Cervical Spine: Anatomy, Kinesiology and Pathology

Beth K. Deschenes, PT, MS, OCS

Cervical Spine

Bony Anatomy

Cervical Vertebrae Overview

- Most mobile joints in the spine
- Interconnected with the shoulder and many of our senses
- Upper Cervical O-C2
- Lower Cervical C3-7

Cervical Vertebrae Anatomy

- Body of the vertebrae: transverse diameter > A/P and height
- Transverse foramen for VA and spinal nerves
- Bifid spinous process
- C1 has no spinous process but an articulation for dens of C2

Cervical Vertebrae

Cervical Vertebrae
Cervical Vertebrae

- Facet orientation is 45 degrees

Cervical Vertebrae Specifics

- Uncinate process increases stability by limiting SB and posterior translation
- Form the uncovertebral joints which guide flexion and extension
- Osteophytes appear at ages 20 to 25

Typical Cervical Vertebrae

- C3-C6

Vertebral Body

- Small broad body
- Superior surface-concave transversely
- Uncinate processes posterolateral

Uncinate Process

- Begin development 6-9 yrs of age
- Fully developed by 18
- Articulate with vertebral body above to form the uncovertebral joint
Vertebral Foramen Borders

- Anterior
  - Vertebral body
  - IVD
  - PLL
- Posterior
  - Lamina
  - Ligamentum flavum
- Lateral
  - Pedicle

Mean mid sagittal diameter is 17mm

Spinal cord occupies 60% of this space

Sagittal diameter
- ↑ with flexion
- ↓ with extension

Transverse Process/Transverse Foramen

- Face lateral, anterior and inferior
- Cervical nerve root groove superiorly
- Transverse foramen-vertebral artery

Intervertebral Foramen (Medial Zone)

- Superior border-pedicle
- Inferior border-pedicle
- Anterior border-UVJ
- Posterior border-facet joint
- More narrowed

Intervertebral Foramen (Medial Zone)

- Nerve roots occupy approx ¼ of the medial zone
- Ventral root-smaller/inferior
- Dorsal root-larger/superior

Dural Sheath Covers the Ventral & Dorsal Roots

- Merge to form spinal nerve
- Spinal nerve roots and nerve are numbered according to the vertebrae above which it lies
Spinal Nerve Roots

Cervical Spinal Nerve Roots
- C3 exits the C2-3 IVF
- C4 exits the C3-4 IVF
- C5 exits the C4-5 IVF
- C6 exits the C5-6 IVF
- C7 exits the C6-7 IVF
- C8 exits the C7-T1 IVF

*C5-6 foraminal stenosis will affect the C6 roots
*C6-7 foraminal stenosis will affect the C7 roots

Intervertebral Dynamics
- Decrease foraminal diameter with
  - Extension
  - Ipsilateral rotation
  - Ipsilateral sidebend
- Increase foraminal diameter with
  - Flexion
  - Contralateral rotation
  - Contralateral sidebend

Facet Joint
- Formed by a superior/inferior articulating process
- Inferior articulating process-anterior/inferior
- Superior articulating process-posterior/superior

Facet Joint
- Articular pillar
- Oriented approximately 45° to the horizontal-range 30°-60°
- Lax joint capsules permitting mobility
- Synovial joint lined with hyaline cartilage
- Small synovial fold with varying degrees of projection into the joint

Atypical Cervical Vertebrae
C1, C2, C7
C1
- Bony Ring
  - Anterior Arch-short
    - Small facet posterior for dens articulation
- 2 lateral masses
  - Superior aspect-biconcave

C1
- 2 lateral masses
- Inferior aspect
  - Articulating process
  - Biconvex

C1
- Long transverse process
- May project up to 90mm in males
- Palpable just inferior to mastoid process

C2
- Dens projects superior
  - Articulates with anterior arch of C1 posteriorly

C2
- 2 lateral masses
- Superior aspect
  - Articulating process
  - Biconvex
- Inferior aspect
  - Articulating process
  - Oriented anterior/inferior

C2
- Small/blunt transverse process
- Long/prominent spinous process
- Spinous process- "key palpation landmark"
**C₇**
- All the features of C₃-C₆ (typical vertebrae)
- Long spinous process

---

**Ligaments of the Lower Cervical Spine**

---

**Ligamentum Nuchae**
- Posterior border of the occiput
- Spinous process of C₇
- Counterbalances flexion movement created by head

---

**Ligamentum Flavum**
- Connects lamina of adjacent vertebrae
- First arises between C₂-C₃

---

**Ligamentum Flavum**
- Predominant tissue is yellow elastic tissue
- Permits/controls spinal flexion
- Elastic nature prevents buckling during extension
- Loss of disc height or degenerative changes may allow infolding and contribute to spinal stenosis


**Posterior Longitudinal Ligament**
- Terminates at the level of C2
- Widest in the cervical spine
- Barrier against disc herniation
- Limits spinal flexion

**Tectorial Membrane**
- Continuation of the PLL
- Body of C2
- Posterior over the Dens
- Turns anterior 45°
- Anterior edge of foramen magnum

**Alar Ligament**
- Paired
- Dorsolateral aspect of Dens
- Medial surface of occipital condyles

**Ligaments of the Upper Cervical Spine**
- Limits flexion, extension and vertical translation

**Tectorial Membrane**
- Limits flexion, extension and vertical translation

**Alar Ligament**
- Limit contralateral sidebend and rotation of occiput on axis
Cruciate Ligament

- 3 components
  - Ascending
  - Descending
  - Transverse

- Ascending component
  - Anterior edge of foramen
  - Control inferior displacement of transverse component

- Descending component
  - Body of C2
  - Control superior displacement of transverse component

- Transverse component
  - Extends across posterior aspect of Dens
  - Synovial articulation between ligament/Dens
  - 7-8mm thick
  - Most important stabilizer of the UCS

Transverse Component

- 2 articulations between Dens and arch of C1
- Anterior articulation
  - Anterior articulation of C1/Dens
- Posterior articulation
  - Transverse ligament/Dens

Anatomy of the Intervertebral Disc

- Should not be considered as a smaller version of the lumbar disc
- Adult disc is best described as a fibrocartilaginous core penetrated by a cleft extending from the UVJ’s and surrounded by a discontinuous annulus
- There is no disc between C1-2 and Occ-C1
Annulus Fibrosus
- Development of posterior fissure from the UVJ (adolescence)
- By adulthood fissure extends thru posterior annulus/nucleus
- Formation of ellipsoid joint posterior

Vertebral Endplate
- Layer of cartilage on superior/inferior surfaces of adjacent vertebrae
- Continuous with the annulus

Biomechanics of the Cervicothoracic Spine

Components
- Upper cervical spine
- Lower cervical spine
- Cervicothoracic spine

Upper Cervical Spine
- Occ-superior aspect of C2
- Occ-C1
- C1-C2
Occiput/C₁
- Biconvex occipital condyles
  - Articulating with biconcave surfaces on superior surface of C₁
- Flexion (10°-14°)
- Extension (25°-35°)
- Sidebending (3.9°±1.6°/14°)

Occiput/C₁ Flexion
- Occipital condyles during flexion
  - Anterior roll
  - Posterior glide
- Axis of motion
  - Ear
- May be restricted in chronic forward head

Occiput/C₁ Extension
- Occipital Condyles during extension
  - Posterior roll
  - Anterior glide
- Axis of motion
  - Ear

Occiput/C₁ Sidebend
- Medial inferior and anterior or “MIA”
- Lateral posterior superior or “LPS”
  - MIA and LPS depend on shape of atlantial sockets (variable)
- Axis of motion
  - Nose

Alar ligament tension
- “C₂ kick”
  - C₂ will rotate to same side as occiput/C₁ sidebend
- “C₂ kick” may be palpated by movement of the spinous process and sets the basis for the “Alar ligament test”

C₁-C₂
- Biconvex facet on inferior surface of C₁, articulating with biconvex facet on superior surface of C₂
- Central articulation
  - Anterior arch of C₁
  - Dens
  - Transverse ligament
  - Axis of rotation for C₁-C₂
C1-C2 Rotation
- Allows rotation of head/atlas
- Rotation 43°± 5°
- Flexion/extension 8°-10°

C1-C2 Flexion/Extension
- Flexion
  - Anterior roll/posterior glide
  - Separation between dens/C1
- Extension
  - Posterior roll/anterior glide
  - Arch of C1 abuts against dens

C1-C2 Rotation
- Alar ligament tension
- Contralateral occiput sidebend

Lower Cervical Spine
- C2-3 to C6-7
- Forms a column to support the head
- Primary motions
  - Segmental flexion/extension 10°-20°
  - Most segmental flexion/extension at C4/5 (20°)
  - Segmental rotation/sidebend are coupled. Coupling is ipsilateral

Segmental Flexion
- Anterior rotation
- Anterior translation
- IAP moves up/forward
  - Segmental opening
Segmental Extension

- Posterior rotation
- Posterior translation
- IAP moves down/back
  - Segmental closing

Segmental Sidebend/Rotation Right

- Left translation of superior vertebrae
- UVJ/facet joint (right)
  - UVJ-medial/inferior glide
  - Facet joint-down/back
  - ‘Segmental closing’
- UVJ/facet joint (left)
  - UVJ-superior/lateral glide
  - Facet joint-up/forward
  - ‘Segmental opening’

Hypomobility of Segmental Closing

- Closing pattern
- Limitation of:
  - Extension
  - Ipsilateral sidebend
  - Ipsilateral rotation

Hypomobility of Segmental Opening

- Opening pattern
- Limitation of:
  - Flexion
  - Contralateral sidebend
  - Contralateral rotation

Pathologies of the Cervical Spine

- Degenerative spondylisis: joint or nerve
  - Nerve root irritation
  - Radiculopathy
  - Myelopathy
  - Vertebral artery dysfunction
- Disc Herniation
- Joint Dysfunction
- Fractures
Pathologies of the Cervical Spine

Degenerative Spondylosis

- Age
- Most common at C₄-₅, C₅-₆ or C₆-₇
- 3 structures most vulnerable as a result of this process
  - Cervical nerve roots
  - Spinal cord
  - Vertebral arteries

Degenerative Spondylosis

- Posterior fissuring and thinning of the disc posteriorly
- Increase weightbearing of the UVJ and facet joint with
  - Secondary osteophyte formation
  - UVJ osteophyte and disc bulge form a ‘posterior bar’

Degenerative Spondylosis (Nerve Roots)

- UVJ-posterolateral osteophyte
- Facet joint-anterior osteophyte
- Create a ‘close confinement’ of the roots within the IVF
- Hypoxia and eventual inflammation of the roots (nerve root irritation)

Cervical Nerve Root exiting the IVF

Degenerative Spondylosis (Nerve Roots)

- Signs/Symptoms
  - Neck/UE pain
  - UE pain may be deep aching or sharp and follow a particular dermatome
  - Parasthesias
  - Tends to worsen with movements or postures that narrow the IVF (extension, ipsilateral sidebend and rotation)
  - If conduction loss-radiculopathy
Degenerative Spondylosis (Spinal Cord)

- Myelopathy (Cervical Compression Myelopathy)
- ‘Posterior bar’
  - Disc bulge/marginal osteophytes
  - Project into anterior epidural space
- Degeneration/buckling of the ligamentum flavum
- Cord compression/indentation

Degenerative Spondylosis (Spinal Cord)

- Signs/symptoms
  - Neck pain/paresthesia (unilateral/bilateral)
  - LE paraesthesia (unilateral/bilateral)
  - May worsen with cervical flexion or extension ROM
  - UMN (‘cord’) signs
- Natural history-s/s may be progressive with long periods of stable neurofunction between exacerbations

UMN (‘Cord’) Signs

- Hyperreflexia
- Clonus
- Positive Babinski sign
- Loss of hand and finger dexterity
- Gait disturbances

UMN (‘Cord’) Signs

- Multisegmental sensory disturbance
- Hoffman’s reflex
- Bowel/bladder disturbance

Pathologies of the Cervical Spine

Joint affecting the vertebral artery

Vertebral Artery

- Provide the posterior circulation to the brain and is vital in maintaining brainstem function
- Course of the artery may be divided into 4 parts
Vertebral Artery (Part 1)
- Originates from the subclavian artery
- Passes upward along the anterior aspect of the longus colli

Vertebral Artery (Part 2)
- Enters transverse foramen of C₆
- Variation in entry point
- Ascends thru transverse foramen up to C₁

Vertebral Artery (Part 3)
- In transverse foramen of C₁-bends posterior/medial
- Winds around post arch of atlas

Vertebral Artery (Part 4)
- Projects upward
- Pierces OA membrane
- Enters foramen magnum
- Joins vertebral artery from the other side to form basilar artery

Vertebral Artery ‘Injuries’
- Trauma
  - High velocity flexion-distraction (MVA)
  - High velocity end range rotary manipulation (hypermobile neck)
- Mechanical compression from cervical spondylosis

Degenerative Spondylosis (Vertebral Artery)
- Laterally directed osteophytes from the UVJ
- Change in arterial orientation from straight to more tortuous ‘kinking’
Vertebral Artery Symptoms
- Dizziness
- Diplopia
- Dysarthria
- Dysphagia
- Drop attacks
- Light headedness
- Syncope
- Headache
- Neck pain

Pathologies of the Cervical Spine
- Joint

Cervical Joint Dysfunction
- Osteophytes at uncovertebral joint
- Facet degeneration
- Trapped meniscoid

Cervical Joint Dysfunction
- Joint hypomobility or joint stiffness
- Commonly called degenerative joint disease DJD
- Maybe the result of osteophytes at facet joint

Signs and Symptoms of Joint Dysfunction
- Localized neck pain
- No radicular symptoms
- Restricted ROM with only neck pain
- Joint hypomobility
- Negative neuro exam

Stability vs. Instability
- Stiffness is represented by the stress and strain curve
- Instability is that lack of stiffness
Clinical Instability as Defined by Panjabi

- Inability of the spine under physiological loads to maintain its normal pattern of displacement so there is no neurological damage or irritation, no development of deformity and no incapacitating pain.

Neutral/Elastic Zone (Spinal Segment)

- Neutral Zone
  - Initial portion of ROM; toe region of the stress/strain curve
  - The amount of motion present up to the first onset of resistance
  - Zone of movement around the joints neutral position
- Elastic Zone
  - ROM near end range
  - Motion produced against increasing passive resistance

Stress and Strain Curve Review

Instability

- We clinically measure the size of the neutral zone when performing segmental mobility testing.

Sub-systems that Stabilize the Spine

- Passive: vertebral bodies, facets joints and capsules, spinal ligaments and passive tension from spinal mm and tendons.
  - Stabilizes in elastic zone and limits neutral zone
- Active: mm and tendons that generate forces required to stabilize spine in response to changing loads.
  - Controls motion in and size of neutral zone.
- Neural control: through peripheral nerves and CNS.
  - Determines amount of spinal stability needed and acts on mm to produce required forces.

Instability

- A loss of control or excessive motion within the spinal segments neutral zone which is associated or caused by injury (trauma), degenerative disc disease and muscle weakness.
- At present, no gold standard for diagnosis.
Instability
Subjective Complaints
- Intolerance to prolonged static postures
- Fatigue/inability to hold head up
- Frequent need for manipulation
- Frequent episodes of acute attacks
- Neck may frequently lock
- Sharp pain with sudden movements
- Better in an unloaded position

Instability
Objective Findings
- Disturbance in motor control, strength and coordination
- Guarding, provocation or hesitancy of motion with movement assessment (AROM)
- Finding of hypermobility with segmental mobility testing

Clinical Example: Torticollis
- Acute locking of a cervical segment
- Entrapment of the capsule or meniscoids within the facet joint
- Mechanical catching of arthritic roughened surfaces
- Intradiscal shift-disc torticollis

Clinical Example: Torticollis
- Most common at C2-3
- May resolve spontaneously (~24-48 hours) or may require treatment (manual mobilization)
- Recurrent
  - Typically hypermobile
  - Requires cervical stabilization

Pathologies of the Cervical Spine
Ligamentous injuries

Ossified Posterior Longitudinal Ligament
- Degenerative disorder
- Hypertrophy and bone formation within PLL
- May lead to narrowing of the spinal canal (central stenosis)
Disease processes such as rheumatoid arthritis, ankylosing spondylitis or Down’s Syndrome may affect the synovial articulation between transverse component and Dens.

Weakening of ligament and destabilization.

Signs and Symptoms of Upper Cervical Instability (Red Flags):
- Occipital headache or numbness
- Upper cervical pain
- Signs of myleopathy
- Significant ROM loss in all directions or lacks willingness to move

Pathologies of the Cervical Spine:
- Disc

Disc Herniation:
- Nature of pathology less clear than identified in the lumbar spine
- Different morphological make up in C spine
- ‘Soft disc herniation’
  - Disc herniation in the absence of arthritic changes in the UVJ or facet joint

Disc Herniation:
- Herniation may involve combinations of nuclear, annular, and vertebral end plate material
- May be classified as:
  - Protrusion
  - Extrusion
  - Sequestration
- Capable of compressing the nerve root or spinal cord

Disc Herniation:
- Symptoms
  - May produce pain in a variety of locations:
    - Head
    - Neck
    - Throat
    - Shoulder
    - Anterior chest
    - Scapula
    - Arm-not below elbow
If encroachment on the nerve root or spinal cord:
- Nerve root irritation
- Radiculopathy-root signs
- Myelopathy-cord signs

Signs/symptoms
- Discogenic torticollis-acute stage
- Primary limitation of sagittal plane motion (↑ intradiscal pressure)
- The primary ROM limitation may be flexion and peripheralization of symptoms associated with cervical flexion should be considered disc related until proven otherwise

Pathologies of the Cervical Spine

Bone

History of trauma
- Crepitus
- Severe pain on compression
- Strong multi-directional spasm
- Painful weakness on isometric testing

Cervical Fractures

- Jefferson fracture
- Dens fracture
- Clay Shovelers fracture

Jefferson Fracture

- Fracture of the 1st cervical vertebrae
- MOI-compression
- May involve 1 to 4 parts of the C1 ring
- If lateral mass of C1 overhang-transverse ligament rupture
Jefferson Fracture
- Upper neck pain/stiffness following compressive trauma
- Detected with open mouth x-ray

Dens Fracture
- Fracture of the Dens or odontoid process
- Type 1, Type 2, Type 3

Type 1 Dens Fracture
- Oblique fracture thru upper dens
- Uncommon
- No instability

Type 2 Dens Fracture
- Fracture at junction of dens and body of C2
- Unstable

Type 3 Dens Fracture
- Fracture thru the upper body of C2
- Unstable

Clay Shovelers Fracture
- Fracture of 1 or more spinous process in LCS or upper thoracic spine
- Patients who are deconditioned performing physical labor