Thoracic Spine
Anatomy and Biomechanics Level III

Thoracic Spine - Anatomy and Biomechanics

Level III Upper
Lenerdene Levesque BScPT, MCISc, FCAMPT

Primal Pictures

Thorax

- Vertebromanubrial
- Vertebrosternal
- Vertebrochondral
- Thoracolumbar junction


Thorax - osteology

- Height of body is slightly higher posteriorly than anteriorly – kyphosis
- Vertebral bodies decrease in size from T1-T3

Grays Anatomy

Thorax - osteology

- Paired costal demi-facets superior and inferior (except T1, T10-T12)
- Spinous processes project posterior and inferior to varying degrees – very irregular

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BSc.P.T., MCLsc, FCAMPT
Typical Thoracic Vertebra

- Demifacets for the head of the ribs
- Transverse processes project posteriorly as well as laterally
- Facets for the articular portion of the tubercles of the ribs

Internal structure of thoracic vertebral body:
Within a thin shell of compact bone, vertical trabeculae predominate; these loadbearing beams are stiffened by transverse trabeculae (cross-ties) which resist buckling of the vertical trabeculae under axial load.

Cervico-thoracic junction

- Width of the transverse processes
- Presence of the uncinate processes
- Shape of the spinal canal
- Orientation of the facets – coronal plane
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Thoracolumbar Junction
- Transitional vertebra - usually T11 or T12
- Superior articular facets are orientated in the coronal plane and the inferior in the sagittal plane
- Transverse process is replaced by three tubercles
- Single complete facet on the side of the vertebral body

Thorax – osteology

Ribs

A Typical Rib
- Head
- Neck
- Tubercle
- Shaft

Thorax - osteology

Typical Ribs (3-9)
- Two articular facets on the head of each rib
- Distal to the head is the neck
- Distal to the neck lies two tubercles for the CT joint and the CT ligament

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Vertebrosternal Region

- Ventral aspect of the transverse process contains a deep, concave facet for articulation with the rib
- Orientation of the facet - anterolateral

Sternum

- Eight concave facets which articulate with the costocartilages of ribs 3 to 6

McMinn RMH. Hutchings RT. Color Atlas of Human Anatomy 1985

Lee, D. The Thorax An Integrated Approach 2003

Grays Anatomy
Vertebrochondral Region

Facet on the superior aspect of the transverse process is flat and faces anterolateral and superior.

McMinn RMH, Hutchings RT. Color Atlas of Human Anatomy 1985

Vertebrochondral Region

Anteriorly, the 8th, 9th and 10th ribs articulate indirectly with the sternum via a series of cartilaginous bars which blend with the 7th costal cartilage.


Vertebrochondral Region

Thorax-osteology

Atypical Ribs (1,2)

1st rib
- Small, flat, and most curved of all ribs
- Broad
- Small round head with one single oval articular facet

2nd rib
- Longer, not as flat
- Classified as atypical only because of its attachment to the manubrium

McMinn RMH, Hutchings RT. Color Atlas of Human Anatomy 1985
Thorax-osteology

- Atypical Ribs
  - 10th rib – single costal facet to T10
  - 11/12th ribs – single costal facet and no attachment anteriorly

Thorax - Arthrology

- Interbody Joint
  - Thoracic discs are thinner compared to the lumbar
  - Annulus fibrosis may be thicker in this region
  - Laterally supported by the costovertebral articulation

Thoracic Discs

- Relatively small nucleus with less capacity to swell
- Annular fibres criss-cross forming an angle of 27-30 degrees to the horizontal, posterior fibres are thin and vertical
- May be the presence of horizontal clefts

Contrast lower cervical (L) & upper thoracic discs (R)
Thoracic discs have flat end-plates with no uncus & no uncovertebral clefts
Thorax – arthrology

Facet Joints

- Plane of the facet joints – flat, nearly vertical
- The superior articular processes face backward, slightly superior and lateral as their slope undergoes a gradual change from the cervical spine

Zygapophyseal joint

- Superior articular facets are slightly convex, 60° from the horizontal and 20° from the frontal
- Inferior articular facets are slightly concave, face anteriorly slightly inferiorly and medially

Typical Thoracic Vertebra

- Z joint is gently convex in both the transverse and sagittal planes
- This orientation permits multidirectional movement

Arthrology – zygapophyseal joint
Rib - Joints

Costovertebral joints

Costotransverse joints

Costovertebral Joints

Ribs 2-9 articulate with the vertebral body of their level, IVD and the vertebral body of the level above

Arthrology – Costovertebral Joint

Head of rib

AC

PC

disc

Vertebral body

Joint capsule

Taylor
Thorax - arthrology

**Costovertebral Joint**

- Stabilized by the capsular, radiate and intra-articular ligaments

**Thorax - arthrology**

- Radiate ligament
  - Superior, intermediate and inferior bands attach to the vertebral body above and below and to the IVD

**Thorax - arthrology**

- Intra-articular ligament
  - Only from those ribs articulating with two vertebral bodies
  - Attaches from the crest between the demi-facets and the ribs

**Costotransverse Joint**

- Synovial joint between an oval facet on the transverse process and facet on the tubercle of the rib
Costotransverse Joints

- Upper 6 ribs – articular surfaces are curved
- Lower 6 ribs – flattened or planar

Costotransverse Joints - Ligaments

- Interosseous Ligament
- Lateral Costotransverse Ligament

Blood Supply

- Superiorly supplied via the anterior spinal and paired posterior spinal
- Augmented throughout course via medullary feeders
- Larger Artery of Adamkiewicz (T9)
Blood Supply

Note the supply to the nerve root and feeder supply to the cord.

Neurology of the Thoracic Spine

- **Sinuvertebral nerve** — supplies the dura mater, epidural blood vessels, PLL, and the posterior portion of the ribs.
- **Dorsal rami** — supplies the posterior thoracic muscles, Z joints, and the costotransverse joints.
- **Intercostal nerves** — anterior aspect of the ribs.
- **Innervation of the disc** is not well understood.

Sympathetic Nervous System

- Butler D. Mobilization of the Nervous System 1991
Anatomy – Force Closure

Local System

- Maintain low force continuous activity in all spinal positions and during all directions of motion
- Control of angular and translatoric motion especially in the neutral zone
- Anticipatory action prior to loading

Global System

- Action is direction specific – especially active during rotation
- Generate torque and control motion concentrically, isometrically and eccentrically

Local System

- Multifidus
- Levator Costarum breves
- Rotatores thoracis
- Levator Costarum longus

Global System

- Multifidus
- Levator Costarum breves
- Rotatores thoracis
- Levator Costarum longus
Osteoporosis:

Predominantly affects post-menopausal women and generally affects men about a decade later.

The x-ray shows collapse of the vertebral endplates with marked increase in endplate concavity or loss of vertebral height. The decreased bone density of the internal cancellous bone contrasts with the preservation of the peripheral compact shell.

Adequate exercise, calcium & hormones can prevent it.

Osteoporosis

- Central collapse of the end plates
- Marked central porosity of the vertebral bodies
- Biconcavity of the vertebra – “Fish mouth vertebra"

Osteoporosis – Risk Factors
Canadian Guidelines for Osteoporosis 2002

Major Risk Factors
- Age > 65
- Vertebral compression fracture
- Fragility fracture after age 40
- Family history of osteoporotic fracture
- Systemic glucocorticoid therapy of > 3 months
- Malabsorption syndrome
- Primary hyperparathyroidism
- Propensity to fall
- Osteopenia apparent on x-ray
- Hypogonadism
- Early menopause (before age 45)

Minor Risk Factors
- RA
- Past history of clinical hyperthyroidism
- Chronic anticonvulsant therapy
- Low dietary Ca intake
- Smoker
- Excessive alcohol intake
- Excessive caffeine intake
- Weight < 57 kg
- Weight loss > 10% of weight at age 25
- Chronic heparin therapy

Metastases

Metastatic Tumours

- 60 year old male with a primary carcinoma of the colon
- Total collapse of the body of T9

Malignant melanoma

In the absence of marked bone production or bone destruction, extensive metastatic disease may be present without any obvious radiographic changes.

Lenerdene Levesque
BSc.P.T., MCLsc, FCAMPT
Metastases – Thoracic Spine

Ankylosing Spondylitis

DISH – Diffuse Idiopathic Skeletal Hyperostosis

- Ligamentous ossification without significant disc disease
- Usually is manifest in older males and clinical symptoms are generally mild

DISH

- Cortical hyperostosis
- Intact vertebral end plates
- Normal disc height
- Flowing ossification of the A.L.L.
- Absence of facet or SI joint involvement

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Scheurmann’s Disease

Thoracic injuries:

In flexion or axial compression vertebrae are injured more often than discs
In order of severity
- endplate fracture
- bone bruising
- wedge compression
- burst fracture

In upper thoracic extension, thoracic facet injuries are almost as common as cervical facet injuries

An endplate fracture of T1 with bleeding into adjacent disc

Axial compression with bone bruising from a fall (32M)

T3-9 close-up of T6 bone bruising + endplate #
T1-2 fracture dislocation: severe extension injury (49 male)
upper thoracic injuries often resemble lower cervical injuries

T2-3 facet tip fracture: extension of T2 against shelf of lamina below
T2-3 facet joint injury in T7 partial AC separation: AC fragment & torn capsule

Thoracic Spine Biomechanics

Extension injuries to upper thoracic facet joints in MVAs

Wedge Compression Fractures

T7 fracture 41 male
Degrees of Freedom

1. Flex/Ext: 2-6 per joint (less in upper and greater in the lower thorax)
2. Side flexion: 3-6
3. Rotation: 6-8 per joint (rotation range reduced in lower thorax)

Flexion - osteokinematics

- Vertebral segment
  - Anterior sagittal rotation coupled with anterior translation (.5mm) and slight distraction

Flexion – arthrokinematics (spinal)

- Zygapophyseal joints
  - Inferior facet of the superior vertebrae glides supraanteriorly along the plane of the facets

Flexion – arthrokinematics (costal)

- Vertebrosternal region
  - Costotransverse joint
    - Concave/convex
    - Superior glide of the tubercle of the rib
  - Costovertebral joint
    - Spin with an anterior roll
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Flexion – arthrokinematics (costal)

Vertebrochondral
- Costotransverse joint
  - planar
  - posterosuperomedial glide

Extension - osteokinematics

Vertebral segment
- Posterior sagittal rotation coupled with posterior translation (1mm) and slight distraction

Extension - osteokinematics

Costal Region
- Posterior rotation

Extension - arthrokinematics

Zygapophyseal Joint
- Inferior facets of the superior vertebra glides inferoposteriorly along the plane of the facets

Lee, D. The Thorax An Integrated Approach 2003

Lee, D. The Thorax An Integrated Approach 1994
Extension - arthrokinematics

- Vertebrosternal region
  - Posterior rotation of the rib results in an inferior glide of the tubercle of the rib at the costotransverse joint

Extension - arthrokinematics

- Vertebrochondral region
  - Anterolateral inferior glide of the tubercle of the rib along the plane of the TP

Lateral Bending - osteokinematics

- Theory
  - As the thorax side flexes to the right, the ribs on the right approximate and on the left separate
  - Costal motion stops first and the thoracic vertebra continue to side flex to the right

Lateral Bending - osteokinematics

- Theory
  - In the vertebrosternal region this creates a relative superior glide of the tubercle of the right rib and a relative inferior glide of the left rib
  - The effect of this motion is to rotate the vertebral body contralaterally
Lateral Bending - osteokinematics

- In the vertebrochondral region the pattern of movement coupling is either ipsilateral or contralateral dependent on the movement pattern.

Lateral Bending - arthrokinematics

- Zygopophyseal joint
  - The left inferior articular facet of the superior vertebra glides superomedially and the right inferolaterally.
- Costotransverse joint
  - Left tubercle glides inferior
  - Right tubercle glides superior

Thoracic Rotation

Rotation - osteokinematics

- Clinically observe rotation / side flexion occur to the same side
- Experimentally the side bending was inconsistent
- Rotation was coupled with contralateral translation
Rotation - osteokinematics

Theory
- Right rotation of the superior vertebra pushes the superior aspect of the head of the left rib forward at the costovertebral joint inducing anterior rotation of the left rib and posterior rotation of the right.


Rotation - osteokinematics

Theory
- The coupled contralateral translation tightens the ligaments of the costotransverse joint.
- Further right rotation of the superior vertebra occurs as the superior vertebra tilts to the right along the costotransverse joint.


Rotation - arthrokinematics

- Zygapophyseal
  - Ipsilateral - inferior glide
  - Contra - superior glide
- Costotransverse
  - Ipsilateral - inferior glide
  - Contra - superior glide
- Costovertebral
  - Ipsilateral - posterior roll
  - Contra - anterior roll


Vertebrosternal Right Rotation

- T5
- T6
- 6h

References:

Panjabi MM. Brand RA. White AA. Mechanical Properties of the human thoracic spine. JBJS 1976;58A:642

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