic explanation

- Some argue it’s sympathetic fibers connecting into the RLN rather than concurrent NRILN
- If it’s sympathetic connection fibers their function is unclear
- Conclusion: all nerves that cross the space medial to the carotid sheath and travel toward the thyroid, trachea and larynx should be preserved
RLN injury in horses

- Equine recurrent laryngeal neuropathy
- Appears to be disease of axons, high prevalence in thoroughbreds, more common in larger horses
- Left side nearly exclusively
- Presents with stertor- "roaring" and worsening performance
Surgery

- Improve airway, breathing, performance (no voice concerns)
- Prosthetic Laryngoplasty
  - “tie back” of arytenoid
- Ventriculectomy/Cordectomy
- Arytenoidectomy
  - Only for failed tie-back or infected arytenoid
- Nerve graft
Ortner’s Syndrome

- Cardiovocal syndrome

- Paralysis of left RLN due to cardiovascular disease
  - Dilated LA from mitral valve stenosis, pulmonary htn, atrial myxoma, aortic anerysms
  - 0.6%–5% in mitral valve stenosis
  - Actually appears to be compression between the pulmonary artery, aorta, and left atrium (not by the dilated left atrium)
  - Poor prognostic sign of heart disease

Superior Laryngeal Nerve

- Arises from nodose ganglion of vagus

- Crosses anterior to the cervical sympathetic chain, posterior to the internal carotid
  - Receives a branch from the superior cervical sympathetic ganglion that contributes to the innervation of the carotid body and thyroid gland - at least 21 variations in this anatomy

- Divides into internal and external branches at a variable distance (0-20mm from origin) usually within bifurcation of the carotid

- Exit carotid sheath 20mm inferior to the bifurcation of the carotid
Superior Laryngeal Nerve

- External branch of SLN
  - lies immediately posterior to the superior thyroid artery
  - Innervates cricothyroid muscle - tenses vocal cords to increase pitch
  - Branches to pharyngeal plexus
  - Branches to the superior portion of the inferior pharyngeal constrictor
  - Also communicates with superior cardiac nerve
SLN

- Internal branch of SLN
  - Descends to the thyrohyoid membrane with the superior laryngeal artery
  - Sensory branches to epiglottis, base of tongue, aryepiglottic fold
  - Essentially all laryngeal sensation above vocal folds
  - Vocal fold sensation dually innervated by SLN and recurrent nerve
Ansa of Galen

- Areas of anastomosis between the SLN and recurrent laryngeal nerve
- Present in 75-95% of human larynges
- Also can be connections between the iSLN and RLN within interarytenoid muscle and thyroarytenoid
Identification of SLN

- Type 1 (68%) EBSLN crosses STA more than 1cm superior to upper pole of thyroid
- Type 2a (11%) crosses less than 1cm superior to the upper pole of the thyroid
- Type 2b (14%) crosses the STA while covered by the upper pole of the thyroid gland

In goiters

- Type 1: 23%
- Type 2a: 15%
- Type 2b: 54%

Importance of SLN

- Recurrent laryngeal nerve anatomy has been extensively described with its variations
- SLN has received much less attention by both anatomists and surgeons
- It has even been termed “the neglected nerve” in head and neck surgery
- SLN denervation known to cause hoarseness, decreased vocal projection, decreased pitch range, and vocal fatigue

Innervates Cricothyroid

- Three muscle bellies - oblique and rectus superficially and horizontal deep to those.

Findings in SLN injury

- Subtle, heterogeneous
- Ipsilateral posterior glottal rotation
- Bowing and inferior displacement of the affected vocal cord
- Decreased mucosal travelling wave
- Pretty much all these findings are controversial
Deficits in SLN

- “rotation of the larynx” was previously most-quoted but that was disputed
- Also have been reports of high disparity between vocal cords
- Sliggishness of ipsilateral vocal fold during repetitive adduction and abduction tasks
- Decreased longitudinal tension
Petiole deviation

- Can be seen in upward glissando maneuver. Appears to be most specific FFL sign of SLN paralysis
- Not present in RLN paralysis

Petiole deviation

- Only seen in high pitch
- Reported in case reports of SLN paralysis
- Also reported consistently when anesthetizing SLN with lidocaine

Sensory inputs in swallowing

- Sensory inputs from oropharyngeal region are important for voluntarily initiated swallows

- Innervation from the pharyngeal plexus including CN IX as well as some contribution from X
Decrease in sensation

- 12 healthy volunteers 24-46 years
- Tonsillar pillars, soft palate, and posterior pharyngeal wall were anesthetized with 22-24 puffs of 10% xylocaine
- Confirmed with absence of touch sensation to light contact with a tip cannula
- Loss of palatopharyngeal reflexes

Swallowing Liquid

- Given increasing amounts of water and asked to swallow at once
- Prior to anesthesia, no dysphagia in under 20mL of water
## Aspiration

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<th>Subject number</th>
<th>Age</th>
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N, normal; DL, dysphagia limit.
SLN contribution

- 5 healthy volunteers 26-35 y/o
- FEES in normal state and after bilateral SLN block
Results

<table>
<thead>
<tr>
<th>Puree swallows</th>
<th>Sensate Swallows (n = 15)</th>
<th>Insensate Swallows (n = 15)</th>
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<td>Tracheal aspiration</td>
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*On χ² test.

Transection of SLN in pigs

- Right carotid sheath with dissected SLN
- CV: cervical vagus nerve
- NG: nodose ganglion
- SCG: superior cervical sympathetic ganglion

Results

- Penetration occurred in 27.8% of pre-lesion swallows as assessed by MBS
- Aspiration occurred in 0.7% of pre-lesion swallows
Results post-lesion

- 75.6% penetration
- 34.1% aspiration
- No coughing even with aspiration

Like mice and babies...

- Several sucks to every swallow
- Average 2.64 sucks per swallow pre-lesion
- Average 3.59 sucks per swallow post-lesion
Timing

- Other timing of swallow parameters also changed
- Increased duration of sucks
- Increased duration of pharyngeal swallows
- Increased interval between the suck preceding a swallow and the swallow itself
SLN dissection

- Both the external and internal SLN were interrupted
- iSLN is a sensory branch
- eSLN thought to originally innervate only the ipsilateral cricothyroid muscle
- eSLN in pigs innervates the cricoiothyroid muscle as well as the inferior pharyngeal constrictor muscle
Lever Lab LAR
SLN contribution to murine LAR

- Intact SLN essential to normal swallowing
- Is it essential to LAR?
- Severed SLN and attempted to get murine LAR
Unexpected finding

- In one of our four mice, transection of SLN showed vocal fold paralysis!
More than we thought...

- 46% of dissected larynges had a SLN branch to the thyroarytenoid muscle
- 67% had a branch to the subglottic mucosa
- 25% had a branch that connected to the RLN

Implications for practice

- SLN in some humans may have a larger contribution to vocal fold movement than previously thought
- Variable anatomy not always accounted for in our typical dissections