Vertebral Column Injury (SPECIFIC INJURIES)

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Flexion

1. Compression (wedge) fracture
2. Flexion teardrop fracture
3. Clay shoveler's fracture
4. Anterior Subluxation
5. Transverse ligament disruption, Anterior atlantoaxial dislocation ± odontoid fracture
6. Atlantoaxial dislocation

Flexion-Distraction

1. Distractive flexion fracture, s. Chance ("seat belt") fracture
2. Bilateral facet dislocation

Flexion with Lateral component

1. Odontoid fracture with lateral displacement
2. Fracture of transverse process
3. Lateral flexion fracture

Flexion-Rotation

1. Unilateral facet dislocation
2. "Sickle" fracture-dislocation, s. torsional injury
3. Rotatory atlantoaxial dislocation
   - failure of posterior and odontoid columns with varying degrees of anterior column insult – due to combination of:
     1) rotation (→ disruption of posterior ligaments and articular facet)
     2) lateral flexion
     3) a posterior-anteriory directed force.
   - uncommon in thoracic region due to limited range of rotation (at thoracic facet joints).

Fractures According to Mechanism

1. Mechanical Stability
2. Occipital-Condylary Fractures
3. Atlantoaxial Disassociation
4. Posterior arch fracture (C1)
5. C1 burst fracture (Jefferson fracture)
6. Lateral mass fracture (C1)
7. Rotatory atlantoaxial dislocation (s. atlantoaxial rotatory fixation)
8. Grisel's syndrome
9. Osteotomy (Denis) fractures
10. Type 1
11. Type 2
12. Type 2 with transverse ligament disruption
13. Type 3
14. Type 3A
15. Onodi's fracture
16. Hangman's fracture (s. traumatic spondylolisthesis of C2)
17. Fractures of Axis Body
18. Combined C1-C2 fractures
19. Biochemicals
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21. Classification
22. Lateral mass fracture (C1 spinous process injury)
23. Fracture of transverse process
24. Clay shoveler's fracture
25. Atlantoaxial sprain, hyperextension injury
26. Thoracolumbar spine
27. Thoracolumbar fracture
28. Lateral flexion fracture
29. Fracture of transverse process
30. Pathologic fractures

VCT – vertebral column trauma
SCI – spinal cord injury.

N.B. MRI can directly image ligamentum damages' (best sequences: STIR > T2) – normal ligaments are dark, linear structures (on both T1 and T2), when acutely injured, they are outlined by bright edema or blood, making torn ends quite conspicuous.

The primary management of spine injuries consists of realignment (when necessary), decompression of the neural elements when indicated), and stabilization.

- if the spine is in good alignment and no decompression is necessary, external immobilization may be all that is required to protect the neural elements while healing occurs:
  • primary ligamentous instability is much less likely to resolve after immobilization – early surgical stabilization.
  - this is particularly true when the major cause of the instability is bony injury,
**Extension**

1. Posterior neural arch fracture
2. Hangman’s fracture (s. traumatic spondylolysis of C2)
3. Extension teardrop fracture
4. Distractive extension injury
5. Posterior atlantoaxial dislocation ± odontoid fracture
6. Whiplash injury (s. cervical sprain, hyperextension injury)
   - most common in neck
   - most stable as long as vertebral column is flexed.
   - if ligamentum flavum buckles into spinal cord → central cord syndrome.
   - prevertebral (retropharyngeal) swelling may be the only sign (hyperextension injuries may reduce spontaneously or when spine is placed in neutral position by paramedical personnel).

**Vertical (axial) compression**

1. Burst fracture of vertebral body
2. C1 fracture, incl. Jefferson fracture
3. Lateral mass fracture (C1)
4. Isolated fractures of articular pillar and vertebral body
   - force is applied from either above (skull) or below (pelvis).
   - fractures occur in cervical and thoracolumbar junction regions – they are capable of straightening at time of impact.

**Shearing** (by horizontal force)

1. Translational fracture-dislocation
2. Lamina fracture

**MECHANICAL STABILITY**

Cervical spine injuries in order of instability (most to least unstable):

1. Rupture of transverse ligament of atlas
2. Odontoid fracture
3. Flexion teardrop fracture (burst fracture with posterior ligamentous disruption)
4. Bilateral facet dislocation
5. Burst fracture without posterior ligamentous disruption
6. Hyperextension fracture-dislocation
7. Hangman fracture
8. Extension teardrop (stable in flexion)
9. Jefferson fracture (burst fracture of ring of C1)
10. Bilateral facet dislocation
11. Anterior subluxation
12. Simple wedge compression fracture without posterior disruption
13. Fracture of posterior arch of C1
14. Spinous process fracture (clay shoveler fracture)
15. Unilateral facet dislocation
16. Simple wedge compression fracture with posterior disruption
17. Anterior subluxation
18. Hyperextension fracture-dislocation

**CERVICAL SPINE (C1-2)**

Upper neck anatomy is specific - fractures are different from other parts of vertebral column! (> 85% cervical fractures occur below C3, except in infants and young children)

**Rule of thirds** - dens, spinal cord, and empty space each occupy approximately 1/3 of spinal canal at arch of atlas.

**OCCIPITAL CONDYLAR FRACTURES**

See p. TrH5 >>

**ATLANTOOCCLIPITAL DISASSOCIATION**

(unsable)

- may be complete (dislocation) or incomplete (subluxation)
- occurs predominantly in children, pediatric occipital condyles are small and almost horizontal & lack inherent stability.
- usually but not invariably fatal due to respiratory arrest caused by injury to lower brain stem (complete disruption of all ligamentous relationships between occiput and atlas → brainstem stretching).
- caused by severe hyperextension with distraction: non traumatic causes - Down's syndrome, RA.
- along w/ joint capsules, tectorial membrane is torn.
- 48% patient have cranial nerve deficits at presentation; 20% are normal at presentation.
VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)

(detection is difficult in cases of partial disruption or if reduction occurs after initial subluxation; plain X-ray has only 50% sensitivity)

A. Condyle-C1 interval (CC1) determined on CT has 100% sensitivity and 100% specificity in pediatric patients (Class I evidence); distance between occiput & atlas > 5 mm at any point in joint

NB: atlanto-occipital condyle distance should be < 5 mm regardless of age

Lateral radiograph of pedestrian struck by car who sustained fatal atlanto-occipital dislocation. Note marked widening of space between base of skull and atlas.

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NB: atlanto-occipital condyle distance should be < 5 mm regardless of age

B. CNX/AANS recommended method (proposed by Harris et al, 1994) - most sensitive and reproducible radiographic parameter: on lateral X-ray - increased distance between clivus & dens – basion-axial-interval-basion dental interval (BAI-BDI):

C. Disruption of basilar line of Wackenheim (anterior / posterior subluxation);

Wackenheim's line - drawn down posterior surface of clivus and its inferior extension should barely touch posterior aspect of odontoid tip;
VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)

- this relationship does not change in flexion and extension
- if this line runs behind odontoid, posterior subluxation has occurred and vice versa;

D. Powers ratio > 1 (anterior subluxation)

\[
\text{Powers ratio} = \frac{BC}{OA}
\]

BC - distance from basion to midvertical portion of posterior laminar line of atlas;
OA - distance from opisthion to midvertical portion of posterior surface of anterior ring of atlas.

E. Prevertebral soft tissue swelling (70% patients)

TREATMENT

- avoid flexion of C-spine (can occur on standard adult trauma boards!) - ensure that mattress allows child's head to remain in anatomic position; head is immobilized w/ sandbags.
- cervical traction is absolutely contraindicated (→ stretching of brainstem and vertebral arteries!!! → 10% patients experience neurological deterioration).
- definitive treatment - occiput to C2 fusion.
  - rigid immobilization in halo allows adjustment to obtain reduction, & maintains position during and after operation.
**ATLAS FRACTURES**

**Landell type 1** (stable) – isolated fracture of anterior arch OR posterior arch. see below >>

**Landell type 2** – burst fracture of C1 (Jefferson fracture), see below >>
  a) transverse ligament intact (stable)
  b) transverse ligament disrupted (unstable)

**Landell type 3** (stable) – fracture through lateral mass of C1, see below >>

- rarely associated with neurological sequelae

Spinal Canal - Steele’s rule: 1/3 cord, 1/3 dense, 1/3 empty

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**GENERAL TREATMENT**

No Class I or Class II medical evidence!

*Intact transverse ligament:* collar or halo [for Jefferson] for 8-12 weeks

*Disrupted transverse atlantal ligament:*
  a) halo for 10-12 weeks
  b) C1-2 fusion

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**POSTERIOR NEURAL ARCH FRACTURE (C1)**

(potentially unstable – because of location – but otherwise stable because anterior arch and transverse ligament remain intact)

- forced neck extension → compression of posterior neural arch of C1 between occiput and heavy spinous process of axis.

Vertebral artery injury:

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**RADIOLOGY**

**LATERO-AP VIEWS**

- fracture line through posterior neural arch

**LATERAL VIEW**

- lateral masses of C1 and articular pillars of C2 fail to reveal any lateral displacement
  - differentiating from Jefferson fracture.
VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)

**Treatment**

Collar (after differentiation from Jefferson fracture).

**C 1 BURST FRACTURE (JEFFERSON FRACTURE)**

Classic Jefferson fracture (C 1 burst fracture) – burst fracture of C 1 ring in 4 places**±** disruption of transverse ligament.
- Vertical compression force* (transmitted through occipital condyles to superior articular surfaces of lateral masses of atlas) drives lateral masses laterally.
- Extremely unstable if transverse ligament is disrupted.
  - E.g. in diving accidents
  - Or at least in two sites - one anterior and one behind lateral masses.
  - Usually spinal cord is not damaged - canal of atlas is normally large (fracture fragments spread outward to further increase canal dimensions).
  - Fractures in other parts of cervical spine are found in 50% patients!!!

**Radiology**

X-ray - difficult to recognize if fragments are minimally displaced; H: CT

Lateral view:
1) Widening of atlantodental interval see below
2) Prevertebral hemorrhage & retropharyngeal swelling

Odontoide view: margins of lateral masses of (C 1C 1) lie lateral to margins of articular pillars of (C 2C 2) – Spence's rule. see below

CT is best diagnosis.

Diagnosis of transverse atlantal ligament rupture – 3 criteria:
1) MRI - most sensitive test (more sensitive than rule of Spence)
2) Spence's rule: ≥ 7 mm (sum of bilateral distances between dens and lateral mass) displacement of lateral masses in coronal CT view (or > 8 mm on plain XR open-mouth view to consider effects of radiographic magnification)
3) Widening of atlantodental interval (ADI, s. predental space) in sagittal CT view (or lateral XR view): > 3 mm in adults (> 2.5 mm in females), > 4.5 mm in children.

N.B. if > 12 mm - rupture of all ligaments about dens.
Some experts say > 5 mm in adults.
TREATMENT
A. **No transverse ligament injury** → long-term (10-12 weeks):
   a) C-collar
   b) halo (with mild cervical traction);
B. **Transverse ligament damage**:
   a) halo (12 weeks) - discomfort of prolonged immobilization + poor healing/union rate
   b) fusion (fixation between occiput and laminae of axis: outer table of occiput is removed and bony struts are affixed to remaining occipital bone and decorticated C2 laminae; bony struts are supported by wires or metallic plates) → halo.

LATERAL MASS FRACTURE (C1)
A. Normal lateral cervical spine.
B. Axial CT - slightly displaced lateral mass fracture:
   a) Comminuted fracture – collar, halo
   b) Transverse process fractures – collar

ROTORARY ATLANTOAXIAL DISLOCATION (S. ATLANTO-AXIAL ROTATORY FIXATION)
(unsable - because of location - despite fact that facets may be locked)
- specific type of unilateral facet dislocation at C1-C2 level (rotational injury usually without flexion).

ETIOLOGY
1) trauma
2) Grisel syndrome – see below
3) abnormal ligament laxity, e.g. Down syndrome, connective tissue diseases, osteogenesis imperfecta, neurofibromatosis type 1

RADIOLOGY
(odontoid view) - asymmetry between odontoid process and lateral masses of C1, unilaterally magnified lateral mass (wink sign).
N.B. considerable care during interpretation of odontoid views - if skull is shown obliquely (asymmetrical basilar skull structures, esp. jugular foramina), there is false-positive asymmetry between odontoid process and lateral masses of C1. H: three-position CT with C1-C2 motion analysis.
> 5 mm of anterior displacement of arch of C-1 indicates disruption of both facet capsules as well as transverse ligament (Fielding type III)

**TREATMENT**

- subluxation is reduced in:
  - a) halter traction (if < 4 weeks duration)
  - b) tong/halo traction (if > 4 weeks duration)

- specific forms of immobilization are recommended to ensure ligamentous healing:
  - Fielding Type I (transverse ligament intact and bilateral facet capsular injury) - soft collar
  - Fielding Type II (transverse ligament + unilateral facet capsular injury) - Philadelphia collar or SOMI brace
  - Fielding Type III (transverse ligament + bilateral facet capsular injury) - halo

- following 6-8 weeks of immobilization, stability is assessed by flexion-extension XR; recurrence or residual instability → posterior atlantoaxial (C1-2) arthrodesis.

**GRISEL’s syndrome**

- unilateral or bilateral subluxation of atlanto-axial joint from inflammatory ligamentous laxity
- etiology - inflammatory process in head and neck (e.g. upper respiratory tract infections, retropharyngeal abscess, tonsillitis / adenoiditis, otitis media)
- causative organisms: Staphylococcus aureus, Group B streptococcus, oral flora.
- rare cause of torticollis
- usually occurs in infants / young children
- neurological complications (occur in 15% of cases) range from radiculopathy to death from medullary compression.
- treatment - manual reduction under sedation and collar; if recurs - traction brace; residual subluxation after 8 weeks of treatment or neurological symptoms may require operative treatment (posterior atlantoaxial arthrodesis).

**ODONTOID (DENS) FRACTURES**

- ≈ 10% of cervical spine fractures.
- all odontoid fractures are often effectively managed with external cervical immobilization, with understanding that failure of external immobilization is significantly higher for type 2 - type 2 has lowest rate of union (healing).
- management of odontoid fractures in elderly patients is associated with increased failure rates, and higher rates of morbidity and mortality irrespective of treatment offered.
- all odontoid fractures are effectively managed with external cervical immobilization, with understanding that failure of external immobilization is significantly higher for type 2 - type 2 has lowest rate of union (healing).
- union is verified with CT (historical alternative – dynamic XR).

**Type I** – oblique fractures through upper portion of dens.

**Type II** – fractures across dens base near junction with axis body.

- **Type IIA** (Hadley, 1988) – comminuted dens base fracture with free fracture fragments

- **Type III** – dens fractures that extend into axis body.

**Treatment**

- MRI
- Comminuted
- Failed
- Simple fx
- Ant vs post-fus
- Postfusion
- Posterior Fusion
- TL disrupted
- Braces/ halo
- TL intact
- Collar
- Surgery
- No AOD
- AOD
- ??

AOD – atlanto-occipital dislocation

TL – transverse ligament

- union is verified with CT (historical alternative – dynamic XR).
Indications for surgical fusion:

1. Type 2 fracture in patient > 50 yrs
2. Type 2 or 3 fracture with dens displacement > 5 mm post attempted reduction (or inability to maintain alignment* with external immobilization); some experts say even > 2 mm
3. Den's comminution (type 2A fracture)
4. Transverse ligament disruption
5. Atlanto-occipital dislocation

**TYPE 1**

(stable) - fracture across tip of dens

- treated with cervical collar (successful in 100% cases).
- may be associated with life-threatening atlanto-occipital dislocation (1 fusion).

**TYPE 2**

(most unstable type!) - fracture at base of dens - most common type;

- odontoid process develops embryologically as body of atlas; during development, body becomes separated from ring of atlas and fuses to body of axis - cartilaginous material at site of fusion is present until maturity is reached - separation at base of odontoid may occur with relatively slight injury to head during childhood (resulting bony segment is os odontoideum).

Embryologically - fracture line corresponds to fetal intervertebral disc!

Treatment

- unfavorable healing potential:
  1. considerably less trabecular bone at base of the odontoid
  2. the distracting forces from the apical ligament
  3. dens is surrounded by synovial cavities, resulting in diminished periosteal blood supply
- patients rarely seen initially with significant neurological deficits, but risk of posterior displacement - managed with halo vest for 3-6 months → flexion-extension XR to confirm stability; inability to maintain dens displacement < 5 mm is indication for surgery.
- limited vascular supply, small area of cancellous bone - high prevalence of nonunion (43-47% for collar, 16-35% for halo) and ischemic necrosis of odontoid; risk groups - elderly patient*, delay of treatment, failed reduction or secondary loss of reduction; H: operative fixation
- *NB: consider surgical fusion for type II odontoid fractures in patients > 50 yrs (age > 50 yrs increases nonunion risk 21-fold when treated in halo!); reported union rates in elderly patients treated with halo vary between 20% and 100% in literature; plus, elderly mortality rates as high as 20-40% with use of halo have been reported)

A. **C1-2 fusion** via posterior approach see technical details at p. Op210 »
   a) C1 and C2 screws (no longer popular alternative - transarticular C1-2 screws); if C2 posterior elements are fractured → add C3 (same with C1 – add occipit).
   b) quick alternative - wiring between C1, lamina and C2 spinous process + iliac; grafts; methylmethacrylate (between decorticated spinous processes); (historical - fixation with Halifax clamps – poor results)

B. **odontoid screw** via interlateral approach (preserves rotation motion!); high fusion rates (87-100%) if performed during first 6 weeks after fracture – odontoid screw works best if placed early see technical details at p. Op210 »
   *fusion rates in elderly may be as low as 60% (same as with halo) - age is important factor but not all studies agree with that (plus, fibrous union with radiographic stability may be a suitable outcome in elderly patients)


**TYPE 2A**

H: Horizontal fracture pattern and < 1 mm of displacement → extraarticular immobilization

**TYPE 2B**

Oblique fracture extending from the anterospinous to the posteriorinferior portion of the dens → anterior screw fixation

**TYPE 2C**

Oblique fracture beginning anteroinferiorly and extending posteroinferiorly and associated with significant anterior comminution → posterior C1-2 fusion

**TYPE 2 WITH TRANSVERSE LIGAMENT DISRUPTION**

(unstable because of transverse ligament disruption)
Vertebral Column Injury (Specific Injuries)

a) transverse oralar ligament ruptures are uncommon unless there are predisposing factors (rheumatoid arthritis, posterior pharyngitis, ankylosing spondylitis, etc).
b) transverse ligament rupture (with intact odontoid) can cause immediate death from respiratory failure (cord compression between odontoid and posterior arch of C1).

Radiology:

i. predental (ADI) space [see above] >> ii. disrupted posterior cervical line
iii. retropharyngeal swelling.

T2-MRI - traumatic transverse ligament injury (arrow):

Flexion and extension dynamic CT - craniocervical junction instability (atlanto-dens interval > 3 mm) caused by traumatic transverse ligament injury (arrow):

Treatment

- traction (with neck in extension) → C1-C2 fusion (as for type 2 odontoid fracture); odontoid screw is contraindicated in transverse ligament disruptions!

Fixation with posteriorly placed plate held in place with sublaminar and occipital wires:

- on occasion, reduction is impossible and odontoid must be removed by drilling (through transoral or anterolateral approach) → fusion.

TYPE 3

- fracture extending into body of C2.

- treatment:
a) collar (fails in 35-50% cases).
b) halo vest (fails in 1-16% cases)

TYPE 3A

- horizontal osseous fracture through body of C2 extending into C1-2 facet joints:
associated with circumferential (atlantoaxial ligament, TM, intercapsular and capsular joints) ligament avulsion - highly unstable!!!

- described by Jea et al.

OS ODONTOIDEOME

**Definition** - ossicle with smooth circumferential cortical margins representing odontoid process that has no osseous continuity with body of C2.

**Etiology** - remains debated in the literature with evidence for both acquired and congenital causes.

**Clinical features**: 1) occipital-cervical pain 2) myelopathy - transient (commonly after trauma), static, or progressive. 3) vertebrobasilar ischemia - sudden spinal cord injury in association with os odontoideum after minor trauma have been reported.

**Evaluation** - flexion-extension lateral XR. Most often, there is anterior instability, with os odontoideum translating forward in relation to body of C2. At times, one will see either no discernible instability or "posterior instability" with os odontoideum moving posteriorly into spinal canal during neck extension. Degree of C1-C2 instability on XR does not correlate with presence of myelopathy; sagittal diameter of spinal canal at C1-C2 level < 13 mm does correlate with myelopathy detected on clinical examination.

**Classification** - 2 anatomic types: Orthotopic - ossicle that moves with anterior arch of C1. Dystopic - ossicle that is functionally fused to basion; dystopic os odontoideum may sublux anterior to arch.

**Management** - indications for surgery: 1) neurological symptoms → C1-C2 fusion 2) irreducible DORSAL cervicomedullary compression → occipital-cervical fusion ± C1 laminectomy 3) associated occipital-atlantal instability → occipital-cervical fusion ± C1 lamunection vs. irreducible VENTRAL cervicomedullary compression → ventral decompression.

N.B. Odontoid screw fixation has no role!

**HANGMAN’S fracture** (S. TRAUMATIC SPONDYLOLYSIS of C2)

(unsable - but cord damage is rare because AP diameter of neural canal is greatest at C2 level and because bilateral pedicular fractures permit spinal canal to decompress itself with forward displacement of C2 body)

- abrupt deceleration (e.g. hanging with knot in submental position, striking chin on steering wheel in head-on automobile crash) → cervicomedullary (skull, atlas, and axis functioning as unit) is thrown into extreme hyperextension → bilateral pedicle fractures of axis (± broken subjacent disc bond → forward subluxation of C2 on C3).

- cervical spine / spinal cord damage happens in only those hangings that involve fall from distance greater than body height.

Potential dislocation:

1) fracture lines extending through pedicles of C2 (i.e. anterior to inferior articular facets).
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2) disrupted posterior cervical line (base of C2 spinous process lies > 2 mm behind posterior cervical line).
3) prevertebral swelling (may cause respiratory obstruction!).

CLASSIFICATION AND TREATMENT

Effendi classification:

Type I (stable): isolated hairline (< 1 mm) fracture of axis ring with minimal displacement of C2 body associated with axial loading and hyperextension → 6 weeks C-collar.

Type II (unstable): fractures of axis ring with displacement (> 1 mm) of anterior fragment with disruption of disk space below axis associated with hyperextension and rebound flexion → 12 weeks of halo → if instability on dynamic XR then add C2-3 fusion.

Type III (unstable): fractures of axis ring with displacement of axis body in flexed forward position (angulation), in conjunction with C2-3 facet dislocation associated with primary flexion and rebound extension → open reduction and C2-3 fusion → halo for 12 weeks.

Francis classification - grades of increasing severity of displacement and angulation of C2 on C3:
Grade I: fractures with 0-3.5 mm displacement and/or C2-C3 angulation < 11°
Grade II: fractures with displacement > 3.5 mm and angulation > 11°
Grade III: fractures with displacement > 3.5 mm but less than half of C3 vertebral width and angulation > 11°
Grade IV: fractures with displacement > 3.5 mm but less than half of C3 vertebral width with angulation > 11°
Grade V: fractures with complete C2-3 disk disruption.

Levine and Edwards classification (modification of Effendi classification with added flexion-distraction as a mechanism of injury (type IIA)):
type 1 (stable) - hyperextension and axial loading → C2/3 disc remains intact (stable) - no change in anatomy: insignificant displacement (< 3 mm horizontal displacement) or angulation.

Treatment: rigid cervical collar / occipital-mandibular brace for 4-12 weeks.

type 2 - initial hyperextension and axial loading followed by hyperflexion → C2/3 disc and PLL are disrupted with vertical fracture line (unstable): significant horizontal translation (> 3 mm) and angulation (> 11°).

Treatment:
- < 5 mm displacement → reduction with traction + halo for 6-12 weeks.
- > 5 mm displacement → consider surgery or prolonged traction.

Usually heal despite displacement (autofuse C2 on C3).

type 2A - results from flexion-distraction → horizontal fracture line: no translation but severe angulation (> 11°).

Treatment: reduction with hyperextension + halo immobilization for 6-12 weeks. Avoid traction! (type 2A fractures experience increased displacement in traction but are reduced with gentle extension and compression in halo vest)

Resume - indications for surgery (anterior or posterior C2-3 fusion):
- severe angulation (Francis grade II and IV, Effendi type II)
- severe (> 5 mm) translation
- C2-3 disc disruption (C2 translation > 3 mm over C3) (Francis grade V, Effendi type III)
- facet dislocations
- failure of external immobilization - inability to achieve or maintain fracture alignment.

FRACTURES OF AXIS BODY

Comminuted fracture – evaluate for vertebral artery injury.

Fractures of the ring of the axis are typically associated with low rates of neurological injury as displacement of most fracture patterns results in spinal canal expansion;
- fractures involving the posterior cortex of C2, when accompanied by translation, can result in canal compression causing neurological dysfunction:
**TREATMENT**
- **external immobilization**
  - indications for surgery:
    1) Severe ligamentous disruption
    2) inability to achieve or maintain fracture alignment with external immobilization.

**COMBINED C1-C2 FRACTURES**
- increased incidence of neurological deficit compared with either isolated C1 or isolated C2 fractures.
- management decisions must be based on characteristics of axis fracture.
- historically, as proposed by Levine and Edwards, combination fractures of C1 and C2 have been managed sequentially, allowing 1 fracture to heal (usually atlas) before attempting definitive management of axis injury.
- rigid external immobilization is typically recommended as initial management for majority of patients
- modern approach:
  - atlas fractures in combination with type II or III odontoid fractures with atlantoaxial interval > 5 mm → early surgical management
  - atlas fractures in combination with Hangman fracture with C2-C3 angulation > 11° → surgical stabilization and fusion
- surgical options:
  - posterior C1-2 internal fixation and fusion
  - combined anterior odontoid and C1-2 transarticular screw fixation with fusion.

**CERVICAL SPINE (SUBAXIAL)**

**BIOMECHANICS**

Lateral cervical spine - anatomical location of main discoligamentous structures contributing to physiological stability of a single motion segment:

**CLASSIFICATIONS**

SLIC (Subaxial Injury Classification) and CSISS (Cervical Spine Injury Severity Score) classifications are recommended (Level I)

**SLIC (SUBAXIAL INJURY CLASSIFICATION)**

by Vaccaro and Colleagues


**MORPHOLOGY**

No abnormality 0
Compression 1
Burst 4+1 = 2
Distraction (facet perch, hyperextension) 3
Rotation/translation (facet dislocation, unstable teardrop or advanced stage flexion compression injury) 4

**INCOLIGAMENTOUS COMPLEX (DLC)**
**Vertebral Column Injury (Specific Injuries)**

**INTRODUCTION**

- **Historical**
  - Intact 0
  - Root injury 1
  - Complete cord injury 2
  - Continuous cord compression in setting of neurological deficit (NeuroModifier) +1 = 1

**Neurological Status**

- Intact 0
- Root injury 1
- Complete cord injury 2
- Continuous cord compression in setting of neurological deficit (NeuroModifier) +1 = 1

**Signs of major disruption of anterior or posterior ligamentouscomplex:**

1. Horizontal sagittal plane translation > 3.5 mm (or > 20% of AP diameter of involved vertebrae)
2. Sagittal plane rotation (angulation) > 11 degrees

**CT evidence of facet joint disruption:**

- Articular apposition < 50%
- Diastasis > 2 mm through facet joint

**SLIC scores:**

1. 1-3 = non-surgical management
2. ≥ 5 = surgical fixation.
3. 4 = either non-operative or operative approach.

**TREATMENT PRINCIPLES**

- **Decompression / Restoration** of spinal canal is the goal.
- **Internal fixation** or **external immobilization** is recommended (to allow for early mobilization and rehabilitation): failure rates
  - Internal fixation - 9%
  - External immobilization only (traction or orthosis) - 30% risk factors: vertebral compression ≥ 40%, kyphosis ≥ 15%, vertebral subluxation ≥ 20%
- **Efect anterior or posterior** fixation and fusion is acceptable in patients not requiring particular surgical approach for decompression of spinal cord; complication rates:
  - Anterior fusion - 9%
  - Posterior fusion - 37%
- **Advantages**:
  - Anterior approach - safe and straightforward patient positioning (no need to turn patient prone with potential of unstable injury), dissection along defined tissue planes with little if any iatrogenic muscle injury.
  - Posterior approach - superior biomechanics, straightforward reduction of facet dislocations.
- **Prolonged bed rest in traction** is recommended if more contemporary treatment options are not available.

**COMPRESSION (WEDGE) FRACTURE**

(mechanically stable - intact posterior column)

- During flexion, longitudinal pull is exerted on strong posterior ligaments (tolerate longitudinal pull very well - usually remain intact) → most of force is expended on vertebral body anteriorly → simple wedge fracture.
- Fragment of posterior vertebral body may be displaced into spinal canal.

**RADIOLOGY**

1. Anterior border of vertebral body - decreased height (> 3 mm than posterior border) and increased concavity
2. Increased density of vertebral body resulting from bony impaction
3. Slight separation of spinous processes (exaggerated in flexion films)
4. Prevertebral soft-tissue swelling

**Treatment**

a) wedge fractures (not associated with neurologic impairment / additional radiographic abnormalities) can be managed on outpatient basis with orthosis (soft or hard cervical collar).

b) bone / disk impingement on spinal canal → decompression via anterior approach (corpectomy).

- Flexion compression fracture of C5 fixed by corpectomy and fusion maintained with Caspar plate.

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**Compression fracture**: Compression of anterior element and failure of middle element (displacement of superior posterior lip of vertebral body into spinal canal)

**Reconstructed sagittal CT**: Compression of anterior element and failure of middle element (displacement of superior posterior lip of vertebral body into spinal canal).
BURST FRACTURE OF VERTEBRAL BODY
see THORACOLUMBAR > >

TEARDROP FRACTURE
Teardrop fracture is marker of potential for high instability (may be stable or highly unstable)

Two trauma mechanisms:
A. **Flexion** (+ vertical compression) force fractures (burst**s**) vertebral body - wedge-shaped fragment (resembles teardrop) of anterosuperior portion of vertebral body is displaced anteriorly (indicates anterior longitudinal ligament disruption); at same time posterior ligamentous disruption happens (= posterior column fracture – rest of vertebral body may be posteriorly displaced) - disruption of all 3 columns → frequent neurologic damage.

B. Forced abrupt **extension** (e.g. diving accidents) → dense anterior longitudinal ligament pulls anterosuperior corner of vertebral body away from remainder of vertebra → classic innocent-appearing triangular-shaped fracture (true avulsion); no subluxation!!! (vs. flexion teardrop fracture) but anterior ligament may be disrupted (stable in flexion; highly unstable in extension)
- often occurs in lower cervical vertebrae (C5-C7).

Diagnostic work up - flexion-extension XR to document stability

Management
a) no ligamentous damage – cervical collar for 3-4 months
b) ligamentous damage – surgical fusion

DISTRACTIVE EXTENSION INJURY
- rarely demonstrates significant damage by X-ray.

ANTERIOR SUBLUXATION
(able in extension but potentially unstable in flexion)
- posterior ligamentous rupture without bony fracture
• Injury begins posteriorly in nuchal ligament and proceeds anterior to involve other ligaments to varying extent.
• Anterior longitudinal ligament (anterior column) remains intact - rare neurologic sequelae.

N.B. significant displacement can occur with flexion → very rare cases of neurologic deficit!

**Radiology**

- In order of evaluation:
  1. Lateral radiograph (neck in neutral position) - subtle findings (often missed if flexion / extension views are not obtained):
     - Widening of interspinous space
     - Gaping of intervertebral space posteriorly.
  2. Oblique views - widening or abnormal alignment of facets.
  3. Lateral radiograph (flexion / extension views) - risk of causing neurologic injury?!! - perform only if above views cannot confirm subluxation - disrupted anterior and posterior contour lines.
  4. MRI can visualize ligaments

![Radiology Diagram](image)

A. Lateral cervical X-ray - prevertebral soft tissue swelling and slight C2 subluxation over C3 (arrow).
B. Sagittal T2 MRI demonstrates ligamentous disruption (double arrows) with blood tracking along both ligaments and prevertebral soft tissues (arrowheads).
C. Lateral cervical X-ray - prevertebral soft tissue swelling and slight C2 subluxation over C3 (arrow).
D. C4-C5 fracture subluxation (MRI) - 50% anterolisthesis of C4 on C5; fracture of posterior C4 vertebral body; interruption of normally black anterior longitudinal ligament at C4-C5 disc space; bright signal in spinal cord is combination of edema and hemorrhage.
**Facet Subluxation / Perch / Dislocation**

**Unilateral**
- Rotation about one of facet joints (acts as fulcrum) + simultaneous flexion → contralateral facet joint dislocates with superior facet riding forward and over tip of inferior facet and coming to rest within intervertebral foramen (mechanically locked in place - stable injury even though posterior ligament complex is disrupted).
- Neurologic deficits are rare.

**Bilateral**
- Extreme form of anterior subluxation: flexion (± axial distraction) causes soft-tissue disruption to continue anteriorly to involve annulus fibrosis and anterior longitudinal ligament; forward movement of spine causes inferior articulating facets to pass upward and over superior facets of lower vertebra (anterior displacement of spine above level of injury).
- High incidence of spinal cord injury!!!

**Radiology**

**Unilateral**
- Plain films
  - AP view: disrupted line bisecting spinous processes, asymmetry of uncovertebral joints.
  - Lateral view:
    1. Dislocated superior articulating facet forms "bow tie" deformity with nondislocated superior articulating facet.
    2. Upper vertebral body is anteriorly subluxed (< ½ of AP diameter of vertebral body; vs. bilateral facet dislocation).
  - Oblique view:
    1. Superior articulating facet projects within neural foramen.
    2. Expected tiling of laminae is disrupted.
    3. Widening of apophyseal joint (may be strongest differentiation from torticollis!).

- CT → "empty facet" sign.
**VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)**

**BILATERAL**

**LATERAL VIEW** - vertebral body subluxed anteriorly with displacement greater than ½ of AP diameter of lower vertebral body; lower vertebral body may be compressed. AP view - widening of intervertebral disc space at joint of Luschka.

**TREATMENT**

- keep in C-collar until reduction attempts.
- reduction is safest in cooperative examinable patient - therefore is best with skeletal traction.
- reduction under anesthesia is less safe (at least use monitoring).

**CLOSED REDUCTION WITH SKELETAL TRACTION**

- prior to attempted reduction ensure that diagnosis is correct; *pure cervical distraction injuries* (at first glance can resemble facet dislocation) - should not be managed traction since this would be expected to only worsen the injury.
- alert and cooperative patient → immediate reduction w/o MRI; N.B. some experts recommend MRI before traction or operative intervention is attempted - significant number of bilateral facet dislocations are accompanied by *disk herniation* - catastrophic compression of spinal cord may occur if injured disk retropulses during cervical traction! (monitor reposition clinically).

N.B. prior to traction / operative manipulation on obtunded patient, ensure (e.g. with MRI) that no concomitant disc rupture has occurred (present in 30-50% patients with fracture dislocation). If yes → perform discectomy first! (otherwise, increased neurological deficits can result during manipulations).

Methods of traction

a) **TONGS** (Gardner-Weills tongs, Crutchfield tongs) – 2 screws into outer table of skull. see p. TrS5

b) **HALO fixation** – 4-6 screws; very rigid external immobilization; may be used for *cervical traction* in recumbent position or attached to body jacket lined with sheepskin (patient may be ambulatory in halo cast or vest). see p. TrS5

c) sterilized **FISH HOOKS** applied to posterior zygomas - for patients with severe skull injuries.

Traction Force (needed amount is variable) - weight is added incrementally, X-rays being made after each addition.

- begin with: 10 lbs is added for occiput; additional 5 lbs for each vertebra to level of injury (but begin with < 20 lbs)
- re-evaluation: after placement of weight, check lateral X-ray & full neuro exam; if reduction does not occur, weight is then added in 5 lb increments, in approximate half hour intervals, being certain to repeat lateral X-ray and neuro exam after each weight increase.
max amount of traction weight that can be applied safely is unknown (up to one third of body weight may be required; reports include up to 60–75 lbs). up to 20 lbs can be applied to C1 & C2, up to 50 lbs can be applied in lower cervical region (C3-C7)

- weights aid in spinal realignment:

  - Rule of thumb: 5 pounds (2.25 kg) for each cervical level is required for reduction (e.g. to reduce C3 dislocation – start with 25 pounds; if insufficient, additional weight increments are applied every 20–30 minutes until reduction is attained).
  - weight is increased by 5-pound increments.
  - in routine clinical practice (especially for injuries such as bilateral facet dislocations) weights in excess of 50 pounds may be necessary to achieve reduction.
  - maximal weight that can be safely applied to Gardner-Wells tongs is 80-90 pounds (36–40 kg) or 2/3 of body weight.
  - head of bed elevated enough to counter weight of traction.
  - traction is best accomplished in rotating bed* (to minimize risks of decubitus and to help mobilize respiratory secretions). *e.g. RotoRest

During traction

- when traction is applied, patient is continually monitored (radiographically and clinically) for reduction success - overdistraction may cause cranial nerve deficits or neurological worsening.
- muscle relaxants (e.g. scheduled HAZARDOUS) - reduce spasm, which may inhibit reduction efforts.

If reduction is achieved → traction weight is reduced to 20 lbs (9.1 kg) or less to maintain alignment (redistillation is prevented with moderate cervical extension)

- some experts would apply halo, others would go to ACDF (esp. with bilateral facet dislocation – all ligaments and disc are disrupted – will not heal without arthrodesis). If reduction does not occur: closed reduction attempts are discontinued when:
  a) > 1 cm of distraction occurs at site of injury
  b) maximum amount of weight is applied
  c) neurological status deteriorates
  d) unsuccessful reduction by 3-6 hrs after trauma with neurological deficit present

- proceed to MRI → open reduction in OR
- if reduction is not achieved, bony or soft tissue interposition should be suspected.

OPEN REDUCTION

Pain free to reduce manually; after patient is under general anesthesia and complete paralysis (remove C-collar and apply Holter traction* in preparation for ACDF):

- may have halo crown ready in OR in case will need more manipulation
- under live fluoroscopy: apply axial traction and gentle neck flexion (lever action allows superior facetto reduce dislocation and open foramen)
- proceed to surgery (ACDF).

Surgical open reduction options:

a) posterior approach is gold standard for straightforward open reduction of facet dislocations
b) ACDF to reduce dislocation and open foramen (going from posterior cannot place pedicle screws because of fracture; would need screws level above and level below); some experts think it is equally acceptable alternative to posterior approach.

**FACET FRACTURE**

a) unilateral – may cause subluxation up to 25%
b) bilateral – may cause subluxation up to 50%

**TREATMENT**

- if not subluxation or nerve root dysfunction → C-collar with XR in collar and then follow up in 2 weeks – if subluxation or nerve root dysfunction (that happens quite often) → one-level ACDF

Cervical subaxial nondisplaced unilateral facet fractures


Facet fractures were classified:

- type A1 fractures: superior facet fracture of caudal vertebra
- type A2: inferior facet fracture of rostral vertebra
- type A3: floating lateral mass (fracture of pedicle and vertical laminar fracture).
- all patients were given a trial of hard cervical collar.
- mean follow up was 2.7 ± 1.4 mo.
- outcome: nonoperative management was successful in 82.9% patients (others developed instability requiring surgery); no significant association was found between the type of facet fracture and outcome (Fisher's exact test, P = 0.18).

**LAMINA FRACTURE**

- evidence of nerve root dysfunction → surgical decompression.

**FRACTURE OF TRANSVERSE PROCESS**

(stable)

F: if above C7, need CTA to check for VA injury
CLAY SHOVELER’S FRACTURE

(mechanically stable)

- oblique fracture of spinous process base
- in one of lower cervical vertebrae.

G. commonly occurred in clay miners (Australia during 1930s) - when miner lifted heavy shovelful of clay, abrupt flexion of his head, in opposition to stabilizing force of strong supraspinous ligament, resulted in spinous process avulsion.

H. modern etiology
- a. direct trauma to spinous process.
- b. forced neck flexion (e.g. sudden deceleration in motor vehicle crashes, direct trauma to occiput).

RADIONUCLEOTIC CLASSIFICATION

CLASSIFICATION

1. Cervical sprain - acute traumatic injury to ligaments, without objective findings.
2. Cervical strain - acute traumatic injury to muscles, ligaments, or both.

TREATMENT

- as for cervical sprain - soft orthosis for comfort (2-3 months).

WHIPLASH INJURY (S. CERVICAL SPRAIN, HYPEREXTENSION INJURY)

• cervical myofascial injury
  - mechanism: different sequences and combinations of flexion, extension, and lateral motion.
  - Most common mechanism: hyperextension followed by flexion (motor vehicle is hit from behind by another vehicle, i.e. rear-end collisions).
  - cause 85% whiplash injuries
  - = 1 million cases per year in USA.
  - women* > men.
  - narrower neck with less muscle mass supporting head
  - N.B. cases with fractures, disk herniations, head injuries are excluded; hyperextension may cause central cord syndrome due to spinal cord damage.

Clinically:
1. Persistent neck pain without objective findings.
   - onset within 24 hours (in 93% cases).
   - can persist for months (in minority of patients – for years).
   - risk factors for more severe symptoms - unprepared car occupant, rotated or inclined head position at moment of impact.
   - psychosocial factors, negative affectivity, and personality traits are not predictive of symptom duration.
   - despite common belief that pending litigation is responsible for persistent symptoms, most patients are not cured by verdict.

2. Possible concomitant symptoms:
   - 80% patients complain of headaches (muscle contraction type ± greater occipital neuralgia, third occipital neuralgia*). i.e. pain referred from C2,3 facet joint innervated by 3rd occipital nerve
   - neck stiffness in one or more directions of motion.
   - localized areas of muscle tenderness (trigger points) in posterior musculature may develop.
   - dizziness is common complaint (dysfunction of vestibular system / cervical proprioceptive system / brain stem / cervical sympathetic nerves).
   - paresthesias of upper extremities.
   - cognitive impairment is controversial topic (attention deficits present in 18% patients 2 years after injury).
   - intercostal pain (20%), low back pain (35%).
   - rare sequelae: cervical dystonia or torticollis.

Diagnosis - cervical spine MRI (if abnormalities are present, possibility that they are pre-existent should be considered!)

Differential – psychological problems, malingering.

TREATMENT

- instruct patient that complete resolution of symptoms may require 6-12 weeks!
  - 1) ice → heat
  - 2) NSAIDS, muscle relaxants.
  - 3) try to avoid soft cervical collars (esp. after first 2-3 weeks) → gentle stretching & early mobilization, range-of-motion exercises, physical therapy, trigger point injections, TENS
  - if pain persists > 12 weeks, patient has cervical disc degenerative disease.

THORACOLUMBAR SPINE

CLASSIFICATION

Classification system should

1) enhance communication among clinicians with varying degrees of experience
2) reliably guide treatment
3) predict the outcome of various treatment options

Historical Denis classification (3-column concept) provided level III evidence and became a popular scheme in North America. However, the system does not clearly identify injuries, which may or may not require operative intervention.

- clinicians thought that if ≥2 columns were involved then the patient needed surgical intervention. However, McAfee quickly determined, there were burst fractures which were stable and could be treated nonoperatively.

CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)

VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES) T559 (21)
Inaccurate evidence to recommend a universal classification system or severity score that will readily guide treatment of all injury types and thereby affect outcomes.

Grade B Recommendation - a classification that uses readily available clinical data (e.g. CT with or without MRI) should be used to improve characterization of injuries and communication among treating physicians:

1. Thoracolumbar Injury Classification and Severity Scale (TLICS) - cannot be yet be adapted to predict management in all populations (there is still wide variation in treatment recommendations) >>

2. AO Spine Thoracolumbar Spine Injury Classification System >>

AO Spine Thoracolumbar Spine Injury Classification System (AO Arbeitsgemeinschaft für Osteosynthesefragen, 1994)
- it is derivative of Magert's Comprehensive Classification: type A-axial compression, type B-distraction of anterior and/or posterior elements, and type C-axial torque leading to anterior or posterior element disruption with axial compression.
  - many observers believe that identification beyond the three basic types (A, B, or C) is confusing, and the AO system does not specifically include the degree of neurological injury.
  - inclusive of all injury patterns observed at the thoracolumbar junction, it did not help guide treatment.

Type A injuries - compression injuries with injury of the anterior elements and preservation of the posterior ligamentous complex: A0 fractures represent transverse or spinous process fractures; A1 are wedge-compression fractures of 1 endplate without involvement of the posterior wall of the vertebral body; A2 are split or pincer fractures with involvement of both endplates; A3 are incomplete burst fractures which involve the posterior wall of the vertebral body but only 1 endplate, and A4 fractures are complete bursts, which involve both endplates and the posterior wall.

Type B injuries - failure of the posterior or anterior tension band in distraction: B1 injuries are transverse monosegmental failure of the posterior tension band; B2 are bony and/or ligamentous failure of the posterior tension band in conjunction with an A fracture of the vertebral body; B3 injuries are hypotension injuries through the disc space or bone as commonly seen in ankylosing spondylitis. There is some confusion because the first iteration of this new AO Classification System included these injuries under type C. However, for the purposes of this guideline, the authors will include them as type B as this is the classification which has been investigated for internal and external reliability.

Type C injuries suffer disruption of all elements with displacement or dislocation of the cranial spinal elements relative to the caudal elements. There are no subtypes any longer for this injury pattern.

In addition to the morphological classification, there is also a neurological grading component (N0 = intact, N1 = transient symptoms, N2 = radiculopathy, N3 = incomplete or cauda injury, and N4 = complete) and case-specific modifiers.

<table>
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<tr>
<th>Types</th>
<th>Groups</th>
<th>Subgroups</th>
<th>Specifications</th>
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<td>B3.3.1, B3.3.2, B3.3.3</td>
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</tbody>
</table>

Injuries with ≤ 3 points = non-operative
Injuries with 4 points = nonop vs op
Injuries with ≥ 5 points = surgery

AO Spine Thoracolumbar Spine Injury Classification System

Types Groups Subgroups Specifications

A1.1
A1.2, A1.2.1, A1.2.2, A1.2.3
A2.1
A2.2, A2.3
A3.1
A3.1, A3.1.1, A3.1.2, A3.1.3
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A3.3, A3.3.1, A3.3.2, A3.3.3
B1.1
B1.1.1, B1.1.2, B1.1.3
B2.1
B3.1
B3.1.1, B3.1.2, B3.1.3
B3.2
B3.2.1, B3.2.2, B3.2.3
B3.3, B3.3.1, B3.3.2, B3.3.3

C1
C1.1, C1.2, C1.2.1, C1.2.2, C1.2.3, C1.2.4
C1.3, C1.3.1, C1.3.2, C1.3.3
C2
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C3
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C3.3, C3.3.1, C3.3.2, C3.3.3

AO Spine Thoracolumbar Spine Injury Classification System

AO Arbeitsgemeinschaft für Osteosynthesefragen, 1994)
**VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)**

**RADIOLoGICAL EVALUATION**

* CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)  
Grade B Recommendation: MRI has been shown to influence the management of up to 24% of patients - providers may use MRI to assess posterior ligamentous complex integrity, when determining the need for surgery.  
Insufficient evidence that radiographic findings can be used as predictors of clinical outcomes.

**COMPRESSION (WEDGE) FRACTURE**

**etiopathophysiology**

- results from compression-anterior flexion mechanism (middle column remains intact and acts as hinge) → **anterior wedge fractures** (most common type of thoracolumbar fractures!)  
  N.B. traumatic compression fracture in young patient - suspect possible flexion-distraction (Chance) fracture!  
- often as **pathologic fractures** (esp. elderly white women). see **pathologic fractures >>

**clinical features**

- **Radiology**
  - anterior column failure (stable) - wedging of anterior component of vertebral bodies (loss of anterior vertebral body height is < 50%), soft tissue swelling, anterior superior cortical impaction, buckling of anterior cortex of vertebral body, trabecular compaction, endplate fractures, disk-space narrowing.
  
  - anterior column failure & posterior column ligamentous failure (possibility of being unstable) - anterior wedging (loss of vertebral body height > 50%*) + increased interspinous distance. see **flexion-distraction fracture >>**
  
  - > 50% loss of vertebral body height in wedge fracture → CT to rule out middle column and burst fractures (up to 25% fractures diagnosed initially as wedge fractures are actually burst fractures).

- failure of all 3 columns (unstable!!) - anterior wedging + varying degrees of posterior vertebral body disruption. see **flexion-distraction fracture >>, burst fracture >>**

- 8 - 14% are asymmetric – caused by compression-lateral flexion (stable **lateral wedge fractures**).

- Denis classification system:
  - type A - involvement of both endplates  
  - type B - involvement of superior endplate  
  - type C - involvement of inferior endplate  
  - type D - buckling of anterior cortex with both endplates intact.

- compression fractures can be devastating for 2 reasons:
  1) bony pain (from fracture itself) sometimes does not resolve.
  2) fracture can alter mechanics of posture → increase in kyphosis (sometimes to point that patient cannot stand upright → hip flexor contractures [due to iliopsoas shortening], secondary pain in hips, sacroiliac joints, spinal joints).

**treatment**

Best MANAGED IN HOSPITAL:

1) patients have marked discomfort, often requiring parenteral narcotics.
2) associated intra-thoracic & abdominal injuries should be considered.
3) often associated with prolonged ileus (secondary to hemorrhage of sympathetic ganglia), requiring continuous nasogastric suction.

- for malignant causes – emergent radiotherapy, steroids.
- for infectious causes – antibiotics.

Analgesia (avoid NSAIDs) and muscle relaxants
N.B. bony and neuropathic pains are treated differently
- if pain is not improved with bracing over 2-12 weeks → kyphoplasty or vertebroplasty.

Bracing
- for 8-12 weeks to prevent progressive angulation:
  a) custom made TLSO (body cast)
  b) “off-the-shelf” adjustable TLSO
  c) no bracing

- extension brace is best – prevents kyphosing.
- young people heal very well but many refuse brace (H: percutaneous stabilization).
- bracing is more prone to high stress areas (e.g. thoracolumbar junction) – follow up with new X-ray in 2 weeks (the older the fracture, the more difficult it is to reduce once kyphosis happened)
- bracing is more prone to fail in obese patients.

Early rehabilitation - become ambulatory as soon as comfortable (increased incidence of thromboembolic events)
- restrictions for 8 weeks: forward bending, hip flexion < 90°, lifting / carrying ≤ 5 kg
- first 4 weeks simply walking → isometric spine stabilization exercises for 4 weeks → isotonic exercises.

Radiographic monitoring
- some fractures can worsen over ensuing months - might require surgical stabilization.

Serial radiographs for 1 year - progressive kyphosis can occur!

INDICATIONS FOR SURGICAL STABILIZATION
- inability to wear external brace or external brace failure
- kyphosis > 30° - indicates instability
- major anterior column comminution with height loss > 50% - indicates instability
- N.B. vertebral body comminution is risk factor per se that bracing will fail as bone fragments will keep “floating”
- significant posterior element disruption - indicates instability
- neurological deficits - add decompression to list

- percutaneous screws (“internal brace”) may suffice if no need to decompress and enough fractured bone contact to heal (esp. young people) – see p. Op220
- postoperative TLSO bracing (10-12 weeks).

Vertebroplasty - high-pressure injection of cement polymer into fractured vertebral body → better vertebral body resistance to upright loads → decreased pain.
- anesthesia - local or general.
- fluoroscopy guidance
- percutaneous trocar or large needle is introduced into fractured body through pedicle, and cement is injected

- complications:
  1) spread to neural structures
  2) adjacent-level vertebral body fractures (risk increased > 4 times).

N.B. according to study by Kallmes and colleagues, vertebroplasty for compression fractures is not associated with improvements in pain or function vs placebo!

Kyphoplasty - similar to vertebroplasty, except balloon is used to expand volume of fractured segment → cement polymer is delivered under low-pressure* into closed balloon (less likely extrusion of cement into spinal canal!)
- much lower complication rate
- canal compromise contraindicates kyphoplasty (and sometimes vertebroplasty).
- ideal for cancer pain (pathologic fractures due to metastasis)**, indicator - STR signal on MRI.

EVOLVE Trial
Prospective and Multicenter Evaluation of Outcomes for Quality of Life and Activities of Daily Living for Balloon Kyphoplasty in the Treatment of Vertebral Comminution Fractures. The EVOLVE Trial. Douglas P Beall, MD M M Chamberlain, MDSam Thomas, NJ, Douglas A Jacob, MD Douglas A Jacob, MD Richard W Easton, MDDouglas A Jacob, MD Richard W Easton, MDDouglas A Jacob, MD Richard W Easton, MDDouglas A Jacob, MD Richard W Easton, MDDouglas A Jacob, MD Richard W Easton, MD

- study demonstrates that kyphoplasty is a safe, effective, and durable procedure for treating patients with painful VCF due to osteoporosis or cancer.

- Percutaneous vertebroplasty (PVP) and kyphoplasty (PKP) have widely gained acceptance as a line of treatment in symptomatic osteoporotic vertebral fractures and osteolytic primary or secondary lesions in the spinal column.

- The introduction of vertebroplasty by Galibert et al. in 1984 and kyphoplasty by Garfin et al. in 1997 offered two similar, fast, and minimally invasive treatment modalities for these conditions. Vertebroplasty consists of injecting polymethylmethacrylate (PMMA) into the vertebral body through a transpedicular or transpedicular approach bilaterally or unilaterally. Through bone biopsy needles, which allow better maneuverability within the pedicle to the middle third of the vertebral body, the procedure is done under image intensification. Ideally, two percutaneous C-arms, or as recommended by some, CT guidance is used. PMMA is injected carefully and under continuous radiographic monitoring in 0.5 mL bolus to enable immediate interruption of the procedure when there are radiographic signs of cement extrusion as PMMA flows into a blood vessel or toward the posterior cortical margin.

- Likewise, kyphoplasty is done with the same radiographic setup. An inflatable balloon is introduced through a compatible pedicular needle through a transpedicular or transpedicular approach. The balloon is then mechanically inflated by a piston and filled with radiopaque liquid. It is then deflated and removed and the resulting void with compressed peripheral bone in the vertebral body is subsequently filled with PMMA. In contrast to vertebroplasty, kyphoplasty allows for direct correction of sagittal plane deformity and, to a much lesser degree, of the coronal plane deformity.

- Kyphoplasty Systems

- Based on an expandable polymer device, the Sky Bone Expander System (Disc-O-Tech Medical Technologies Ltd, Herzliyya, Israel) represents one such kyphoplasty system. The KIV A VCF treatment system (Bonevose Medical Inc., Santa Clara, CA, USA) consists of a sprayed coil implant
made of PEEK-OPTIMA, that is introduced in a transpedicular manner over a shaped memory nitinol arrow, or the OPTIMA, that is introduced in a transpedicular manner over a shaped memory nitinol guidewire. Its shape is maintained by PEEK, a polycarbonate thermoplastic with osteoconductive property, as its matrix.

Vertebral Column Injury (specific injuries)

Bone Fillers

PKP has been found superior to conservative management and at least equal to PVP regarding pain reduction and improvement of the visual analog score at follow-up. The long-term follow-up showed no further substantial improvement of the visual analog score at follow-up. This was also confirmed by Dong et al. emphasizing that there was no statistical relation between vertebral body height restoration and obturation and pain relief.

Barium sulfate is found in a concentration of 10% by weight in arthroplasty PMMA; however, this is not the case in fluoroscopic and angiographic applications, where it is used to reduce X-ray absorption. Barium sulfate is often associated with the formation of a hard mass (PKP) or by interdigitation in the bony trabeculae (PVP), thus preventing extravasation.

Biocompatibility, and reasonable price are clear advantages. Disadvantages include its absent osteoconductive property, calcium phosphate cement can be made osteoinductive by the increase of growth factors like bone morphogenetic protein-2 (BMP-2) and platelet-derived growth factor (PDGF), and basic fibroblast growth factor (bFGF). This is based on the macroporous scaffold-like structure of calcium phosphate and the ability to control its pH quite accurately. Buccopharyngeal and sublingual filling mechanical properties of bone cement in conjunction with ceramics are attractive candidates to replace PMMA in future cement augmentation procedures. Cortts (Orthovita, Malvern, PA) consists of a terpolymer resin reinforced with 95% cross-linked calcium phosphate, and was approved by the FDA in 2003, being true thixotropic cements, whose suspensions dewater when they are packed or injected, reducing their handling characteristics. Calcium phosphate cement can be made osteoinductive by the increase of growth factors like bone morphogenetic protein-2 (BMP-2) and platelet-derived growth factor (PDGF), and basic fibroblast growth factor (bFGF). This is based on the macroporous scaffold-like structure of calcium phosphate and the ability to control its pH quite accurately. Buccopharyngeal and sublingual filling mechanical properties of bone cement in conjunction with ceramics are attractive candidates to replace PMMA in future cement augmentation procedures. Cortts (Orthovita, Malvern, PA) consists of a terpolymer resin reinforced with 95% cross-linked calcium phosphate, and was approved by the FDA in 2003, being true thixotropic cements, whose suspensions dewater when they are packed or injected, reducing their handling characteristics.

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authors do not recommend cement augmentation. Nonetheless, Camels et al. treated 53 vertebrae with pure osteoblastic and 50 vertebrae with mixed blastic and lytic lesions with vertebroplasty. They reported a good to excellent analgesic effect in 92% at 6 mo and that the occurrence of complications was not related to the nature of the lesion. Nevertheless, a filling failure occurred in five vertebrae, all being osteoblastic. A new interesting approach is the incorporation of 13.7% holmium and 8.9% samarium phosphates by weight with calcium phosphate bioceramics, thus marking the advent of radiovertebroplasty. After neutron activation, the Ho–166 and Sm–153 bioactive powder emitted 14.5 and 32.5 MBq/mg, respectively. However, its in vivo applicability and efficiency have yet to be proven.

BURST FRACTURE OF VERTEBRAL BODY

- vertebral body end plate(s) fracture → nucleus pulposus is forced into vertebral body → body is shattered outward from within (burst fracture).
  - Failure of the anterior and middle columns by axial loading → circumferential expansion of entire involved vertebra.
  - Fracture of the posterior vertebral body wall leads to retropulsion.
  - Retropulsed bone splinters and disc material may impinge on ventral surface of spinal cord (with dural laceration) → anterior cord syndrome → immediate decompressive surgery (via anterior approach)!
  - Attempted weight bearing without surgical fixation → severe neurologic injury can be expected.

McAfee classified burst fractures:

STABLE burst fractures - posterior column is intact,

UNSTABLE burst fractures - posterior column has sustained significant insult (dural tears are frequent - portions of cauda equina can herniate through dural defect - if not repaired → scarring and chronic pain).

RADIOLOGY

LATERAL view - comminuted vertebral body, loss of vertebral height (> 50%), retropulsion of bone fragments (canal narrowing > 30%), kyphotic angulation (> 20%).

AP view - characteristic vertical fracture of vertebral body (helps differentiate from simple wedge fracture and flexion teardrop fracture); widened interpedicular distance (indicates instability).

Always perform CT / MRI to document amount of bone retropulsion.

Burst fracture of T12 - anterior deformation, comminution, retropulsion of bone fragments into spinal canal:

TREATMENT

- TL burst fractures in neurologically intact patients are considered to be inherently stable, and responsive to nonsurgical management.
- Burst fractures with significant vertebral collapse, angulation, canal compromise, or associated neurologic deficit are considered to be unstable and necessitate surgical intervention.

Stable / neurologically intact: see also conservative treatment under compression fractures >>

A. Bed rest on firm mattress (6-12 weeks) – in third world countries

B. TLSO brace (custom made molded polypropylene body jacket or “off-the-shelf” adjustable brace)
  - Required to be worn at all times except when lying flat in bed
  - Years ago, burst fractures were traditionally operated on; now most clinicians no longer offer surgery to the majority of their patients.

Kirkham Wood, MD (Chief of Orthopedic Spine Service at Massachusetts General Hospital and Associate Professor of Orthopedic Surgery at Harvard Medical School) - surgical vs. nonsurgical treatment for neurologically intact and stable burst fractures of the thoracolumbar junction:

- Years ago, burst fractures were traditionally operated on; now most clinicians no longer offer surgery to the majority of their patients.
Both Nonburst fractures

- Conflicting evidence

- Burst fractures in neurologically intact patient
  
  N.B. include at least 2 levels above and 2 levels below a fracture; short segment fusions (one of AO principles!)

- Surgical intervention (1 above, 1 below) should not be attempted until adequate ventral decompression is complete.

CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)

GRADE B Recommendation - external bracing in the nonoperative treatment of neurologically intact patients with TL burst fractures:

- Level 1-2 evidence (Bailey et al. 2014, Shami et al. 2014) - studies did not include burst fractures of the upper and midthoracic and lower lumbar spine) - nonoperative management with or without an external brace produces equivalent improvement in outcomes (radiological and clinical [pain and disability]) - decision to use an external brace is at the discretion of the treating physician.

- Bracing is not associated with increased adverse events compared to no bracing.

- No brace leads to shorter duration of stay.

Unstable, canal impingement: see indications for surgery under compression fractures >> surgery via anterior or posterior approach.

- Decompression** + stabilization with restoration of normal vertebral body height (long-term stabilization is provided by interbody arthrodesis using bone graft).

  *posterior approach (laminectomy) increases instability and is ineffective to relieve anterior impingement

  **Decompression is not always needed; should not be attempted until adequate external stabilization (halo-vest) or posterior stabilization has been performed.

- full laminectomy

- if at the coronal level, remove pedicle, drill the cavity behind the fragment, and push the fragmented fragment back into cavity — ligamentotomy.

- for fragment tamping back into place, may do discectomy above the fracture to create room for it.

- may use US to check if ventral decompression is complete.

Stabilization:

a) traditional open approach — fusion with pedicle screws

b) percutaneous approach — stabilization with pedicle screws (it is not fusion!!!, hardware needs to come out later)

N.B. do not use polyaxial screws for trauma (one of AO principles!)

N.B. include at least 2 levels above and 2 levels below fracture, short segment fusions (1 above, 1 below) are rarely acceptable!

CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)

- Burst fractures in neurologically intact patient

Conflicting evidence to recommend for or against the use of surgical intervention to improve clinical outcomes - discretion of the treating provider.

- main emphasis — integrity of posterior ligamentous complex (PLC)

- Nonsuch fractures

  - Insufficient evidence to recommend for or against the use of surgical intervention - discretion of the treating physician.

DISTRACTIVE FLEXION FRACTURE, S. CHANCE ("SEAT BELT") FRACTURE

- Failure of anterior and posterior columns (injury to ligamentous components, bony components, or both) with varying degrees of anterior column collapse

- often due to lap belts in motor vehicle accidents - individual is subjected to sudden deceleration and torso is flexed forward over restraining belt.

SUBTYPES (dependent on axis of flexion):

CLASSIC CHANCE FRACTURE

1) horizontal fracture through posterior and middle columns (bony elements) (spinal processes, pedicles, transverse processes)

2) disruption of supraspinous ligament (increase in interpeduncular distance)
VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)


*all 3 columns are involved

- diagnosis of posterior element failure requires CT.
- if *pars interarticularis* is disrupted (in either type of fracture), then instability is increased → significant subluxation → neurologic sequelae.

18 year-old female with lap belt caused fracture dislocation at L4-5 with spinal cord transection:

**LATERAL FLEXION FRACTURE**

Lateral flexion injury at L1-2 junction - acute scoliosis in frontal view; compression of anterior elements with posterior displacement of middle element in lateral view; fracture of lateral part of vertebrae body and pedicle in CT.

**“SLICE” FRACTURE-DISLOCATION, S. TORSIONAL INJURY**

(unsual) - occurs in lumbar region (articular processes are large, curved, and nearly vertical – unilateral facet dislocation cannot occur) - one or both articular processes fracture → upper vertebra swings anteriorly on lower:
**VERTEBRAL COLUMN INJURY (SPECIFIC INJURIES)**

**Fracture of superior articular facet**

- **FACET FRACTURE-DISLOCATION**
  - direct blow → displacing vertebra off adjacent one with fracture and dislocation of articular processes and rupture of ligaments & disk.
  - failure of all three columns - grossly unstable (although stability may be maintained by rib cage).
  - frequent severe injury to neural elements.
  - imaging represents recolled position of some greater displacement at time of injury.
  - **Treatment** - reduction and fusion
    - N.B. percutaneous internal stabilization is contraindicated as ligamentous complex and disc are disrupted!
    - open reduction of locked facets – bilateral Smith-Peterson osteotomies to remove medial facets (reduction happens spontaneously) → posterolateral fusion.
    - may place ropivacaine infusion pump for postop pain management.

**Fracture of pars interarticularis (spondyloysis)**

- see p. Spinal7

**Fracture of transverse process**

- **stable**
  - associated with severe injury to paravertebral muscles (e.g. psoas with retroperitoneal hemorrhage)
  - correlation exists between L1 transverse process fracture and same-side renal injury.

**Pathologic fractures**

- caused by trivial injury predisposed by disorders with considerable loss of bone substance
  1. *Osteoporosis* (vertebral fracture increases risk of death 9 times!)
     - 50% of all osteoporotic fractures are vertebral (L3 are lumbar, T3 are thoracolumbar, and L3 are thoracic).
  2. Chronic steroid use
  3. Vertebral malignancies (metastases, multiple myeloma)
  4. Vertebral osteomyelitis (incl. tuberculous).
  5. Hyperparathyroidism
  6. Prolonged immobilization
  - most often - thoracolumbar compression (wedge) fractures. see above
    - N.B. compression fracture → seek for treatable risk factors!
      - most common fractures of thoracolumbar spine! (most frequently T12-L1 level).
      - stable in thoracic spine - thoracic cage provides support.
      - compression fractures above midthoracic region are suggestive of malignancy.

**Clinical features**

- many remain undiagnosed - present with progressive painless kyphosis or scoliosis.
- others present with back pain * and tenderness.
- may result in compression of cord or cauda equina.
* axial, nonradiating, aching, stabbing, may be disabling
DIAGNOSIS

- *occult* compression fractures may be detected with Tc\(^{99m}\)-hydroxydimethylpyrimidine bone scans.
- differentiation between benign vs. metastatic fractures (not always possible by imaging):
  - Benign compression fractures: plate-like increased T2 signal beneath fracture, with sparing of remaining vertebral body and pedicles.
  - Metastatic disease: frequently globular, involving more than half of vertebral marrow and often extending into pedicles.

N.B. presence of kyphosis (esp. > 15°) decreases risk of SCI!

AP and lateral views of L\(_1\) osteoporotic wedge compression fracture:

**TREATMENT**

- as COMPRESSION FRACTURE see above >>
- Kyphoplasty is ideal for pain due to pathologic fractures due to metastases!!!!

**BIBLIOGRAPHY** for ch. “Spinal Trauma” → follow this [LINK] >>