Disclosure

- I have no financial interest or other relationship with any manufacturer(s) of any commercial product(s) and/or provider(s) of commercial services discussed in this presentation or with any commercial supporters of the educational activity.
Objectives

- Define laryngohyoid complex
- Review of anatomy and development of thyroid cartilage and hyoid bone
- Description of some anatomic variants that may cause difficulty
- Discuss other causes of hemorrhage or apparent injury to laryngohyoid complex
- Describe an approach to examination of neck with focus on fractures
Why is this important?

• In a potential homicidal strangulation, we look to the neck, and particularly the laryngohyoid complex to provide confirmation about the mechanism of death.

• They are not required but the presence of fractures in the larynx and/or hyoid, along with associated acute hemorrhage, and typical external injuries point to the cause of death.

• Fractures are not the actual cause of the death but they are an important marker for compression to the neck.

• We need to be able to reliably diagnose antemortem injury (fracture) of the larynx and hyoid, rule out other mechanisms of such injury and ensure these are not just anatomic variants or artifacts.
## Neck Compression & Fracture

### Table 1: Summary of Neck Compression Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Cases</th>
<th>Petechiae</th>
<th>External Neck Injury</th>
<th>Internal Soft Tissue Neck Injury</th>
<th>Hyoid, Thyroid, and/or Tracheal Fracture</th>
<th>Sexual Assault Motive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Study</td>
<td>68 F</td>
<td>79% (52/66)</td>
<td>80% (52/65)</td>
<td>93% (62/67)</td>
<td>28% (19/68)</td>
<td>44% (30/68)</td>
</tr>
<tr>
<td>DiMaio (6)</td>
<td>54 F, 35 M</td>
<td>88% (64/73)*</td>
<td>100% (54/54)</td>
<td>Not reported (NR)</td>
<td>28% (15/54)</td>
<td>59% (32/54)</td>
</tr>
<tr>
<td>Harm and Rajs (7)</td>
<td>26 F, 11 M</td>
<td>95% (35/37)*</td>
<td>100% (37/37)</td>
<td>NR</td>
<td>57% (21/37)*</td>
<td>27% (10/37)*</td>
</tr>
<tr>
<td>Luke (2)</td>
<td>12 F, 13 M</td>
<td>60% (12/20)*</td>
<td>60% (15/25)*</td>
<td>84% (21/25)*</td>
<td>72% (18/25)*</td>
<td>NR</td>
</tr>
<tr>
<td>Srivastave et al. (8)</td>
<td>18 F, 8 M</td>
<td>NR</td>
<td>96% (25/26)*</td>
<td>“most”*</td>
<td>35% (9/26)*</td>
<td>NR</td>
</tr>
</tbody>
</table>

Homicidal Neck Compression of Females: Autopsy and Sexual Assault Findings, Gill J, Davalli DP, et al; Acad For Path 2013 3(4) 454-457
Examination of neck: The basics

- Careful external exam looking for injury especially with the neck extended
- Internal dissection of chest, abdomen and head prior to examination of neck
- Layer by layer stepwise dissection of strap muscles with documentation as indicated
- Careful removal of neck organs including surrounding soft tissue with or without tongue
- Removal of tongue if present
- Removal and examination of hyoid, careful removal of soft tissue
- Careful examination of larynx, esp exposing superior horns of thyroid cartilage
- Additional procedures
Good overall photo of neck, laterals
Neck Dissection
Part II- Examination of the hyoid and larynx after removal*

- Xray or CT before dissection*
- Direct visualization and palpation after removal
- Xrays after removal
- Maceration with removal of variable amounts of soft tissue/cartilage
- Anthropology consult
- Histology and/or Stereomicroscopy (Dissecting microscope)
Laryngohyoid complex

- Composed of the hyoid bone and the cartilaginous larynx
- Hyoid bone is the superior border
- Cricoid cartilage is the inferior border
- Hyoid and larynx bound together by three ligaments (the middle and two lateral thyrohyoid ligaments) and thyrohyoid membrane

The Laryngohyoid Complex in Medicolegal Death Investigations”, Pinto DC, Acad Forensic Pathol. 2016 (3) 486-498
Hyoid Bone

• A U-shaped bone located at the base of the mandible and suspended by the styloid processes of the temporal bone through the stylohyoid ligament

• Primary function serves to anchor the tongue and attachment site for multiple muscles of the neck

• Two groups of muscles attach
  • Suprahyoid: mylohyoid, geniohyoid, stylohyoid and digastric
  • Infrahyoid: sternohyoid, omohyoid, sternothyroid and thryohyoid
Hyoid bone

- Greater cornu
- Lesser cornu
- Body
Cool facts (trivia) about: Hyoid Bone

- Composed of fusion of six bony elements (two in body and the greater and lessor cornu)
- 28% of individuals >20 y. o. have at least one pseudo-joint
- The hyoid is the only true bone in body not attached by joint to other bone
  - (patella is a sesamoid bone)
Embryology of Hyoid

- Classically said to develop from 2\textsuperscript{nd} and 3\textsuperscript{rd} branchial arches
- All 5 segments present at end of embryonic period
- Ossification of Body and Greater horns (cornu) occurs as early as 30 weeks gestation; lessor horns ossify at puberty
- The presence of fusion (of the joints between body and greater horns) increases with age but, the ossification and fusion of the joints is highly variable, even within one individual
- Size of hyoid is partly determined by gender
Larynx

- Cartilages, ligamentous membranes and muscles below the hyoid bone and above the trachea
- Anterior to the 3-6\textsuperscript{th} cervical vertebra, develops from the 4\textsuperscript{th} and 6\textsuperscript{th} branchial arches
- Facilitates breathing and sound production
- Two largest cartilages are the thyroid and cricoid cartilages joined by the cricothyroid membrane
Anatomy of the Larynx

Image 3: Anterior view of the articulated thyroid and cricoid cartilage. The perichondrium has been removed. A = thyroid cartilage, B = cricoid cartilage, C = superior horns of the thyroid cartilage, D = laminae of the thyroid cartilage, and E = inferior horns of the thyroid cartilage.

The Larynhoiyd Complex in Medicolegal Death Investigations, Pinto DC, Acad Forensic Pathol. 2016 (3) 486-498
Common anomalies
Individual variation may cause misdiagnosis

- Anomalies and/or developmental variation of the larynx or hyoid may lead to erroneous diagnosis of trauma
  - Triticeal cartilages
  - Agenesis of superior horns
  - Incomplete fusion of hyoid
Triticeal cartilages

- Most common anomaly of the larynx (20-30% of cases)
- Located in the thyrohyoid ligament above the superior horn of the thyroid cartilage
- May be unilateral or bilateral
- May appear to be a fracture of the superior horn
Gross of triticeal cartilage

Picture from: Laryngeal anomalies: Pitfalls in adult forensic autopsies, AS Advenier, G Lorin De La Grandmaison, Medicine, Science and the Law 2014, Vol 54(1) 1–7
# Distribution of Triticeal Cartilage by sex of cadaver

<table>
<thead>
<tr>
<th></th>
<th>Number of cadavers</th>
<th>Cadavers with TC</th>
<th>Cadavers without TC</th>
<th>Bilateral</th>
<th>Unilateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>51</td>
<td>16 (31%)</td>
<td>35 (67%)</td>
<td>6 (12%)</td>
<td>10 (20%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(5R 5L)</td>
</tr>
<tr>
<td>Female</td>
<td>35</td>
<td>12 (34%)</td>
<td>23 (66%)</td>
<td>6 (17%)</td>
<td>6 (17%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3R 3L)</td>
</tr>
<tr>
<td>Totals</td>
<td>86</td>
<td>28 (33%)</td>
<td>58 (67%)</td>
<td>12</td>
<td>16 (8R 8L)</td>
</tr>
</tbody>
</table>

Other laryngeal anomalies

- Unilateral or bilateral agenesis of the superior horns of the thyroid cartilage due to differential development of the horns

Picture from: Laryngeal anomalies: Pitfalls in adult forensic autopsies, AS Advenier1, G Lorin De La Grandmaison, Medicine, Science and the Law 2014, Vol 54(1) 1–7
Agenesis of the Superior Cornua of the Thyroid Cartilage: A Rare Variant of Medicolegal Importance, Petr Hejna, MD, PhD, MBA,† Martin Janík, MD, PhD et al, Am J Forensic Med Pathol 2015;36: 10–12

Variable development: Fusion of hyoid bones
## Hyoid bone fusion

<table>
<thead>
<tr>
<th>Rank / Definition</th>
<th>3D Hyoid Model</th>
<th>CT Scan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distant Non-Fusion (Rank 0):</strong> A large space (greater than or equal to 2.5 mm) in the axial plane between the nearest points of the hyoid body and greater cornu.</td>
<td><img src="image1" alt="3D Hyoid Model" /></td>
<td><img src="image2" alt="CT Scan" /></td>
</tr>
<tr>
<td><strong>Non-Fusion (Rank 1):</strong> A small, measurable space (less than 2.5 mm) in the axial plane between the nearest points of the hyoid body and greater cornu. There is no point of contact between the hyoid body and greater cornu.</td>
<td><img src="image3" alt="3D Hyoid Model" /></td>
<td><img src="image4" alt="CT Scan" /></td>
</tr>
<tr>
<td><strong>Partial Fusion (Rank 2):</strong> Fusion has begun but is not uniform throughout the hyoid bone. Part of the body and greater cornu have fused, but there exists one or more distinct lower intensity (darker) gaps between the structures, visible in the same slices in which the hyoid bone’s marrow (lower intensity) can also be seen.</td>
<td><img src="image5" alt="3D Hyoid Model" /></td>
<td><img src="image6" alt="CT Scan" /></td>
</tr>
<tr>
<td><strong>Fusion (Rank 3):</strong> No measurable space between the hyoid body and greater cornu. A line of contact may be visible in all 3 views (axial, sagittal and coronal), OR the hyoid body and cornu may appear as one continuous structure with no dividing line.</td>
<td><img src="image7" alt="3D Hyoid Model" /></td>
<td><img src="image8" alt="CT Scan" /></td>
</tr>
</tbody>
</table>

From: Hyoid bone fusion and bone density across the lifespan: prediction of age and sex; Fisher E; Austin D; Werner HM; et al, For Sci Med Path (2016) 12: 146-157
Fusion of hyoid-basic facts

- All hyoid bones under age 14 (and ½ ages 14-19) showed bilateral ‘Distant non-fusion’
- No partial, unilateral or bilateral fusion before age 20
- No distant non-fusion after age 20
- 7 cases in the study had complete fusion ages 20-30 (n=30)

From: Hyoid bone fusion and bone density across the lifespan: prediction of age and sex; Fisher E; Austin D; Werner HM; et al, For Sci Med Path (2016) 12: 146-157
Plain radiograph of excised hyoid bone shows synchondrotic joints prior to fusion.

From: Pitfalls and Artifacts in the Neck at Autopsy; Pollanen MS, Acad Forensic Pathol. 2016 6(1): 45-62
Hyoid Bone - Variable fusion

Courtesy of Mark Flomenbaum
Complete fusion

**Image 1:** Superior view of a fused hyoid bone. The white arrows indicate the fused synchondrosis connecting the body and the greater horns. The bone has been chemically processed to remove all soft tissue.

From: The Laryngohyoid Complex in Medicolegal Death Investigations, Pinto DC, Acad Forensic Pathol. 2016 (3) 486-498
INJURIES OTHER THAN STRANGULATION THAT MAY CAUSE FRACTURES
Injury to Laryngohyoid complex

- Blunt force trauma
  - Strangulation*
  - Hanging
  - Motor vehicle crashes
  - Falls from heights
  - Athletic activities
  - Vomiting
- Penetrating injuries
- ? Resuscitation
Fracture mechanisms in Hyoid injury

- **Inward compression fracture**
  - Seen in strangulation-main force is inward compression on the hyoid bone
  - Fingers squeeze the greater horns towards each other causing fracture, posterior fragments are displaced inwards

- **Anteroposterior fracture**
  - Could result from hanging or other force in AP direction
  - Greater horns diverge
  - Fractured fragment angulated or displaced laterally
Avulsion Fractures

- Overactivity of neck muscles without direct action or injury to the hyoid
- Hyoid may be drawn up in a hanging and held rigid, with the sudden suspension and downward movement of the thyroid cartilage, there is traction through the Thyrohyoid ligament
- Fracture fragments are usually displaced outward
- Incidence in hangings 15-20% above age 40
Hanging

- Most common cause of death other than strangulation to show fractures of laryngohyoid complex
- Incidence of fractures increase with age and is additionally influenced by weight
- Significant variation in percentages of fractures reported in hangings from 0-83%
  - Method/methods of examination
  - Prospective vs retrospective study
  - Type of injuries described
Hangings

- Prospective study from Russia found injuries to hyoid or thyroid cartilage in 76.6% of cases of hanging*
  - Methods used included palpation, Xrays and stereomicroscopy
  - Injuries described included displaced and linear fractures, as well as smaller plastic deformities of the compact bone and lamellar fractures

*Trauma to the hyoid bone and laryngeal cartilages in hanging: Review of forensic research series since 1856; Khoklov V, Legal Medicine 17 (2015) 17-23
Image 2: A fractured hyoid from a case of a suicidal hanging. The greater horns are fractured. The white arrow indicates a partially fused synchondrosis. The black arrow indicates an unfused synchondrosis. The bone has been chemically processed. Without removal of all soft tissue, the unfused synchondrosis could be mistaken for a fracture.

From: The Laryngohyoid Complex in Medicolegal Death Investigations, Pinto DC, Acad Forensic Pathol. 2016 (3) 486-498
Healed fracture in an autoerotic hanging may assist in confirming the circumstances.

Image 1: Anteriorly and medially displaced healed fracture of right superior horn of thyroid cartilage.

Laryngohyoid facture in falls

- Occurs less often than other skeletal injuries due to mobility of neck structures and protection of the laryngohyoid by surrounding neck structures such as mandible and sternum.

- Incidence in studies in literature ranges from 2.5% - 9%.

- Injury may be caused by:
  - Exposure of neck structures to direct trauma.
  - Indirect effects of hyperflexion, hyperextension or local trauma which strains the muscles attached to the hyoid or thyroid cartilage.
  - Combination of direct and indirect trauma.
Recently published Study on Falls

- Turkish study from 2013 evaluated 170 falls where there was a clear evidence of accident or strong factors indicating suicide
- Distribution of Fractures of the Neck and Surrounding Bones
  - Rib fractures 123 (72.4%)
  - Clavicle fracture 22 (12.9%)
  - Hyoid bone fracture 9 (5.3%)
  - Thyroid cartilage fracture 11 (6.5%)
  - Total cases with Hyoid and/or thyroid fracture 16 (9.4%)
  - Cervical vertebra fracture 22 (12.9)
  - Mandible fracture 16 (9.4)
- Laryngohyoid fractures more likely with greater heights of fall, older ages and presence of cervical or clavicular fracture (based on their statistical analysis)
- May be found even without external neck injury due to indirect mechanism of injury

Laryngohyoid fractures in Fatal Nonhomicidal Falls From a Height, Huseyin Es, Sahin MF et al, Am J For Med Path 2017, 38:4 289-293
Other Mechanisms of Injury or Findings that mimic injury of Laryngohyoid

- Motor vehicle crash with neck injury
- Neck trauma during athletic injuries
  - Hockey puck to the neck
  - Boxing related injuries
- Vomiting
- Perimortem or postmortem changes which mimic injury
Self induced vomiting*

• Case report 2012: 37 year old woman with prior hospitalizations where multiple facial and subconjunctival petechia were noted
• Patient self reported purging for weight loss
• History alcoholism, no evidence foul play at scene, found in bed 20-30 minutes after having been seen alive
• Fine petechiae of forehead and eyelids seen at autopsy
• Isolated fracture of left greater cornu of hyoid bone with no hemorrhage in neck muscles

*Self-Induced Vomiting as a Probable mechanism of an Isolated Hyoid Bone Fracture, White J & Carver J; Am J Forensic Med and Pathol 33, 2, 170-172
Autopsy

Histology of hyoid showed mixed inflammation extending into soft tissue
Resuscitation

• There are citations in the literature which attribute fractures of hyoid and/or thyroid cartilage to CPR commonly to intubation

• Raven and Reay in 1999 in Am J of Foren Med Path reviewed 50 deaths after CPR to evaluate airway injuries

• Multiple soft tissue injuries, petechiae strap muscle hemorrhage, etc but NO fractures of hyoid or thyroid
Perimortem or Postmortem findings

- Petechiae and soft tissue hemorrhage in the neck are classic findings of strangulation if there is a struggle.
- Perimortem hemorrhage or extravasation should be ruled out if possible based on circumstances.
  - Posterior pharyngeal hemorrhage does not require compression.
  - Postmortem hypostatic hemorrhage is extravasation of blood that occurs when veins are congested due to gravity and there is postmortem loss of vascular integrity (Prone position and decomposition).
    - Tardieu (face, chest, legs)
    - Scleral hemorrhages
    - Neck, soft tissue, even strap muscle hemorrhage

From: Pitfalls and Artifacts in the Neck at Autopsy; Pollanen M S, Acad Forensic Pathol. 2016 6(1): 45-62
Posterior pharynx

From: Pitfalls and Artifacts in the Neck at Autopsy; Pollanen MS, Acad Forensic Pathol. 2016 6(1): 45-62
Postmortem scleral hemorrhage

From: Pitfalls and Artifacts in the Neck at Autopsy; Pollanen MS, Acad Forensic Pathol. 2016 6(1): 45-62
CASE EXAMPLES
Summary

- Injury to the larynx and hyoid bone is most frequently associated with strangulation, usually manual strangulation.
- Many other kinds of trauma can cause similar fractures including hanging, falls, motor vehicle crashes and sports injuries.
- Anomalies and normal developmental variations should be ruled out.
Summary, 2

- Xrays of the neck structures post removal are a good way to identify fractures before removing too much tissue
- Maceration to chemically remove tissue helps to prevent iatrogenic injury and can add a lot of information without a lot of extra expense or work
- Consider consult with anthropologist if there are confounding issues such as fire, postmortem decomposition, possible postmortem injury, difficult removal of neck structures or buried body
- Although rarely used histology may assist with identifying subtle fractures or injuries incurred prior to death