Functional anatomy and biomechanics of the cervical spine

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Gross anatomy of the spine

- Two parts:
  - Mobile part
  - Immobile part

- Mobile part:
  - Cervical region (7 vertebrae)
  - Thoracic region (12 vertebrae)
  - Lumbar region (5 vertebrae)

- Immobile part:
  - Sacrum
  - Coccyx
Spinal curvatures

Spine from the side is “S” shaped. It has anterior and posterior facing, alternating curvatures.

The curvature in the cervical spine is called lordosis and it’s concave part faces posterior. Similar shape and name has the curvature of the bottom of the spine namely the lumbar spine.

In the middle part, the thoracic spine the curvature is reversed and is called kyphosis.
Function of the spine

- Skeleton of the trunk (axial skeleton)
- Supports the body and participates in creation of thoracic and pelvic cavity
- Provides attachments for the ribs and strong muscles
- Protects viscera (thoracic and pelvic)
- Protects the spine cord
- Provides «stable» mobility
Cervical spine

- The most mobile region of the spine
- Supports the weight of the head ($\approx 4\text{Kgr}$)
- High compressive loading due to strong muscles
- Protects the spinal cord and part of medulla oblongata
- Positions the head in space and adapts the visual field according to external stimuli
Anatomy of Cx

- 7 cervical vertebrae
- Intervertebral discs create space between the bones to allow movement
- Functionally separated in lower and upper cervical region
Cervical vertebrae

Vertebrae

(A) Cervical vertebra
- Transverse process
- Uncus of body (uncinate process)
- Rectangular bodies with concave superior and convex inferior surfaces
- Foramen transversarium
- Perforated transverse processes with anterior and posterior tubercles

(B) Thoracic vertebra
- Long, strong transverse processes extend posterolaterally
- Columnar bodies, heart-shaped in superior view
- Circular vertebral foramen, relatively small compared to size of body
- Nearly vertical articular facets directed primarily posteriorly and anteriorly
- Costal facets 2 on each side of body 1 on each transverse process
- Spinous process long and sloping, overlaps inferior vertebra

(C) Lumbar vertebra
- Vertebral foramen triangular, intermediate in size
- Massive columnar body, kidney-shaped in superior view
- Short, broad and blunt spinous process
- Nearly vertical articular facets directed primarily medially and laterally
- Transverse processes long and slender, directed laterally

Atlas & axis

- **Posterior tubercle**
- **Posterior arch**
- **The cranium sits on the atlas at the superior articular facets.**
- **Transverse process**
- **Transverse foramen**
- **Anterior tubercle**
- **Atlas**
- **The spinal cord runs through each vertebral foramen.**
- **Interior articular facet**
- **Dens (odontoid process)**
- **Superior articular facet**

**Axis**

- **Anterior tubercle of atlas**
- **Dens of axis**
- **Superior articular facet of atlas**
- **Vertebral foramen**
- **Posterior tubercle of atlas**
- **Spinous process of axis**

**Transverse ligament** helps maintain the position of the dens against the interior surface of the anterior atlas.

**The joint capsule** helps maintain the position of the atlantoaxial joint, which allows rotation of the head.
Joints

- Intervertebral joint
- Uncovertebral joints or Von Luschka’s joint
Von Luschka’s joints

- Uncovertebral joints or Von Luschka’s joints control rotation and lateral flexion
- Shock absorption by the curvatures of the spine not the disc
Range of movement (ROM)

- 50% of flexion extension happens in the upper cervical
- 50% of rotation happens in C1-2 level
- Lateral flexion mostly on the middle part of the cervical spine

White & Panjabi Clinical Biomechanics of the Spine 2nd Edition
Cervical disc

- Not the same as lumbar disc
- There are clefts on the side for the uncovertebral joints
- It’s ring called annulus is weak and not as wide at the back
- Therefore prone to posterior herniation

Mercer and Bogduk 1999
Apophyseal joints

- $45^0$ angle with transverse plane
- Their orientation determines movement
- They are surrounded by a strong connective tissue called capsule
- Multifidus muscle pulls the capsule during extension and prevents impingement
Miniscoids

Between the apophyseal joints there are small projections of the capsule infiltrated with fat and blood vessels called the meniscoids. Sometimes they can get trapped and this causes pain and block of movement.

Good news is they can get un-trapped with gentle exercises sometimes (Hint at slide 10).
Arthokinematics in protraction

Protraction
Flexion in the lower cervical and extension in the upper cervical

Retraction
Extension in the lower cervical and flexion in the upper cervical
Compressive load

- Partially shared by the disc-body and the apophyseal joint
- Uncovertebral joints support approximately 20% of the axial load in flexion

Distribution of stresses inside the disc before (blue line) and after (pink line) the removal of uncovertebral joint in flexion
Effect of sustained loading on load distribution

Stefanakis M, Biomechanics of IVD pain. Bristol 2012
Effect of sustained loading on load distribution

150 N

32% 40% 28%

Extension

2 h of 150 N

23% 32% 45%

150 N
Flexor muscles

Superficial muscles: Sternocleidomastoid and submandibular muscles prone to tightness

Deep cervical flexors: longus colli and capitis are prone to inhibition
Extensor muscles (superficial)

Trapezius: also elevates the shoulder, moves the scapula and side flexes the neck

Levator scapula: mainly elevates shoulder

Picture from: Christy Cael, Functional anatomy: musculoskeletal anatomy, kinesiology, and palpation for manual therapists, 2010 Lippincott Williams & Wilkins
Extensor muscles (middle layer)

Splenius capitis: extends, side flexes and rotates the head towards the shoulder

Splenius cervicis: extends, side flexes and rotates the neck to the shoulder

Picture from: Christy Cael, Functional anatomy: musculoskeletal anatomy, kinesiology, and palpation for manual therapists, 2010 Lippincott Williams & Wilkins
Extensor muscles (deep layer)

- **Semispinalis capitis and semispinalis cervicis**: extend, side flex and rotate the neck to the shoulder (weak action)
- Stabilize the individual segments
- Provide proprioceptive input

*Picture from: Christy Cael, Functional anatomy: musculoskeletal anatomy, kinesiology, and palpation for manual therapists, 2010 Lippincott Williams & Wilkins*
Lateral flexors

Scalenes: 3 muscles anterior, posterior and middle scalene

Both anterior scalenes working together can flex the neck and both posterior scalenes working together can extend the neck

Also accessory respiratory muscles normally activated only during deep breathing
Cx and breathing

- Diaphragm the main respiratory muscle is innervated by phrenic nerve (C4 level)
- Pathology of the neck might affect the nerve and therefore breathing
- Alternatively breathing with a lot of scalenes action (accessory muscles) increases cervical loading
Stress and breathing

- During stress breathing becomes shallow and fast
- Diaphragmatic breathing is replaced by thoracic breathing
- Sometimes this becomes habit
- Chronic respiratory dysfunction leads to increased exhalation of CO₂
- This leads to respiratory alkalosis (pH>7.4)
- Alkalosis leads to contraction of vessels and increase affinity of hemoglobin and O₂
- So less blood and O₂ reaches the muscles and less O₂ is released to the muscles
- This leads to muscle fatigue, general fatigue and mental fatigue (clearly important in office workers)
Response to breathing dysfunction

- Increased secretion of $\text{HCO}_3^-$ by the kidneys
- This disturbs calcium- magnesium balance
- This imbalance affects neural and muscular function
- Increase in pain due to Trigger Points

Take home message: breathing affects both loading of the Cx spine and muscular pain
Vertebral artery

- Goes through the cervical spine and supplies blood to the brain
- Pathology of the cervical spine can affect the blood flow to the brain
- Important to send for medical examination of VA involvement is suspected

"Vertebral artery 3D AP" by Frank Gaillard -
Symptoms of vertebral artery

- 5 D
  - Diplopia
  - Dysarthria
  - Dysphagia
  - Drop attacks
  - Dizziness

- 2 N
  - Nystagmus
  - Nausea

- 1 T
  - Tinnitus (“bees in your ear”)
End

Breathe you made it...!
Arthokinematics in flexion

Head slides back and roll forward on top of C1

C2-7: top facet glides anterior and upward on the inferior facet

Apophyseal joints act like rails that guide movement
Arthokinematics in extension

Exactly the opposite of flexion
Arthokinematics in rotation

During right rotation apophyseal joints on the right side do extension and on the left flexion.

Opposite happens during left rotation.
Arthokinematics in lateral flexion

During right lateral flexion apophyseal joints on the right side do extension and on the left flexion

Combined with same side rotation