TRANSIENT NEUROLOGICAL INJURY

STINGERS

- episode of transient unilateral **neuropathic** pain, which occurs when contact to the head or shoulders causes injury to the brachial plexus or the cervical nerve root.

- stingers are differentiated from SCI by:

- unilateral nature
- painless active and passive neck range of motion.

CERVICAL CORD NEUROPRAXIA (CCN)

- occurs due to a neck injury: hyperextension, hyperflexion, axial loading.

- clinical features:
  - transient **pain, paresthesias, or motor weakness** involving > 1 extremity (in many cases, all 4 extremities are involved).
  - symptoms typically last < 15 min but can require up to 48 h for the resolution of all symptoms.
- clearance to return to play:
  - athletes with an episode of a CCN who are found to have a defined lesion like a disc herniation need to have surgery to address this problem before returning to play even if asymptomatic.
  - athletes with an episode of CCN but no cervical **stenosis** or **instability** are often cleared to play once neurologically normal with full, painless range of motion.
  - most athletes with cervical stenosis and 2 episodes of CCN usually do not return to contact sports.

SPINAL CORD TRAUMA

- ≈ 10% of remaining cross-sectional area of spinal cord is enough to support locomotion.

Key subacute event is **DEMYELINATION** (post-traumatic degeneration of white matter)

CLINICAL

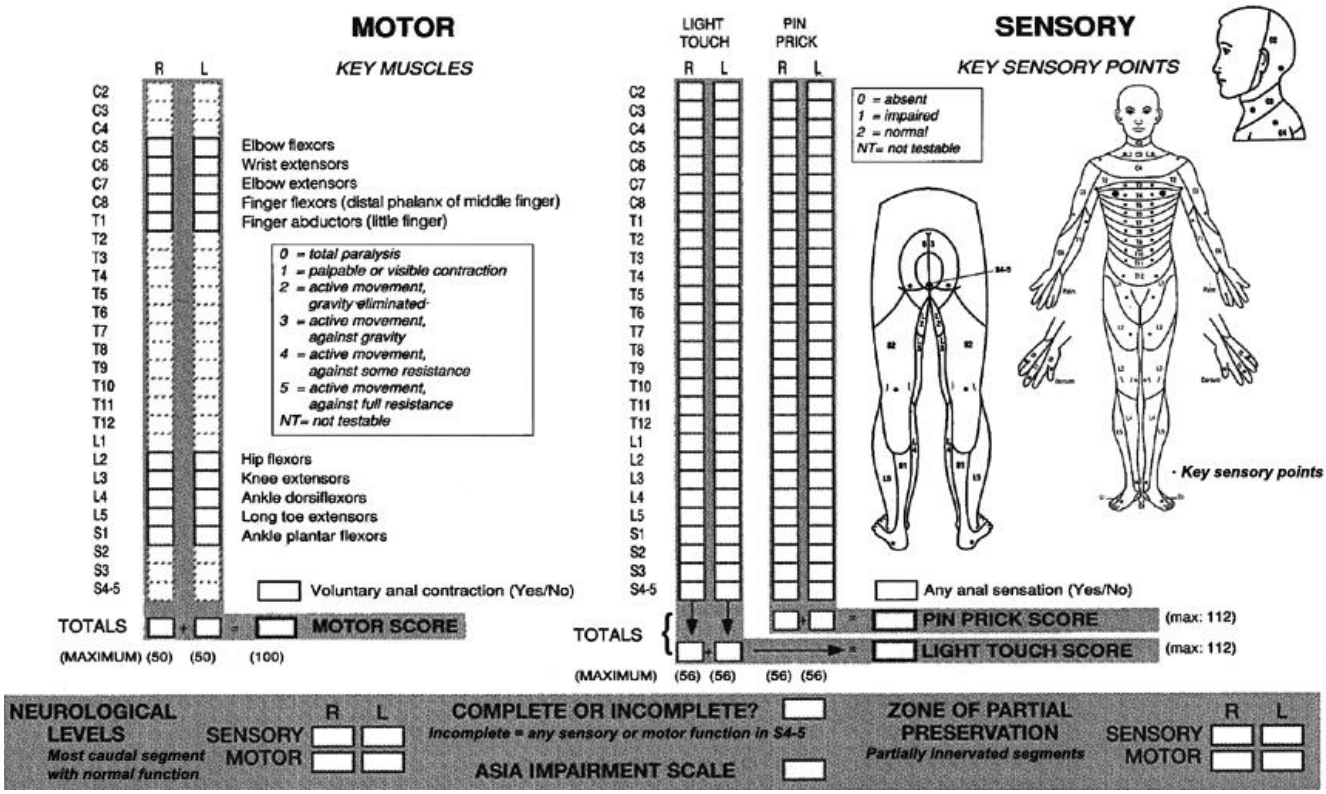
NEUROLOGIC LEVEL - most caudal spinal segment with *normal sensation* and *muscle strength of 3/5 or better* ← level is where you can move antigravity

The neurologic status can only be assessed after the patient has recovered from spinal shock - this almost always occurs within 48 hours of injury!

- ***sacral sparing*** may be only evidence that paralysis may not be complete – always test perineum sensation, **voluntary** anal sphincter contraction and toe flexion!
  N.B. absent bulbocavernosus* & anal wink **reflexes** = spinal shock is present
  (sacral sparing is not testable at this time – wait for return of above reflexes!!!)
  *gently tug urinary catheter → pelvic floor musculature contraction felt by finger placed in rectum
- *SCI completeness may be fully evaluated only after spinal shock* (return of reflex activity below level, but no sensation or voluntary motor control below level = complete cord transection).

CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)
Grade B Recommendation - the following can be used to predict neurological function and outcome:
1) entry ASIA Impairment Scale grade

2) sacral sensation - absence of pinprick sensation predicts poor bladder recovery
3) ankle spasticity - highly accurate in predicting neurogenic bladder dysfunction
4) urethral and rectal sphincter function – reappearance of sphincter function correlates with bladder recovery
5) abductor hallucis (AbH) motor function (e.g. on EMG) – may be earliest and most accurate indicator of supraspinal influence and the recovery of neurologic function



ASIA Impairment Scale:
A = Complete SCI – loss of motor and sensory function in S4-S5 segments.
B = Incomplete SCI – sensory but not motor function is preserved.
C = Incomplete SCI – motor function is preserved (> ½ of key muscles below neurological level have muscle grade < 3/5 [unable to resist gravity]).
D = Incomplete SCI – motor function is preserved (> ½ of key muscles below neurological level have muscle grade > 3/5).
E = Normal.

In unconscious patient (TBI, drugs), only clues to significant SCI may be:
1) lack of *facial grimacing* to **peripherally** applied painful stimuli (sensory loss)
2) lack of *arm / leg withdrawal* to painful stimulation applied to **head** (motor loss).

- ASIA is not applicable to pediatric patients.
- do not announce ASIA A until a month after injury as it may be a spinal shock and some patients recover some function!

"Clinical Assessment Following Acute Cervical Spinal Cord Injury" guidelines (Level 1 evidence) - **International Spinal Cord Injury Basic Pain Data Set** recommended by *as additional scale to ASIA*

DIAGNOSIS

1. CT without contrast

2. MRI without contrast – may not be possible if patient is hemodynamically unstable!

CT – if reported as normal (patient noncooperative):

A. Continue cervical immobilization until **asymptomatic**.
B. Discontinue cervical immobilization following normal **MRI** obtained within 48 hours of injury
C. Discontinue immobilization at **discretion of treating physician**.

David M. Panczykowski et al "Comparative effectiveness of using computed tomography alone to exclude cervical spine injuries in obtunded or intubated patients: meta-analysis of 14,327 patients with blunt trauma"

- modern CT alone is sufficient to detect unstable cervical spine injuries in trauma patients.
- adjuvant imaging is unnecessary when CT scan is negative for acute injury.
- cervical collar may be removed from obtunded or intubated trauma patients if modern CT is negative for acute injury.
- negative CT misses 1 unstable injury in every 4776 patients not able to be cleared by clinical examination - in typical Level I trauma center in the US, this translates into 1 patient every 14 years!

FIRST AID

1. Airway:
   a. **nasotracheal intubation** gives *least stress on cervical spine* but often technically difficult to perform!
   b. careful **orotracheal intubation** (esp. with fiberoptic camera) with in-line spinal immobilization is preferred method!
   c. cricothyroidotomy / tracheostomy may be preceded by temporizing **needle cricothyroidotomy with jet insufflation**.

2. Immobilization:

- minimal axial neck traction and do not flex; minimally disturb patient.
- patient is moved as single inflexible object - LOGROLLING TECHNIQUE - requires minimum of ***three people***
- ***semirigid cervical spine collar*** is applied, and patient is placed on ***back board***.
- properly placed collar must admit (between it and neck) two fingers.
- when on board, head must be extra immobilized - ***rolled blankets*** or ***sandbags*** (alternative - ***head taping*** to rigid backboard).

Cervical collar prevents flexion / extension, **side supports** prevent rotation!

TREATMENT

Treatment encompasses 6 phases:

1. Emergency ABC, immobilization, transfer to specialized center.
2. Treatment of general medical problems (e.g. hypotension, poikilothermy, ileus, urinary retention).
3. Spinal alignment.
4. Surgical cord decompression (if indicated) – must be done **ASAP** if neurodeficits are progressing.
5. Spinal stabilization – more **elective** approach.
6. Rehabilitation.

Boards - always look for all images (incl. head CT)!

- admit to ICU for: **neuro exams**, **ASIA** scoring, and checks of **vital signs** - every 1 hour.
- skin care (pressure sores can develop in < 1 hour in SCI patients!) – use RotoRest bed.
- Foley catheter → voiding trial - intermittent bladder catheterization if > 150 mL PVR (to prevent permanent bladder atony).
- **combination** antiembolic measures must be started within 72 hours (preferred – ENOXAPARIN SC) + pneumatic compression stockings or electrical stimulation → continuation for 3 mo postinjury (or until transferred to wheelchair)

  Lovenox / Coumadin for 3 mos!
- adequate early nutrition!
  - nasogastric tube for first 24-48 hours (longer if ileus persists), PPI stress ulcer prophylaxis → bowel re-training.
  - early enteral nutrition (initiated within 72 hours)

CARDIOVASCULAR CARE

Neurogenic shock = hypotension + bradycardia

- systemic hypotension may exacerbate spinal cord injury (secondary insult).

  Goal MAP 85-90 mmHg for 7 days

  (class III evidence)
- for ***neurogenic shock*** → **fluids** IVI (avoid hypervolemia!; if crystalloids do not restore BP, administer **colloids - albumin**! [avoid in TBI]) + **vasopressor-inotrope** (agent of choice – DOPAMINE* < NOREPINEPHRINE; oral: DROXIDOPA, MIDODRINE, FLUDROCORTISONE + **mechanical adjuncts** (binder, stockings)

  *too many c/v complications (tachyarrhythmias), esp. for > 55 yo (thus, NOREPINEPHRINE is preferred)

  N.B. problem is hypovolemia + cardiac suppression - fluid resuscitation alone may result in pulmonary edema! H: cardiac support

  Avoid α-agonist PHENYLEPHRINE – exacerbates (reflexly) bradycardia!

  Spinal cardiac sympathetic center is at T1-4; lesions:
  a) below T6 – OK to use PHENYLEPHRINE
  b) above T6 – need inotrope
- for severe ***bradycardia*** - titrate ATROPINE IV or temporary **pacing**.

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

- ***Consensus Statement by the Workgroup***: in light of published data from pooled (cervical and thoracolumbar) SCI populations, clinicians may choose to maintain MAP > 85 mmHg in an attempt to improve neurological outcomes.

DVT prophylaxis is for 3 months!

RESPIRATORY CARE

- direct relationship exists between level of cord injury and degree of respiratory dysfunction:
  a) high lesions (ie, C1 or C2), vital capacity is only 5-10% of normal, and **cough is absent**
  b) lesions at C3-6, vital capacity is 20% of normal, and **cough is ineffective**
  c) high thoracic cord injuries (T2-4), vital capacity is 30-50% of normal, and **cough is weak**
  d) **injuries at T11**, respiratory dysfunction is minimal; vital capacity is essentially normal, and **cough is strong**

N.B. respiratory failure may worsen due to *ascending cord edema*!

1/3 of patients with cervical spine injuries will require intubation (most in the first 24 h) - decreasing vital capacity and increasing respiratory rate or PCO2 are all indications for possible emergent or urgent intubation.

STEROIDS

- Incomplete or progressing SCI after **blunt trauma** - high doses of **METHYLPREDNISOLONE** / **DEXAMETHASONE** ASAP (start no later than 8 hrs after trauma) for 24-48 hrs:

  Bracken protocol for nonpenetrating SCI: methylprednisolone ASAP (start no later than 8 hours after trauma) 30 mg/kg IV bolus (over 15 min), then after 45 min, start IVI 5.4 mg/kg/h over 23 h.
  + PPI, AccuChecks and insulin sliding scale.

  N.B. *steroids beyond 24-48 hours are deleterious* (late inflammation is necessary for healing processes!)

  2013 guidelines of Congress of Neurological Surgeons (CNS) and American Association of Neurological Surgeons (AANS) recommend against use of steroids early after acute cervical spinal cord injury

- steroids are not FDA approved for SCI.

  There is **no** Class I or II evidence supporting clinical benefit of steroids in treatment of acute SCI.
  Class I, II, and III evidence exists that high-dose steroids are associated with **harmful side effects*** **including death**.

  *1.5 times higher incidences of GI hemorrhage and pneumonia, 2 times higher incidence of wound infection, 3 times higher incidence of pulmonary embolus in MP-treated patients compared to controls; most compelling is Class I evidence from > 10 000 patients with TBI, indicating that high-dose MP leads to significantly higher mortality independent of injury severity.

Steroids maybe indicated when injury happens in OR (iatrogenic SCI) or when regaining 1-2 levels makes a big difference (esp. in young healthy patient):

1) cervical SCI – improve mobility, avoid vent dependency.
2) autonomic dysreflexia - risk with SCI at T6 and above.

NASCIS (National Acute Spinal Cord Injury Study) I-III studies - the largest study investigating the effects of the methylprednisolone in acute SCI.
Outcome evaluated at 6 weeks, 6 months or 1 year.

	NASCIS I	NASCIS II	NASCIS III
Class of evidence	I	I	I
Randomization	Moderate-dose versus low-dose MePred	MePred versus naloxone versus placebo	24 h MePred versus 48 h MePred versus 48 h tirilazad mesylate
Number of patients	330	487	499

NASCIS Conclusions
MePred improves outcome of acute SCI if given within 8 h of injury.

Steroids for acute spinal cord injury (COCHRANE Review)
Authors' conclusions

High-dose methylprednisolone steroid therapy is the only pharmacologic therapy shown to have efficacy in a phase 3 randomized trial when administered within 8 hours of injury. One trial indicates ***additional benefit by extending the maintenance dose from 24 to 48 hours, if start of treatment must be delayed to between three and eight hours after injury***.

SURGERY

Complete SCI - fixed and permanent (little hope for major recovery of distal function - *DECOMPRESSIVE* surgery is unlikely to be of benefit*):

CERVICAL SPINE - change of single motor level has enormous impact on functional outcome (ventilatory function and upper extremity function).

THORACIC / LUMBAR SPINE - precise level is of less importance.

*problem, only rarely sure that SCI is complete in hyperacute stage (it may take up to 72 hours to assign ASIA A) – operate early even complete SCI, especially if *ongoing cord compression*! Plus, subacute *STABILIZATION* surgery may be performed to expedite rehabilitation. Plus, chronic compression → cord tethering, syrinx!

N.B. in cauda equina syndrome, surgical decompression is recommended even with complete deficits - potential for recovery of peripheral nerves is great!

Incomplete SCI (most improve with time) → sequential neurologic examinations:

a) ***stable*** or ***improving*** → monitor further.
b) ***deteriorating*** → emergency* surgical intervention (*DECOMPRESSION* → *STABILIZATION*).

*surgery within 24 hrs improves outcomes (the biggest room for improvement is with ASIA A patients), shortens length of stay, and lowers costs

Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) - early versus delayed (cutoff 24 hours) decompression for traumatic cervical spinal cord injury

Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). Fehlings MG et al. PLoS One. 2012;7(2):e32037

- patients demonstrated a 19.8% vs. 8.8% improvement of 2 AIS grades in the early and late groups, corresponding to 2.8 times higher odds in the early group.
- critique: early versus late surgery groups were not comparable - in the early surgery group there were 57.7% of patients with AIS A and B injury versus 38.2% in the late surgery group ($p < 0.01$). This can produce a ceiling effect in the degree of improvement patients with AIS C and D type injuries can achieve.

- the biggest disadvantage of early surgery – hypotension during anesthesia induction (esp. elderly) and secondary cord insult – important to communicate with anesthesia team BP goals!

COMPLICATIONS

- 30% SCI patients require hospital admission every year for complications.
- depression (following initial period of denial) occurs in almost all patients and may be masked by jocularity.
- **delayed postmyelography CT** should demonstrate most syrinx cavities in spinal cord.
  N.B. abnormal contrast accumulation in cord may be due to myelomalacia (i.e. not cavity).

SYNDROMES

CENTRAL CORD SYNDROME

neck hyperextension (esp. in patients with cervical stenosis) → cord compression
N.B. central cord syndrome is ischemic lesion (frequently no radiologically identifiable fractures!!!) - neurologic changes tend to improve with time!

Old sick patient → ICU to optimize, keep patient flat (to optimize cord perfusion but risk of aspiration)
Healthier patient → OR ASAP to accommodate cord edema (risks: intraop BP↓, cord hyperperfusion)

ANTERIOR CORD SYNDROME

- cervical flexion resulting in anterior cord contusion; large disc herniation or burst fracture compressing anterior cord; laceration or thrombosis of anterior spinal artery
- *worst prognosis of incomplete SCI syndromes* (only 10-20% recover motor function).

SCI WITHOUT RADIOGRAPHIC ABNORMALITIES (SCIWORA)

Causes:
a) marked cervical spondylosis and spinal stenosis.
b) spontaneously corrected dislocation (esp. children < 8 yrs - flexible spinal columns - greater ligamentous laxity - vertebral elements reduce spontaneously).

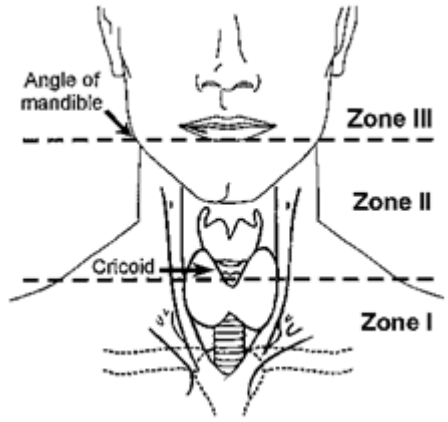
Diagnostic work-up: **MRI**; if *negative* → **flexion-extension XR**.

Treatment: **external immobilization** of spinal segment of injury for up to 12 weeks (discontinue earlier if becomes asymptomatic and flexion-extension XR is negative).
- avoid "high-risk" activities for up to 6 months following SCIWORA.

PEDIATRIC ASPECTS

Biomechanics of pediatric spine are fundamentally different from that of adult:
1) *ligamentous laxity*; if spine is fractured – it indicates significant force! High frequency of SCIWORA - spinal cord injury without radiographic abnormality (up to 50% pediatric SCI cases) - related to direct spinal cord traction, spinal cord concussion, vascular injury; H: MRI
2) *wedge-shaped vertebrae*
3) *horizontally-oriented* cervical *facets* - more frequent subluxations (vs. fracture-dislocations)
4) *predental space ADI up to 5 mm*, *wider prevertebral soft tissue space*
5) *pseudoluxation* of C_2 on C_3 (as well as of C_3 on C_4)
6) *immature neck muscles* and *proportionally large head* - cervical spine acts like fulcrum (fulcrum starts in upper cervical levels and changes progressively to lower levels as pediatric cervical spine matures, until it reaches adult level at C_{5-6} - most injuries occur at C_{1-3} level in children < 8 yrs)

ANTERIOR NECK TRAUMA

X-ray, MRI, CXR (for **zone I**), 4-vessel **angiography** (for any bruit or any penetrating wounds to zones I and III), **Doppler US** (for blunt carotid injuries), **Contrast studies of esophagus, Endoscopy** (laryngoscopy, bronchoscopy, pharyngoscopy, esophagoscopy)	

Blunt-injured patients can appear deceptively benign!
Ensuring airway is highest priority! *Intubate early!*

- ***airway injury*** (esp. ***laryngeal injury***) is strong indication for **tracheostomy**! (intubation may detach larynx → complete loss of airway if larynx dislodges into chest).

SPINAL COLUMN TRAUMA

Cervical Spine fractures

CT; optional - MRI without contrast (for ligamentous injury)
Aspen semirigid collar; upright XR (AP and lateral) in collar; dynamic XR for collar clearance

T/L Spine fractures

Log roll
TLSO brace; upright XR (AP and lateral) in brace
CT; optional - MRI without contrast (for ligamentous injury)

MECHANICALLY stable - fragments are not likely to move and cause neural damage when spine is physiologically loaded.

N.B. **MECHANICALLY stable** injuries may be **NEUROLOGICALLY unstable** - result in spinal cord damage from:

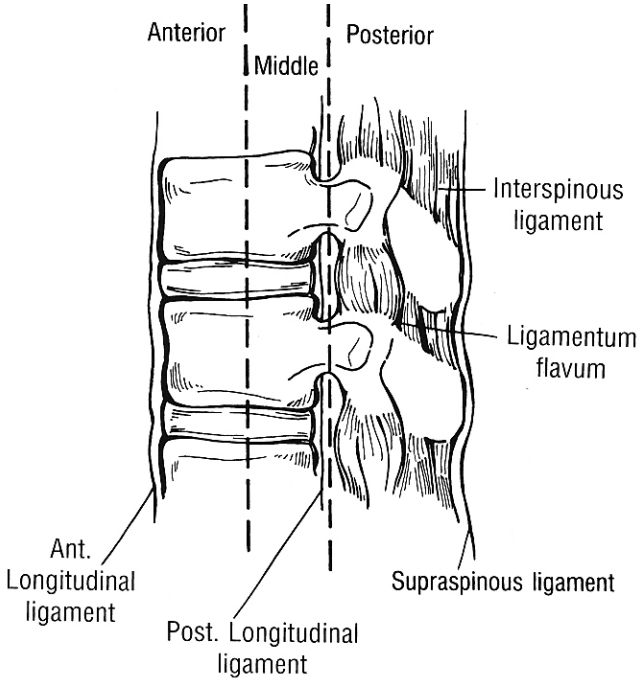
1) fracture fragments (bone splintering)
2) herniated intervertebral disks
3) epidural hematoma
4) vascular compromise

Denis (1983) divided ANTERIOR COLUMN of Holdsworth into two segments:

ANTERIOR SEGMENT - anterior halves of vertebral bodies with intervening disks, anterior longitudinal ligament.

MIDDLE SEGMENT - posterior halves of vertebral bodies and their intervertebral disks, posterior longitudinal ligament.

Injuries involving 2 or 3 columns are unstable!



DIAGNOSIS

Denver criteria - to determine when neck CTA is indicated to detect blunt cerebrovascular injury (BCVI) in trauma; the current criteria are divided into signs/symptoms and risk factors:

Signs and symptoms:

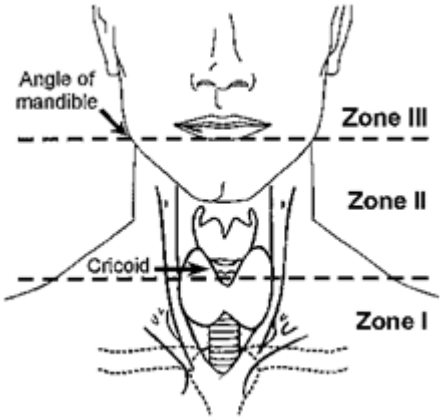
a) potential arterial hemorrhage from the neck, nose, or mouth
b) cervical bruit in patients < 50 years of age
c) expanding cervical hematoma
d) focal neurologic deficit (transient ischemic attack, hemiparesis, vertebrobasilar symptoms, Horner syndrome)
e) neurologic deficit incongruous with head CT findings
f) stroke on CT or MRI

Risk factors - high-energy transfer mechanism plus any of the following:

a) cervical spine fracture, subluxation, or ligamentous injury at any level
b) severe traumatic brain injury with GCS < 6
c) Le Fort II or III displaced midface fracture mandible fracture
d) complex skull fracture (e.g., involving frontal bone and orbit)
e) base of skull fracture (sphenoid, petrous temporal, clivus, and occipital condyle fractures)
f) scalp degloving
g) near hanging with hypoxic-ischemic (anoxic) brain injury
h) clothesline type injury or seat belt abrasion with significant swelling, pain, or altered mental status
i) traumatic brain injury with thoracic injuries
j) upper rib fractures
k) thoracic vascular injuries
l) blunt cardiac rupture

Alternative CTA indications - blunt cervical trauma + **modified Denver Screening Criteria**:

1. Fractures involving C1-6 transverse foramina
2. Facet dislocations
3. C1-3 subluxations
4. Penetrating wounds to cervical zones I and III



MRI

- acute fractures - *vertebral marrow edema* seen on STIR (not seen in chronic fractures!).
- **MRI** can directly image ligamentous damage! (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.
- prognostic value:

  mild or transient loss of function usually is **not accompanied by any signal changes**.
  cord hemorrhage (type 1 contusion) – poorer prognosis.
  cord edema (type 2 contusion) – frequent significant neurologic improvement (but edema extending for > 1 spinal segment predicts poor prognosis).
  N.B. **the length of cord edema** is the only independent predictor of recovery in SCI in multivariate analysis.

TONGS APPLICATION

- head of bed elevated, rotating bed.
- Gardner-Wells tongs are applied symmetrically just above ears - in vertical line of tragus, 1 fingerbreadth (or 1 cm) above ear, below temporal ridges (areas into which tongs are placed should be *below maximal transparietal skull diameter*).
  - alternative to tongs - for patients with severe skull injuries - sterilized **FISH HOOKS** applied to posterior zygomas.
- scheduled DIAZEPAM.
- **begin with:** 10 lbs 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 lbs increments, in 30 min intervals
- **maximal weight** that can be safely applied to Gardner-Wells tongs is 80-90 pounds (36-40 kg) or 2/3 of body weight.

HALO APPLICATION

- four sites for pin placement are located:

  ≈ 1 cm above lateral* segments of eyebrows
  *to avoid supraorbital nerves
  posterior parietal skull (that ring will be 1 cm above pinnae of ears).
- patient keeps eyes closed (if keeps open – may be unable to close due to eyebrow skin pinned to skull)
- tighten to ≈ 8-10 lb and lock in place with hexagonal nuts.
- pins should be *tightened second time* in 24 h.

  N.B. if pins become loose days* after application – likely due to infection – *do not re-tighten* as pins may go intracranially!
  *vs. within 24 hours – safe to retighten!

- local pin care - HYDROGEN PEROXIDE 3 times daily.

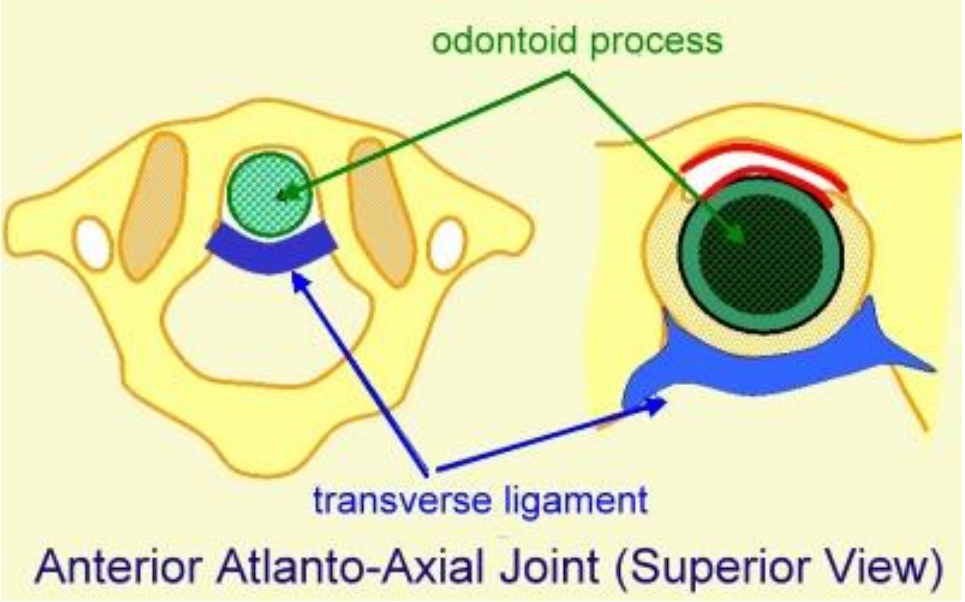
SURGERY

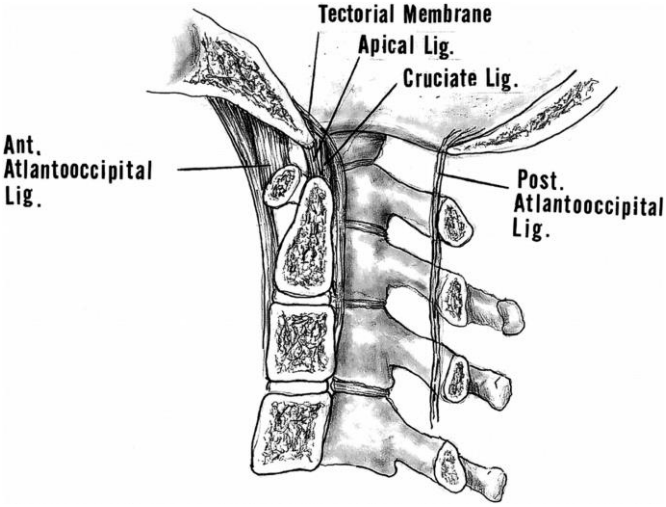
CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)
Choice of surgical approach (anterior, posterior, or combined anterior-posterior):
Grade B Recommendation - selection of approach does not appear to impact clinical or neurological outcomes.
Conflicting evidence to recommend surgical approach for radiological outcomes or complications.
Burst Fractures (patients with no neurologic injury and no need for direct decompression)
Grade A Recommendation - the addition of arthrodesis to instrumented stabilization has *not* been shown to impact clinical or radiological outcomes, and adds to increased blood loss and operative time.
Grade A Recommendation - both open and percutaneous pedicle screws give equivalent clinical outcomes.

- though regional motion was preserved in the nonfusion group, the nonfusion group also underwent additional surgery more often to remove the spinal implants due to screw loosening.

CERVICAL SPINE (C1-2)

Rule of thirds - **Steele's rule**: 1/3 cord, 1/3 dens, 1/3 empty





AO CLASSIFICATION OF UPPER CERVICAL SPINE INJURIES

Injury site vertically (bone and subjacent articulation):

Type I - occipital and craniocervical region
Type II - atlas and C1-2 joints
Type III - axis and C2-3 joints

Injury type:

A – bone injury (clearly stable – brace)
B – ligamentous injury ± bone (potentially unstable – MRI is indicated)
C – translations, i.e. any significant displacements (clearly unstable – surgery)

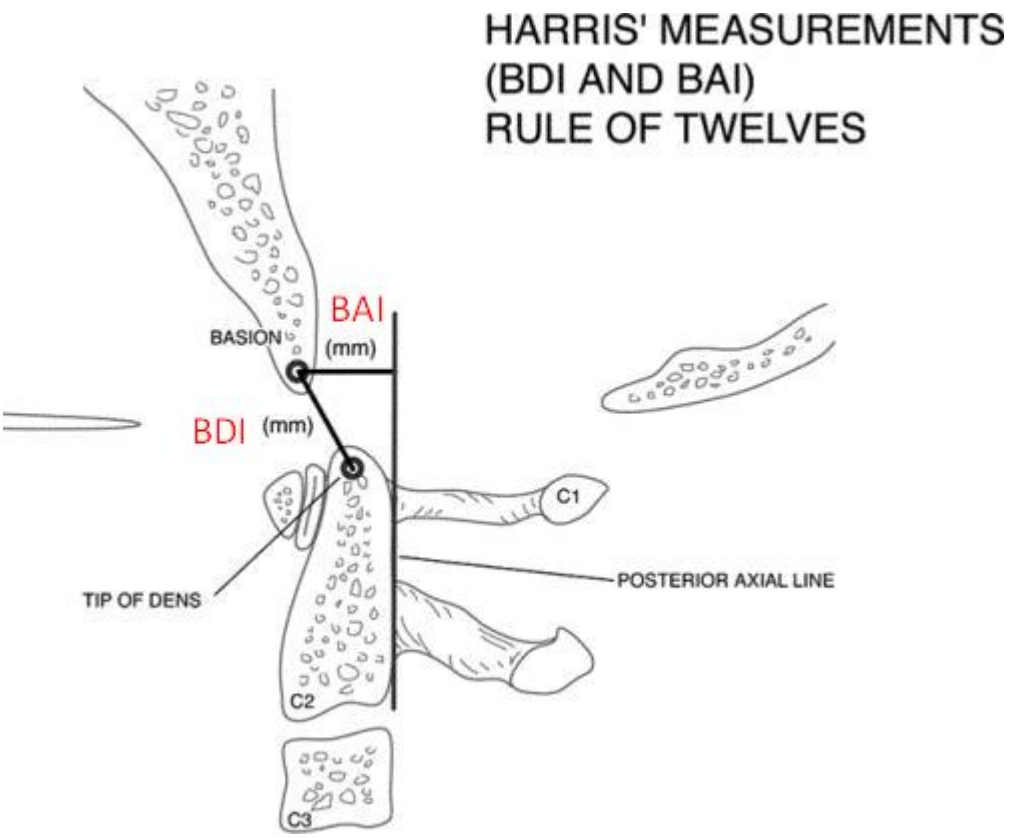
ATLANTOOCCIPITAL DISASSOCIATION

A. **Condyle-C1 interval (CC1) s. atlanto-occipital interval (AOI)** 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
   N.B. atlanto-occipital condyle distance should be < 5 mm regardless of age!

B. CNS/AANS recommended method - most sensitive and reproducible radiographic parameter: on lateral XR / sagittal CT - increased distance between clivus & dens:

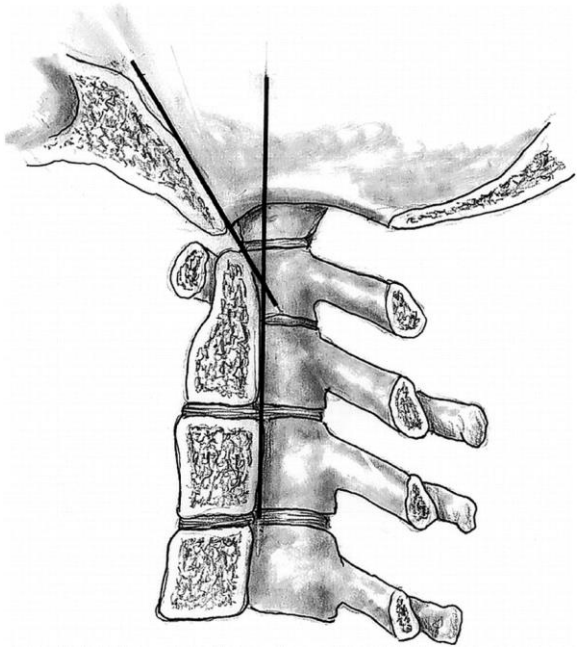
   1) **basion axial interval (BAI)** – distance between line drawn along posterior cortex of axis body and basion: < 12 mm – high interexaminer variability.

   2) **basion dental interval (BDI)** – distance between tip of dens and basion: < 12 mm on plain XR, < 8.5 mm on CT (max 9.0 mm in normal adult)

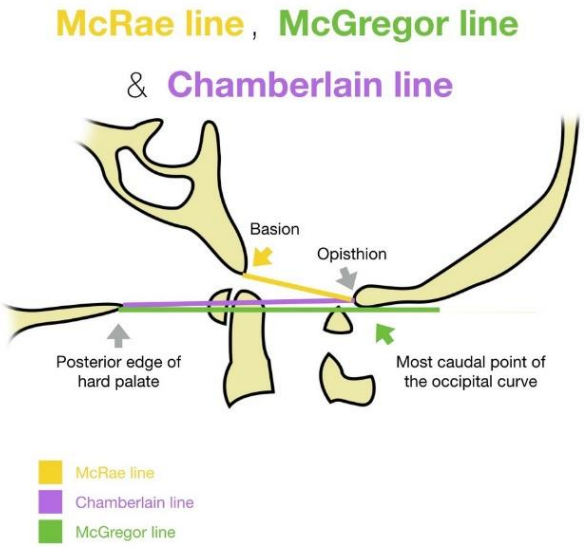


C. Disruption of basilar line of Wackenheim (anterior / posterior subluxation);

WACHENHEIM'S line - drawn down posterior surface of clivus and its inferior extension should barely touch posterior aspect of odontoid tip;



Opisthion - the midpoint on the posterior margin of the foramen magnum.
Basion - the midpoint on the anterior margin of the foramen magnum.



POWERS ratio = BC/OA normal < 0.9 (> 1 = anterior subluxation)

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 C1 ring.

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**.

ATLAS FRACTURES

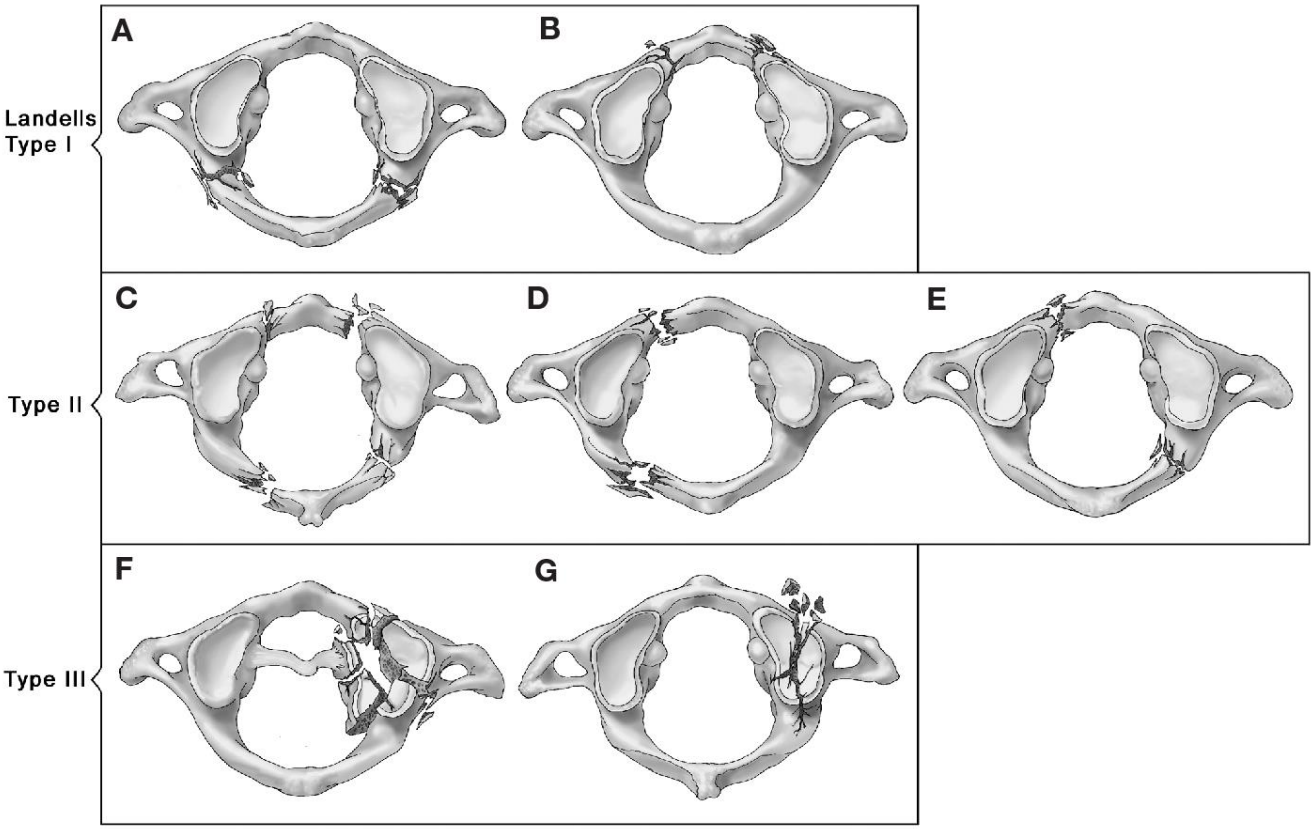
Landell type 1 (stable) – isolated fracture of anterior arch OR posterior arch.

Landell type 2 – burst fracture of C_1 ring (**Jefferson fracture**).

a) transverse ligament intact (stable)
b) transverse ligament disrupted (unstable)

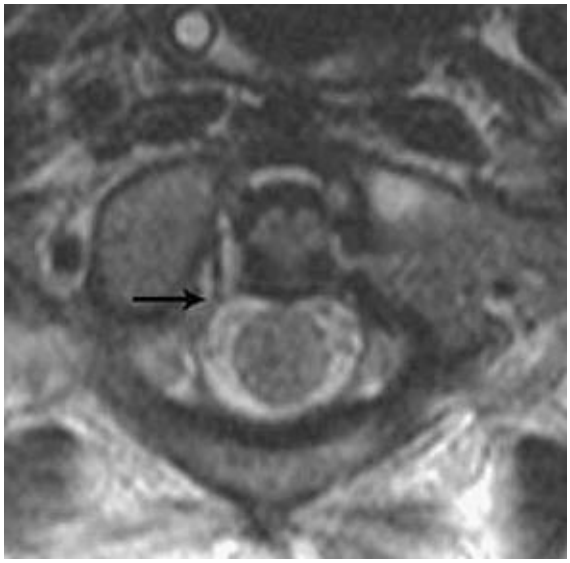
- Classic **JEFFERSON fracture (s. C1 burst fracture)** – burst fracture of C1 ring in 4 places ± disruption of transverse ligament.

Landell type 3 (stable) – fracture through lateral mass of C_1.



Diagnosis of TRANSVERSE ATLANTAL LIGAMENT RUPTURE – 3 criteria:

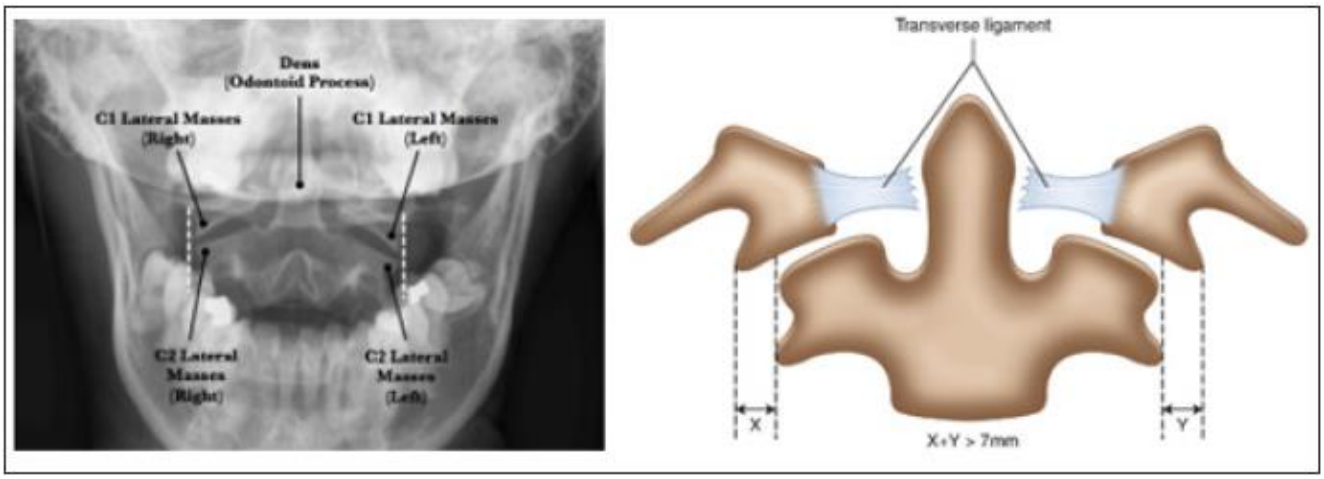
1) **MRI** – most sensitive test (more sensitive than rule of Spence):



2) **SPENCE'S rule**: ≥ 7 mm (sum of bilateral distances between dens and lateral mass) displacement of lateral masses in coronal CT (or > 8 mm on plain XR open-mouth view – effect of radiographic magnification)

Alternative

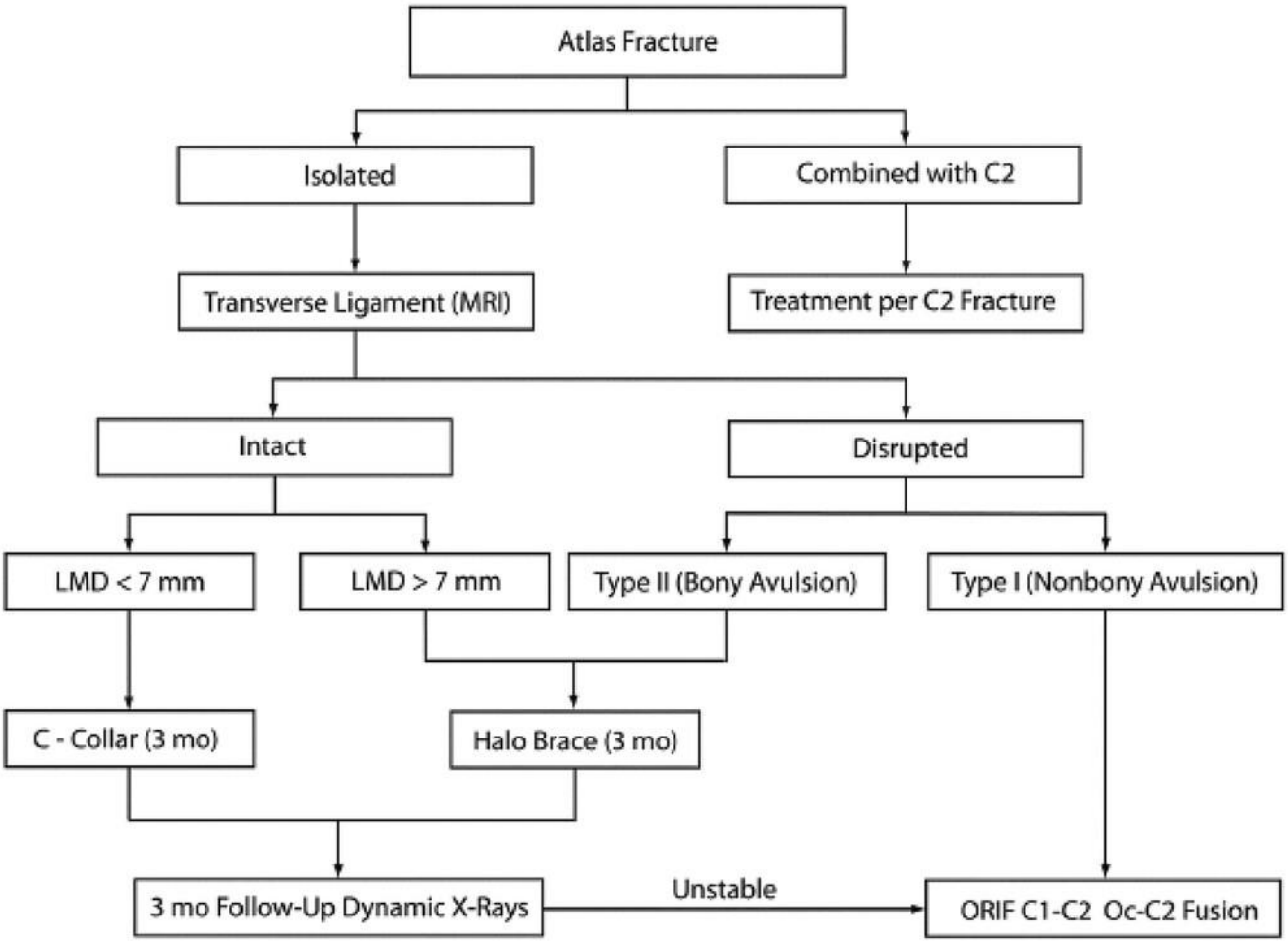
lateral mass displacement (LMD) - distance that the C1 lateral masses extend beyond the C2 superior articular processes; if ≥ 7.0 mm may indicate both a torn TAL and need for surgical management.



3) widening of atlantodental interval (ADI, s. predental space) > 2 mm in **sagittal CT** (or > 3 mm in men, > 2.5 mm in females in **lateral XR view**), > 4-5 mm in children.

Indication for surgery – also PADI < 14 mm

TREATMENT



Intact transverse ligament → collar or halo [for Jefferson] for 8-12 weeks
vs. C1 lateral mass screws connected with rod

Disrupted transverse atlantal ligament: **occ-C2 fusion** → **halo**.

Comminuted C1 lateral mass fracture:

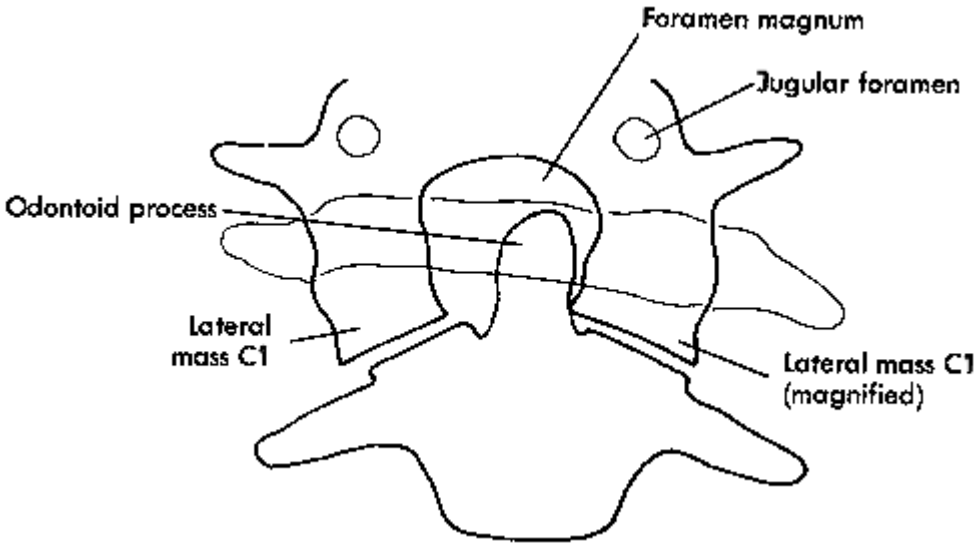
a) **halo**
b) collar (occipital condyle tends to migrate into fractured lateral mass and patient comes with "ear on the shoulder")
c) surgery (apply axial traction – ligamentotaxy pulls fragments together → place C1 lateral mass screws and connect with rod).

ROTARY ATLANTOAXIAL DISLOCATION

RADIOLOGY

(ODONTOID view) - asymmetry between odontoid process and lateral masses of C_1, 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 C_1. 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 - STEPS

1) subluxation is reduced:
   a) **halter traction** (if < 4 weeks duration)
   b) **tong/halo traction** (if > 4 weeks duration)
2) Immobilization 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**
3) following 6-8 weeks of immobilization, stability is assessed by flexion-extension XR; recurrence or residual instability → **C1-2 arthrodesis**.

GRISEL's syndrome

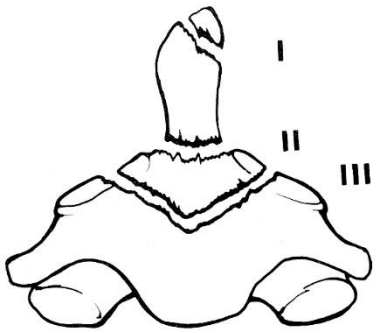
- unilateral or bilateral C1-2 subluxation from inflammatory ligamentous laxity

- etiology - *inflammatory process in head and neck*
- anatomic studies - periodontoidal vascular plexus that drains septic exudates → mechanical and chemical damage to transverse and facet capsular ligaments.

- torticollis
- in infants / young children
- neurological complications (occur in 15% of cases) range from radiculopathy to death from medullary compression.
- treatment – **manual reduction** under sedation → **collar**;
  if recurs - traction brace;
  residual subluxation after 8 weeks of treatment / neurological symptoms → **C1-2 arthrodesis**

ODONTOID (DENS) FRACTURES

Anderson and D'Alonzo (1974):



Type I – oblique fractures through **upper** portion of dens.
- may be associated with life-threatening *atlanto-occipital dislocation*.

Type II – fractures across dens base **near junction** with axis body.
Type IIA (Hadley, 1988) - comminuted dens base fracture with free fracture fragments

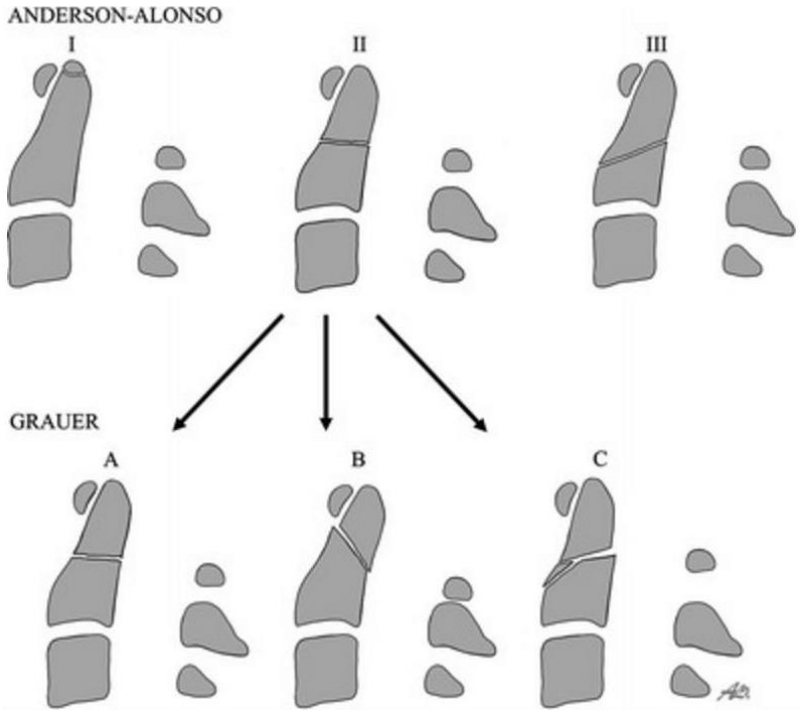
Type III – dens fractures that extend into axis **body**.

- all odontoid fractures are often effectively managed with external cervical immobilization*; *type 2 has lowest rate of union* (healing) esp in *elderly patients*.
  *experts now believe that halo for 3-6 mos offers no advantage
- union is verified with **CT** (historical alternative – **dynamic XR**).

Indications for surgical fusion:
1. **Transverse ligament** disruption
2. Dens **comminution** (type 2A fracture)
3. Type 2 or 3 fracture with dens **displacement ≥ 5 mm** or **> 5° angulation** (between supine and upright films) post attempted reduction (or inability to maintain alignment with external immobilization); some experts say even > 2 mm
4. Type 2 fracture in patient **> 50 yrs**
   (age > 50 yrs increases nonunion risk 21-fold when treated in halo!; plus, *elderly mortality rates as high as 26-42% with halo* have been reported)

Paradigm shift – treatment goal of geriatric patient is stable non-union: management with a semi-rigid collar in older people with type II odontoid fracture is safe and associated with low levels of pain and disability without statistically significant differences (incl. length of survival) between those demonstrating osseous-union or stable or unstable nonunions – C1-2 fusion may not be necessary for patients who fail to achieve union through conservative management!
(e.g. only 25% of UK surgeons advocate surgical management in older patients with nonunion)

Grauer treatment-oriented subclassification of type 2 dens fractures



Type IIA - *horizontal* fracture pattern and < 1 mm of displacement → external immobilization
Type IIB - *oblique* fracture extending from the anterosuperior to the posteroinferior portion of the dens → anterior odontoid screw fixation
Type IIC - *oblique* fracture beginning anteroinferiorly and extending posterosuperiorly and associated with significant anterior comminution → posterior C1-2 fusion

SURGICAL TREATMENT

A. **C1-2 FUSION** via posterior approach

   a) **C1 and C2 screws**; if C2 posterior elements are fractured – add C3 (same with C1 – add occiput);

   b) quick alternative - **wiring** between C_1 lamina and C_2 spinous process + bone **graft**

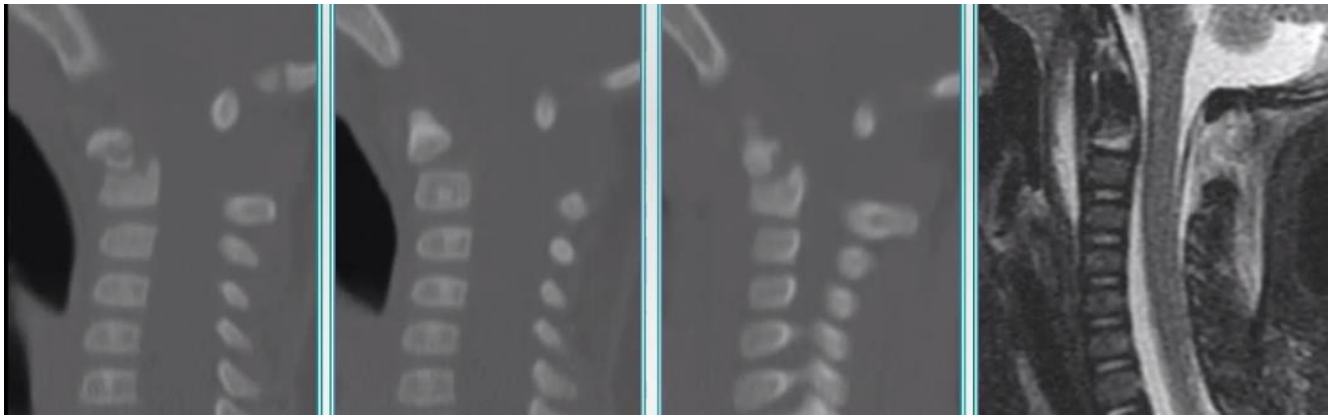
   c) **transarticular C1-2 screws** - no longer popular alternative

B. **ODONTOID SCREW** via anterolateral approach (preserves rotation motion!); high fusion rates (87-100%)* if performed during first 6 weeks after fracture – odontoid screw works best if placed early!

   *fusion rates in elderly may be as low as 60% (same as with halo)

   Contraindications: comminuted odontoid fracture, Grauer type IIC fracture, transverse ligament rupture, nonreducible fractures, osteoporosis, barrel chest, short neck, severe thoracic kyphosis

In kids < 5-7 yo – C2 synchondrosis fracture (H: external orthosis for 3-6 months)



OS ODONTOIDEUM

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

Clinical features:

1) **pain**
2) **myelopathy** - transient (commonly after trauma), static, or progressive.
3) **vertebrobasilar ischemia**

- sudden spinal cord injury after minor trauma have been reported.

Evaluation – flexion-extension lateral XR / kinematic MRI

- most often, there is anterior instability
- 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.

Indications for surgery: neurological symptoms → **C1-2 fusion;** irreducible cervicomedullary compression – add decompression:

1) DORSAL compression → **C1 laminectomy**
2) VENTRAL compression → **ventral decompression (transoral odontoidectomy)**.

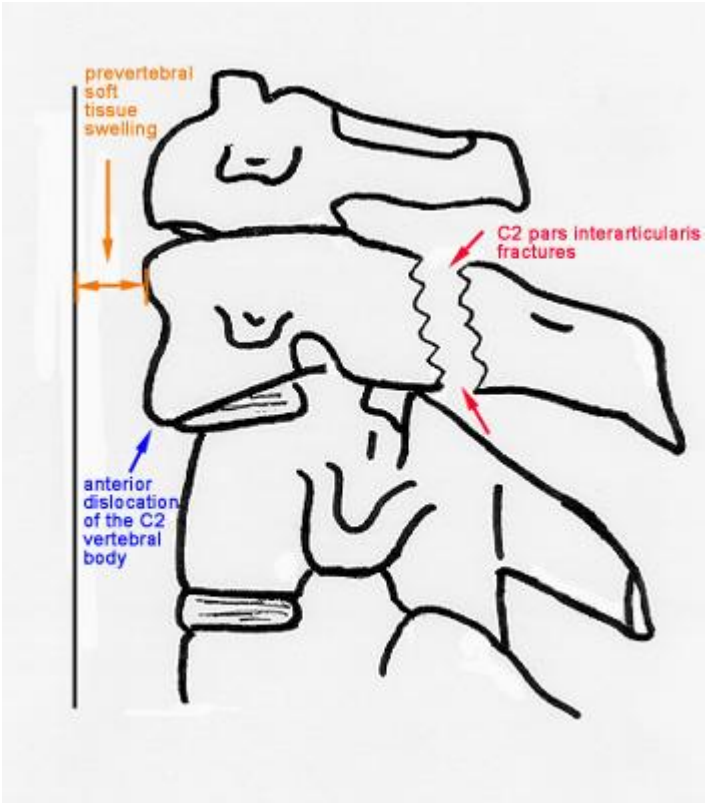
N.B. odontoid screw fixation has no role!

HANGMAN'S fracture (S. TRAUMATIC SPONDYLOLYSIS of C_2)

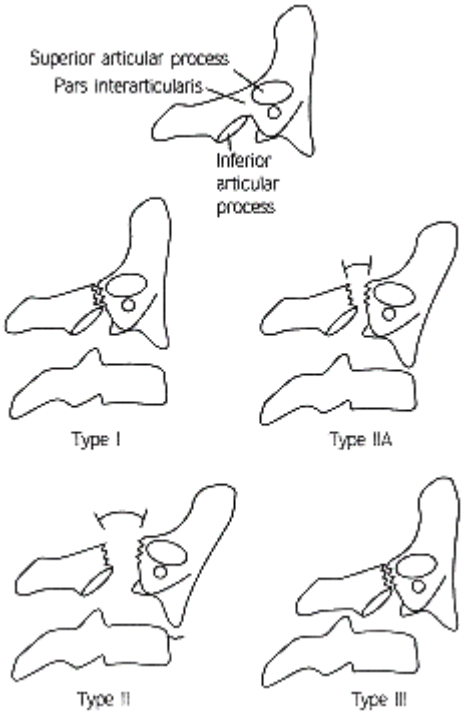
(unstable - but *cord damage is rare*)

– *extreme hyperextension* → bilateral pedicle fractures of axis.

Fracture lines anterior to inferior articular facets of C2



Levine and Edwards classification:



type 1 - C2/3 disc intact (stable) – no change in anatomy: insignificant displacement (< 3 mm horizontal displacement) or angulation.

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

type 2 - C2/3 disc and PLL are disrupted: significant horizontal translation (> 3 mm) and angulation (> 11°)

Treatment:

< 5 mm displacement → **halo** for 6-12 weeks.

> 5 mm displacement → **surgery**.

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 + *compression in* **halo** immobilization for 6-12 weeks.

type 3 (*grossly unstable*) - Type I fracture with unilateral or bilateral C2-3 facet dislocations.

Treatment: **surgery**

a) C2-3 ACDF – 100% fusion at 6 months, helps to remove herniated disc fragments but risk of dysphagia.
b) C1-3 PCF – helps to achieve facet reduction directly.

Indications for surgery in Hangman's fracture (anterior C2-3 or posterior C1-3 fusion):
a) C2-3 disc disruption - C2 translation > 3-5 mm over C3 / severe angulation (> 11 degrees)
b) facet dislocations
Also - failure of external immobilization

SUBAXIAL SPINE

- if ACDF for trauma – aim for bicortical screws!

SLIC (Subaxial Injury Classification)

Morphology	
No abnormality	0
Compression	1
Burst	2
Distraction (facet perch, hyperextension)	3
Rotation/translation (facet dislocation, unstable teardrop or advanced stage flexion compression injury)	4
Disco-ligamentous Complex (DLC)	
Intact	0
Indeterminate (isolated interspinous widening. MRI signal change only)	1
Disrupted (widening of disc space, facet perch or dislocation)	2
Neurological Status	
Intact 0	0
Root injury	1
Complete cord injury	2
Incomplete cord injury	3
Continuous cord compression in setting of neurological deficit (NeuroModifier)	+1 = 1

Signs of major disruption of anterior or posterior ligamentous complex:

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:

1-3 → non-surgical management
4 → either non-operative or operative approach.

≥ 5 → surgical fixation.

N.B. avoid halo in subaxial spine as it is suboptimal!

TEARDROP FRACTURE

Teardrop fracture is marker of potential for high instability (may be stable or highly unstable).
Diagnostic work up – flexion-extension XR to document stability, MRI to explore ligaments.
Management

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

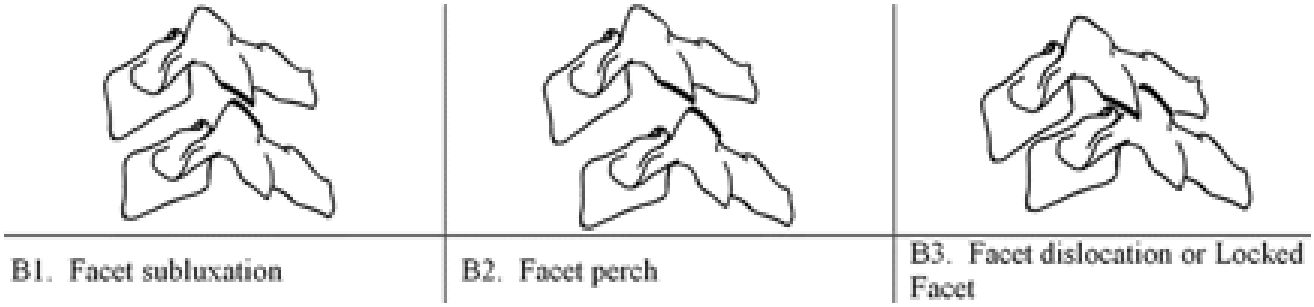
FACET SUBLUXATION / PERCH / DISLOCATION

Upper vertebral body is anteriorly subluxed / anterolisthesis (≤ 25% of AP diameter of vertebral body in **unilateral** facet dislocations; vs. ≥ 50% in **bilateral** facet dislocations).

40% children ≤ 7 yrs have 3-4 mm anterior displacement of C2 on C3 (*PHYSIOLOGIC SUBLUXATION*, s. *PSEUDOSUBLUXATION*)

UNILATERAL

(stable)



BILATERAL

(always unstable)

- high incidence of ***spinal cord injury!!!***
- high level of suspicion for ***vertebral artery injury*** (esp. in bilateral jumped facets) → CTA

TREATMENT

- reduction is safest in cooperative examinable patient – therefore is best with **skeletal traction**.
- reduction under anesthesia is less safe (at least use monitoring – but may not work in spinal cord injury).
- many optional strategies:
  intact patient → MRI → closed reduction* → ACDF
  intact patient but hemodynamically unstable (to get MRI) → open reduction and ACDF without MRI
  SCI, cooperative patient, hemodynamically unstable (to get MRI) → closed reduction* → MRI → ACDF
  *if unsuccessful, proceed with open reduction via posterior approach (drill off facet) → PCF; some experts recommend 360 fusion for bilateral jumped facets

Some experts do not use traction (due to personal experience of reduction nonoccurring despite traction for 24 hours) – they just do **reduction maneuver** at bedside: attach tongs → neck flexion → axial traction → neck extension. N.B. overall skeletal traction is safer than manual (but some prefer manual reduction over traction)

N.B. 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)

*in this case, consider ACDF followed by posterior fusion

Jumped (locked) bilateral facets – optional algorithm:

Four questions in order: MRI → OR feasibility → examinable patient → ASIA

MRI – is there disc herniation / large epidural hematoma = **"unsafe" MRI** (i.e. risk of cord damage with reduction):

A. **"Safe" MRI** → can patient go to OR immediately: *Closed reduction*
   A) **yes** → plan A
   B) **no** → plan B

B. **"Unsafe" MRI** → can patient go to OR immediately: *Open reduction after discectomy*
   A) **yes** → plan C
   B) **no** → plan D

C. **Unavailable MRI** (e.g. hemodynamic or respiratory instability, MRI-incompatible implants) → can patient go to OR immediately:
   Open reduction after discectomy (unless OR is delayed and reliable intact clinical exam substitutes MRI – may try slow closed reduction)
   A) **yes** → plan C
   B) **no** → is patient examinable:
      a) **no** → plan D
      b) **yes** – what is ASIA:
         - intact or ASIA A → plan B
         - incomplete SCI → plan D

Plan A: **closed reduction** (manual in OR ***awake***)* → ACDF (for C3-5) or PCF (for C5-7, large dislocations)

*if fails → plan C (although some experts will attempt less-safe closed reduction ***under general anesthesia*** if ASIA A + MRI is known "safe")

Plan B: **closed reduction** (with weight traction)* → ACDF when feasible

*if fails → plan D (although some experts will do plan A if MRI is known "safe")

Plan C: anterior discectomy → **open reduction*** and ACDF

*if anterior open reduction (after discectomy) fails, place interbody graft and flip prone for posterior superior facetectomies (drill off facet)-reduction-PCF

Plan D: stabilize (not reduce) C-spine with mild traction and C-collar until OR is feasible → plan C

- keep immobilized (either traction or C-collar) until gets to OR.
- if at any moment closed reduction fails (neuro exam changes), stop and proceed to safe plan C.
- aim to use neuromonitoring unless reliably ASIA A (e.g. no cord function in fully examinable patient after spinal shock, transected cord).
- some experts recommend 360 fusion for bilateral jumped facets.

If reduction is achieved → traction weight is reduced to 20 lbs (9.1 kg) → **ACDF**.

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

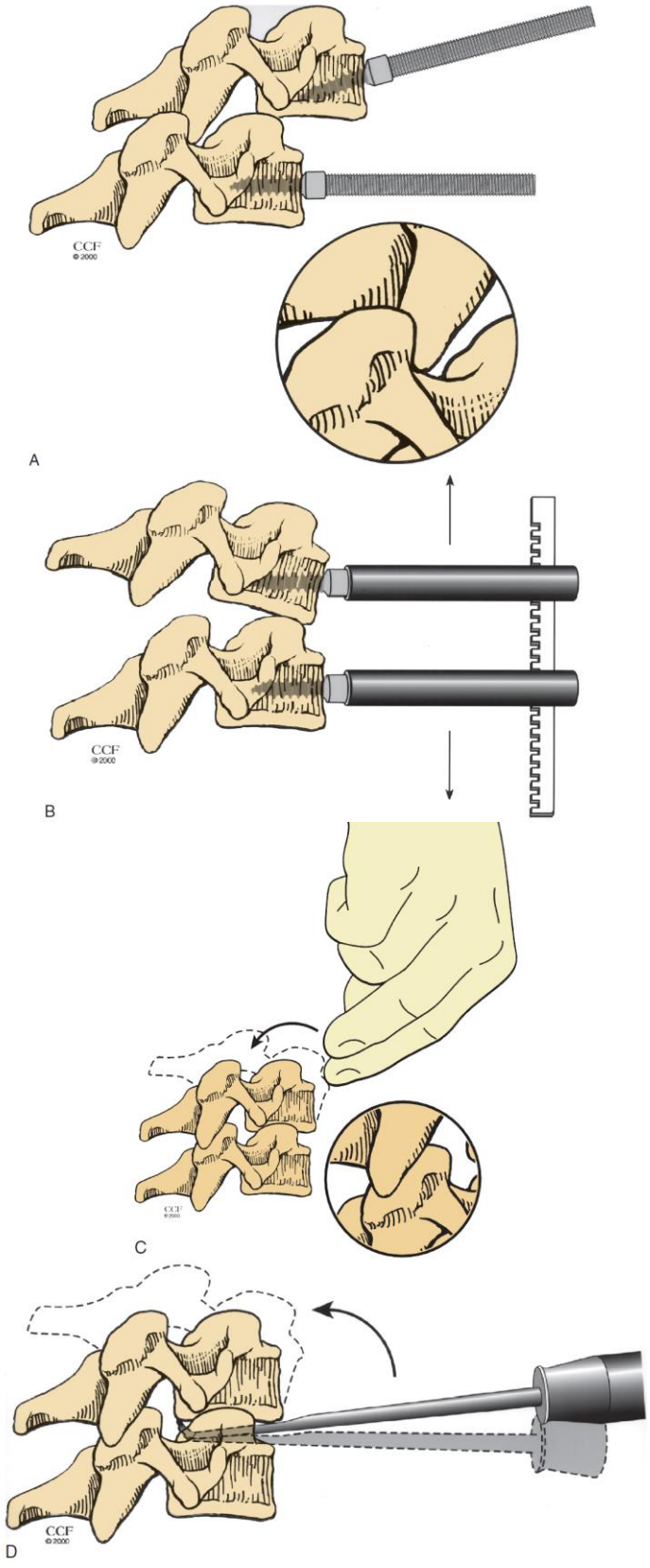
Surgical open reduction options:

A. **Posterior approach** is gold standard for straightforward open reduction of facet dislocations (may place rods transversely into same level screws or may use towel clamps on spinous processes to have "handles" to distract and manipulate); cannot place ***lateral mass screws*** into fractured lateral masses, thus, would need screws level above and level below; some experts would use ***pedicle screws*** to gain more strength and involve just level above and below:

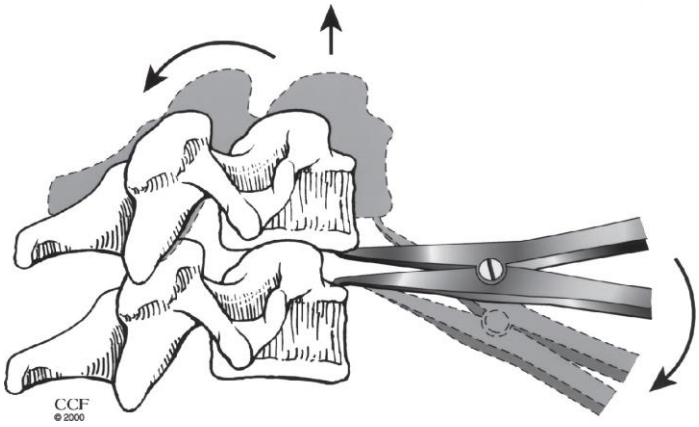
B. **ACDF** to reduce dislocation and open foramena; some experts think it is equally acceptable or even preferred* alternative to posterior approach: perform discectomy (preserve PLL) → perform reduction:

*disc herniation – need discectomy; upper levels (C3-5) – easy to reduce from anterior; significant ligamentous disruption (e.g. ≥ 50% anterolisthesis) – easy to reduce from anterior (although difficult to place the plate – posterior may be preferable)

a) **method with Caspar pins**: place pins in convergent fashion (A); when distraction is applied it disengages facets (B) → reduce rostral vertebra either manually (C) or by placing osteotome into disc space and rotating it rostrally (D):



b) **method with direct disc space distraction**: apply axial traction on tongs, place Cobb elevator / disc interspace spreader into the disc space once the facets are disengaged → rotate spreaders rostrally as a lever:



– aim bicortical screws for trauma ACDF.
– some experts recommend **360º fusion** for bilateral facet dislocations (alternative – after ACDF, flex neck and do XR – if spinous process space widens, add PCF; if not – keep in C-collar)

See Case S1 >>

FACET FRACTURE

TREATMENT

- if neither subluxation nor nerve root dysfunction → **C-collar** then follow up weekly – if subluxation or nerve root dysfunction* (that happens quite often) → one-level **ACDF**.

*pain can be severe and may develop myotome weakness but traumatic radiculopathy uniformly gets better over time!

Rule: lower in the cervical spine, more likely will need surgery ("C7 is a bad actor!")

CLAY SHOVELER'S FRACTURE

- **soft orthosis** for comfort (2-3 months).

WHIPLASH INJURY

- mechanism - hyperextension followed by flexion
- persistent **neck pain** without objective findings.
- 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

THORACOLUMBAR SPINE

N.B. anterior + middle columns (90% of axial surface area, highest blood supply) - take 80% of axial load

Thoracolumbar injury classification & severity score (TLICS) – 3 components:

TABLE 1: The TLICS system*

Variable	Points
injury morphology	
compression	1
burst	+1
translation/rotation	3
distraction	4
neurological status	
intact	0
nerve injury	2
cord, conus medullaris	
incomplete	3
complete	2
cauda equina	3
PLC integrity	
intact	0
indeterminate†	2
injured	3

* As reported by Vaccaro et al.[11]
† For patients with suggested ligamentous injury on STIR imaging or T2-weighted MRI.

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

Cauda equina transection – non-repairable! (dural sac tie-off – only for true spinal malignancies, not for trauma)

Characteristic	TLICS	SLIC
Injury morphology		
No abnormality	0	0
Compression	1	1
Burst component	2	2
Translation/rotation	3	3
Distraction	4	4
PLC integrity/DLC integrity		
Intact	0	0
Indeterminate	2	1
Disrupted	3	2
Neurological status		
Intact	0	0
Nerve Root Injury	2	1
Complete cord injury	2	2
Incomplete cord injury	3	3
Cauda equina injury	3	–

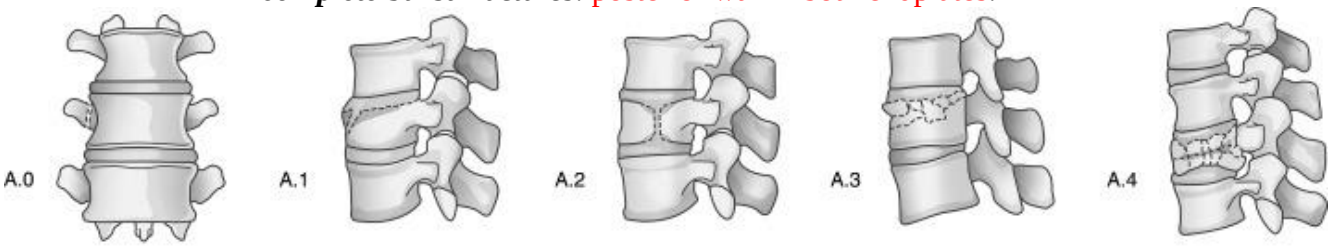
Cervical: Continuous cord compression with neurological deficit: +1

AO Spine Thoracolumbar Spine Injury Classification System

- did not help guide treatment.

Type A injuries (compression) – failure of anterior elements + preservation of posterior ligamentous complex:

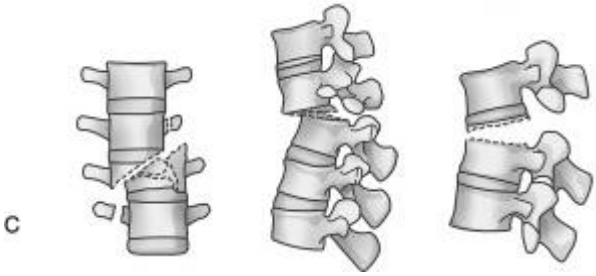
A0 - transverse or spinous process fractures
A1 - wedge compression fractures of 1 endplate
A2 - ***split (pincer)*** fractures: both endplates
A3 - ***incomplete burst*** fractures: posterior wall + only 1 endplate
A4 - ***complete burst*** fractures: posterior wall + both endplates.



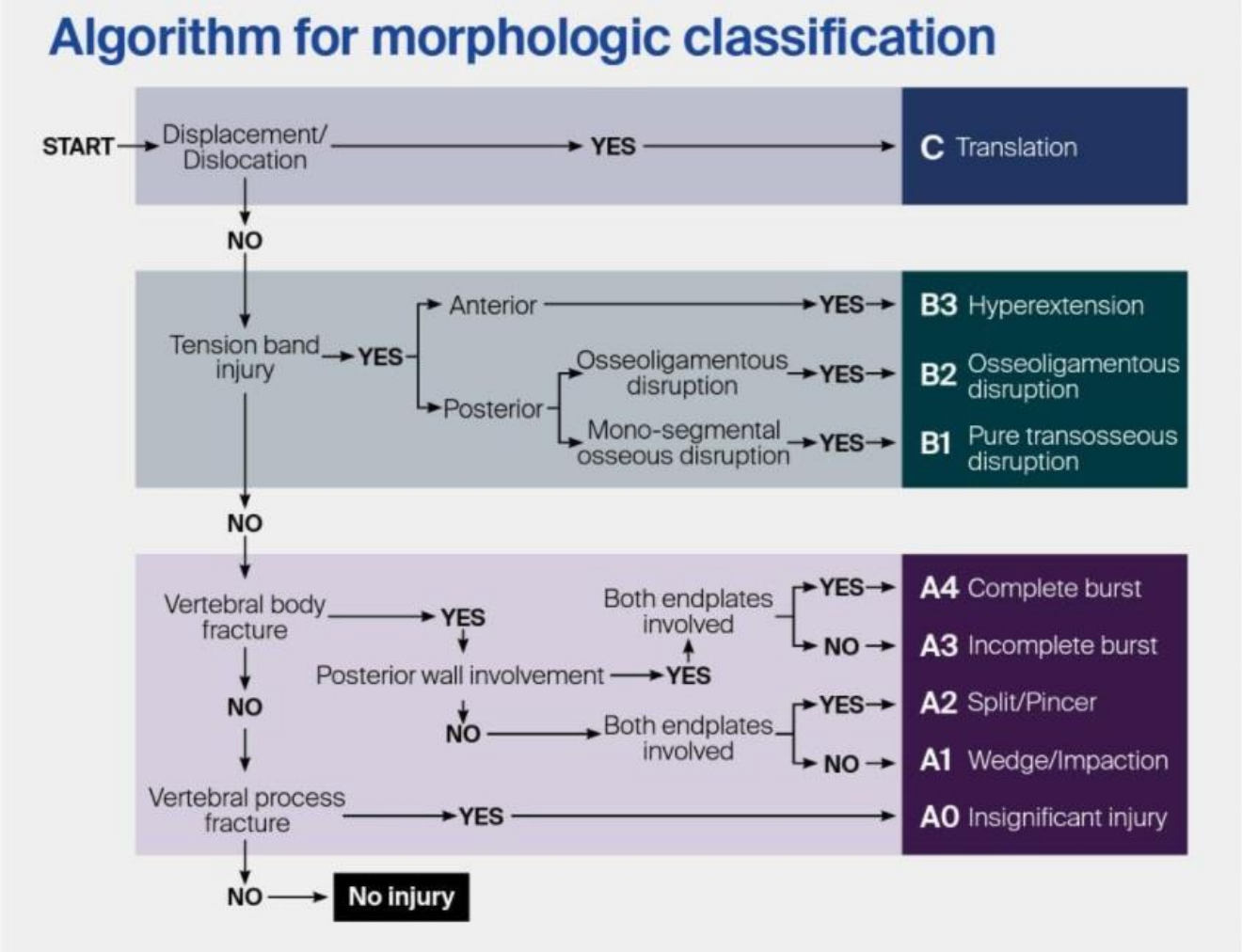
Type B injuries (distraction) – failure of anterior OR posterior ***tension band***:

B1 – **posterior (osseus)**: monosegmental.
B2 – **posterior (osteoligamentous)**: bony and/or ligamentous failure of posterior tension band
+ fracture of vertebral body (i.e. it is NOT anterior tension band injury)
B3 – **anterior**: hyperextension through disc space or bone - as commonly seen in ankylosing spondylitis.

Type C injuries (translation): axial torque leading to failure of all elements with ***displacement or dislocation*** of cranial spinal elements relative to caudal elements.



+ **neurological grading**: N0 = intact, N1 = transient symptoms, N2 = radiculopathy, N3 = incomplete SCI or cauda injury, and N4 = complete SCI.



COMPRESSION (WEDGE) FRACTURE

Anterior column failure

Compression fractures are usually intrinsically stable and rarely cause neurologic deficits – best treated with bracing!

- if pain is not improving with bracing over 2-12 weeks (max 6 months) → **kyphoplasty** or **vertebroplasty** (if STIR signal still present)
- bedrest is not benign - bone density declines 2% per week, muscle strength declines 2% per day.

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.

Serial radiographs for 1 year - progressive kyphosis can occur!

INDICATIONS FOR SURGICAL *STABILIZATION*:

a) neurological deficits, esp. with canal compromise (> 50%)* - add *DECOMPRESSION* to *FUSION*
b) major anterior column comminution
c) significant posterior element disruption* (unstable burst) - kyphosis > 30°, height loss > 50%

- percutaneous screws ("internal brace") may suffice if no need to decompress.

*those are burst fractures

PERCUTANEOUS VERTEBRAL AUGMENTATION (PVA)

- indication – symptomatic (pain) osteoporotic and neoplastic fractures

Fracture age requirement – look for STIR signal (vertebral body edema) on MRI* (absence of STIR signal means fracture has healed, thus, fracture age limit is 6 months).

*if MRI is contraindicated, may do nuclear study to show ongoing metabolism

- contraindications
  1) split fracture
  2) complete burst fracture with posterior wall compromise – now it is only a relative contraindication – modern devices (e.g. KIVA) able to contain cement

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

Vertebroplasty – high-pressure injection of cement polymer into fractured vertebral body

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!)

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*).

The generally accepted differentiation between compression and burst fractures occurs at the **MIDDLE column**, which is spared in compression fractures and involved with burst fractures.

- **retropulsion of the fractured middle column fragments into the spinal canal** - hallmark of a burst fracture.

POSTERIOR column may or may not be involved, though more frequently it is involved when compared with compression fractures; 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

N.B. for classification and descriptive purposes, if on CT scan the **fracture extends into the posterior cortex of the vertebral body**, regardless of the degree of displacement, it is referred to as a burst fracture

TREATMENT

- TL burst fractures in neurologically intact patients are considered to be inherently stable → nonsurgical management (TLSO brace or no brace).

Unstable burst

- unstable burst fractures that necessitate surgical intervention:

a) significant deformity: height loss (> 50%), kyphosis (> 30%)*
b) significant canal compromise (> 50%)*
c) significant **posterior osteoligamentous complex disruption****
d) significant **vertebral fragmentation**
e) associated **neurologic deficit*****

*a) and b) criteria were developed in pre-MRI era as indirect indicators of posterior osteoligamentous complex disruption; as MRI was introduced and the posterior elements could be more reliably imaged, it became clear that this was not necessarily true; of those three classical radiological parameters, in modern times, the most important are: **kyphosis** > 30%, then height loss > 50%, then canal compromise > 50%

**difficulty lies in discerning the extent and significance of this component of the injury and its implications on stability; when the significance of a posterior element injury is borderline (e.g. isolated sagittal lamina fractures, minimally displaced facet or spinous process fractures, minimal facet opening), it is usually safe to carefully mobilize a neurologically intact patient in a brace and assess for progressive instability with serial upright radiographs

***exception is mild isolated nerve root injuries in an otherwise mechanically stable fracture pattern, with a high rate of neurologic recovery under these circumstances

DECOMPRESSION (best results if within 48 hours)

- reserved for patients with neurologic deficits, irrespective of the degree of spinal canal compromise!!!
  N.B. neurologically intact patients with significant canal compromise of ≥ 50% do not benefit from decompression; it has been shown that resorption of retropulsed bone occurs naturally, and late spinal stenosis has not been shown to be a problem provided there is maintenance of spinal alignment.
  - it is possible to have even 80% of the spinal canal filled with bone fragments yet have the patient remain intact neurologically.
- two types of decompression:
  A. **Indirect** – relies on ligamentotaxis (PLL must be intact!) to reduce retropulsed fragments as the fracture is reduced and spinal alignment restored.
  B. **Direct**:
     a) posterior decompression via laminectomy - useful when a piece of fractured lamina or infolded ligamentum flavum is protruding into the canal or for a single nerve root requires decompression
     b) anterior decompression - retropulsed vertebral body fragments* cause most neurologic deficits, and these require a direct decompression.
        *in some instances the decompression may be achieved via a posterolateral transpedicular approach (esp. in the lumbar spine at the nerve root level, where the dural tube may be retracted more safely than at cord level but works in thoracic spine as well) - remove pedicle, drill the cavity behind the fragment, offending bone fragments are either removed or tamped anteriorly.
        – for fragment tamping back into place, may do discectomy above the fracture to create the room for it.
- may use US to check if ventral decompression is complete.

STABILIZATION - posterolateral instrumentation with pedicle screws:

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) - the benefits of percutaneous pedicle screw stabilization in thoracic and lumbar spine fractures have not been scientifically validated, and this technique must be used with caution!

- do not use **polyaxial** screws for TRAUMA (one of AO principles!)
- include at least 2 levels above and 2 levels below fracture.
  N.B. **short segment fusions** (1 above, 1 below) are rarely acceptable but may be considered in flexible (lumbar) spine in young patients with normal bone quality, esp. if pedicle screws can technically be placed at injured level.
- consider postop orthosis if quality of stabilization is questionable.
- significant vertebral body fragmentation / comminution (esp. with > 50% height loss) → **corpectomy** (may need to be supplemented by sort-segment posterior instrumentation, esp. if posterior elements are disrupted).

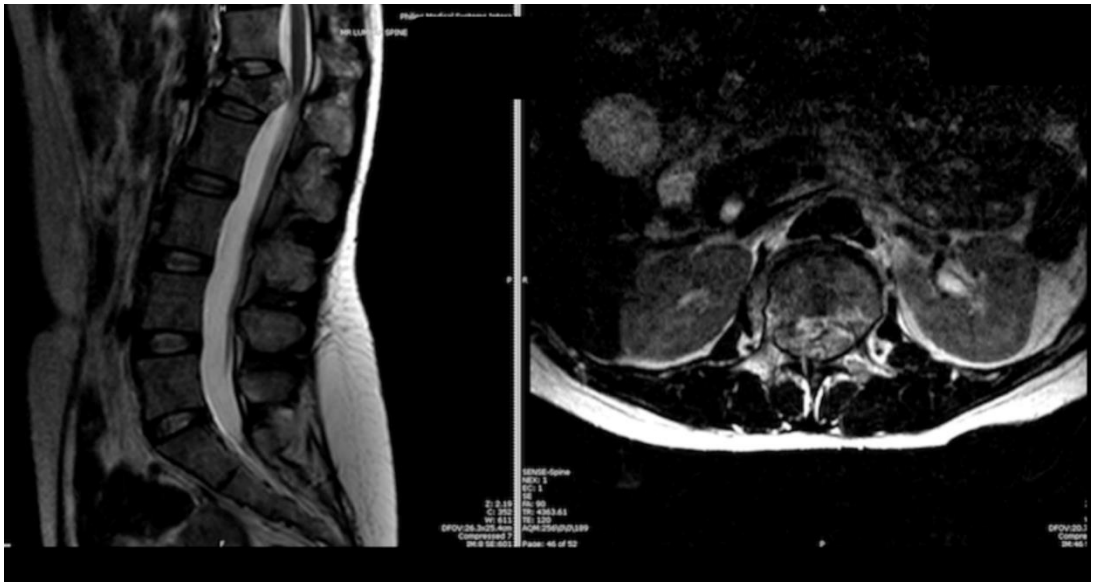
CNS Evidence-Based Guidelines for Thoracolumbar Spine Trauma (2019)
Burst fractures in neurologically intact patient
Conflicting evidence to recommend for or against the use of surgical intervention to improve clinical outcomes - discretion of the treating provider.

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

N.B. the entire goal of surgical treatment – to prevent neurological deficit; surgery or brace do not seem to affect residual pain / ability to return to vigorous work!

- if a kyphotic deformity reduction is performed surgically or with bracing, some loss of correction can be expected on long-term follow-up (kyphosis > 30 degrees is the least desirable and is probably most commonly believed to be a predictor of long-term back pain).

Comminuted unstable burst fracture of L1 with neuro deficits



- patients usually do better with earlier intervention.
- L1 is a particularly challenging - thecal sac (with conus inside) cannot be aggressively retracted + L1 nerve root should not be sacrificed during cage deployment.
  - some authors have reported that sacrificing L1 nerve roots will not yield a functional neurological deficit (careful of possibility of *artery of Adamkiewicz* – place temporary clip and watch for monitoring decline).

Options without corpectomy – differ by decompression method:

1. **Posterior-only**: posterior pedicle screw fixation (open or percutaneous) with ligamentotaxis maneuver (PLL needs to be intact) - only moderate decompression at best, does not correct kyphosis.
2. **Posterior-only**: L1 laminectomy + trans-pedicular fragmentectomy + pedicle screw fixation

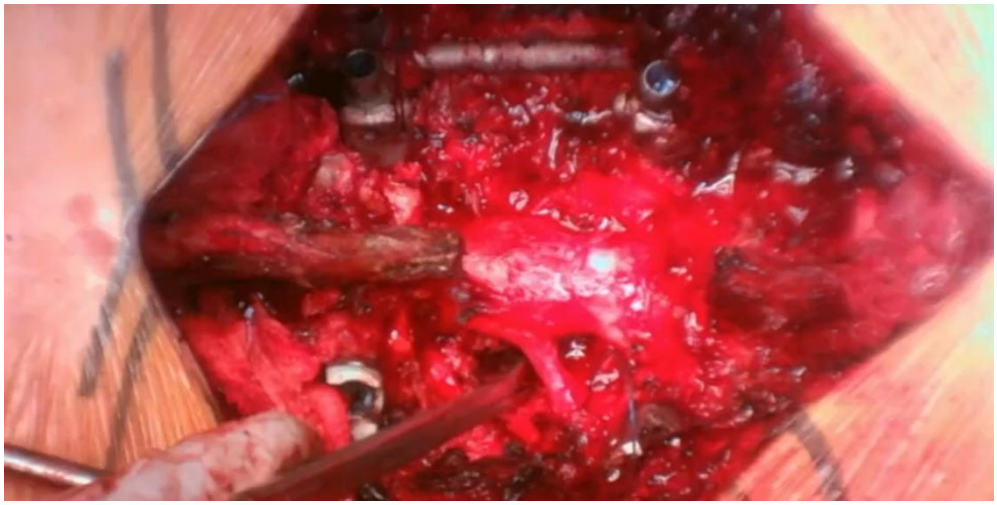
Options with corpectomy (decompression) + cage (anterior column reconstruction)

1. **Posterior-only**: posterior nerve-sparing L1 corpectomy with cage + T11-L3 posterior instrumented fusion.
   Advantages: circumferential decompression, avoidance of retropleural / retroperitoneal structures.
   Disadvantages: significant posterior element resection creates 3-column defect – needs quad rods and longer fusion.
2. **Lateral-only**: lateral retropleural / retroperitoneal corpectomy with cage + lateral plate & vertebral body screw construct.
   Advantages: saves fusion levels, allows wider endcap cage (lesser chance of cage subsidence).
   Disadvantages: requires partial rib resection and disconnection of diaphragmatic attachments to the lower ribs and L1 transverse process.
3. **Combined**: lateral retropleural / retroperitoneal corpectomy with cage + percutaneous posterior fixation.

Posterior nerve-sparing L1 corpectomy, ventral cage, T11-L3 posterior instrumented fusion

- prone positioning on **open Jackson table** - yields significant sagittal plane correction.
- neuromonitoring.
- T11 - L3 pedicle screws (T12 and L2 screws dual-headed)
- T12 - L2 **temporary rod** placement into outside heads:

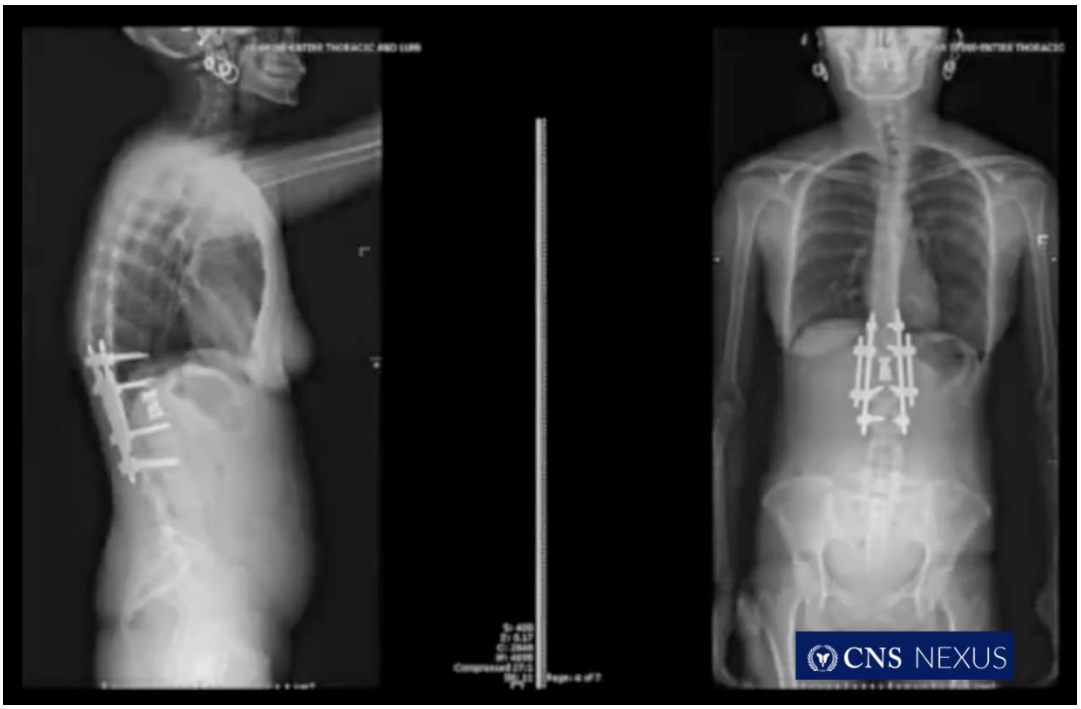
- posterior decompression - inferior T12 laminectomy, complete L1 laminectomy.
- T12/L1 & L1/2 facetectomies.
- identification of B/L T12 & L1 nerve roots.
- wide exposure and **mobilization of L1 nerve roots** lateral to DRG:



- T12-L1 and L1-2 **discectomies**.
- bilateral L1 **pediculectomy**.
- bilateral **trans-pedicular L1 corpectomy** using **8 mm coarse diamond drill bit** working above and below L1 nerve root.

  - large drill bit affords expeditious bone removal, and also inherently causes hemostasis.
  - periodically inject corpectomy defect with liquified hemostatic products (ie. FloSeal / Surgiflo) followed by packing with fibrillar Surgicel, cottonoids, and/or 4x4 gauze.
  - *piecemeal corpectomies* generally cause a fair amount of bone bleeding.
- anterior decompression - **ventral impaction of L1 dorsal wall** into corpectomy defect using down-facing curettes and impactor
  - especially important to properly *dissect PLL and retropulsed fragment away from dura* with Woodsen to avoid **ventral dural defect**; H: wrap thecal sac with dural substitute → fibrin glue → lumbar drain for 48 hours with flat bedrest.
- **ventral cage insertion** (cranial to L1 root);
  - assistant must gently retract L1 nerve root inferiorly (avoid excess traction).
  - cage orientation must be perpendicular to thecal sac → subsequently turned 90 degrees:


  - cage expansion is performed under fluoroscopy; may loosen temporary rod set screws to allow kyphosis correction.
  - *excess cage expansion* should be avoided (can lead to point-loading, and subsequent **subsidence**) – injured ligaments may not check expansion.
- **quad rod construct**;
  - compress across corpectomy site to optimize appropriate lordosis + ensure that cage does not migrate (avoid *non-physiologic over-lordosing* at thoracolumbar junction).
- extensive dorsal osseous defect - ribs and transverse processes are properly decorticated and grafted (fibular strut grafts may be helpful)



FLEXION-DISTRACTION injury, s. CHANCE fracture

- failure of MIDDLE and POSTERIOR column (ligamentous and/or bony) + varying degrees on ANTERIOR column collapse.
  - typical location - thoracolumbar region (T10-L2)
  - up to 50% of patients have associated intra-abdominal injuries – look for **"seat belt sign"**

SUBTYPES (dependent on *axis of flexion*):

CLASSIC CHANCE SUBTYPE, s. osseous Chance (although 2 columns disrupted, but classically **stable**!!!) - axis of flexion anterior to ALL:

1) horizontal fracture through *posterior and middle column bony elements* (spinous process, pedicles, transverse processes)
2) disruption of *supraspinous ligament* (increase in interspinous distance)

FLEXION-DISTRACTION SUBTYPE (**unstable***) - axis of flexion posterior to ALL: Classic Chance fracture + *anterior wedge fracture*.

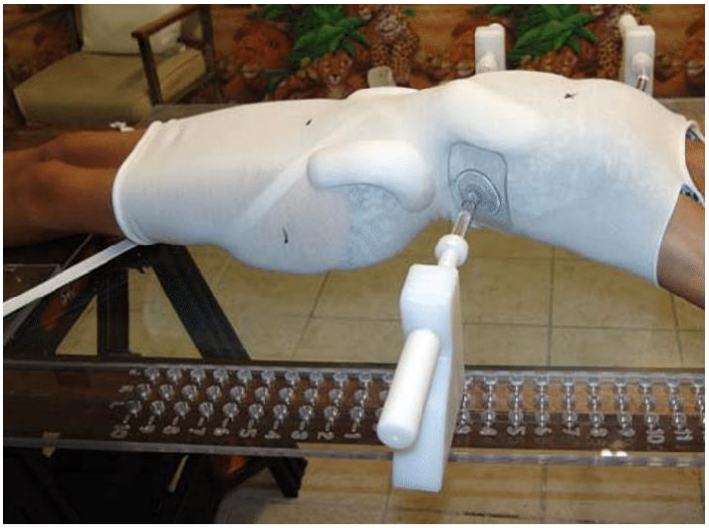
*all 3 columns are involved

SUBTYPES (by element injury):

a) **osseous** Chance injury - fractures of the spinous process, pedicles, and the vertebral body.
b) **ligamentous** Chance injury - rupture of the interspinous ligament, posterior longitudinal ligament, ligamentum flavum, facet joint capsule, and intervertebral disc.
c) **osteoligamentous** Chance injury – combination of osseous and ligamentous injuries.

TREATMENT

A) purely osseous injury + no neurological deficits → **TLSO** (thoracolumbosacral orthosis) for 8-12 weeks
   - chance fracture is reduced on a Risser table by applying hyperextension → custom-designed plaster or fiberglass is then applied:

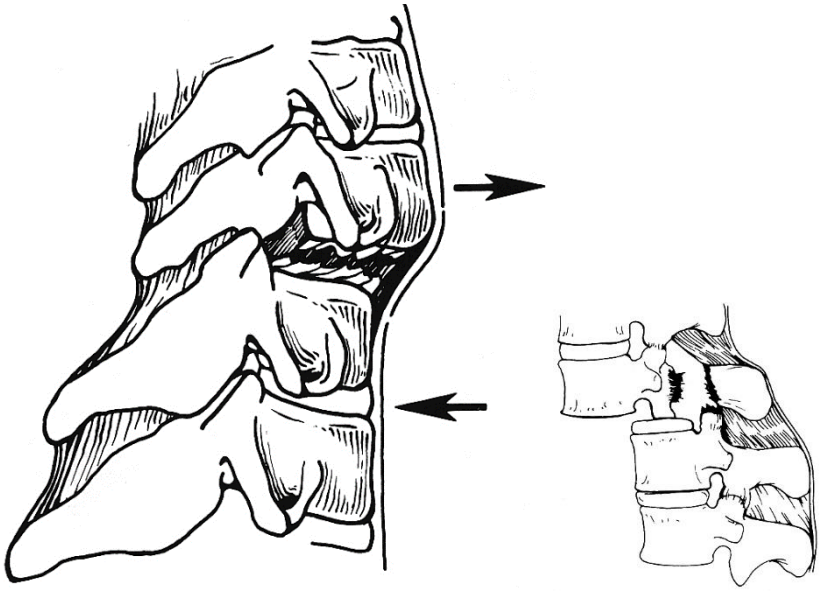


B) ligamentous injury (Magerl type B1), neurological deficits, kyphosis > 15 degrees, obese and large individuals → **surgery**: long-segment posterior fixation using pedicle screws, +/- interbody fusion, +/- decompression.
    - ligamentous injuries need longer instrumentations than purely osseus injuries.
    - if no need for decompression, may consider ***percutaneous techniques*** without arthrodesis.

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).

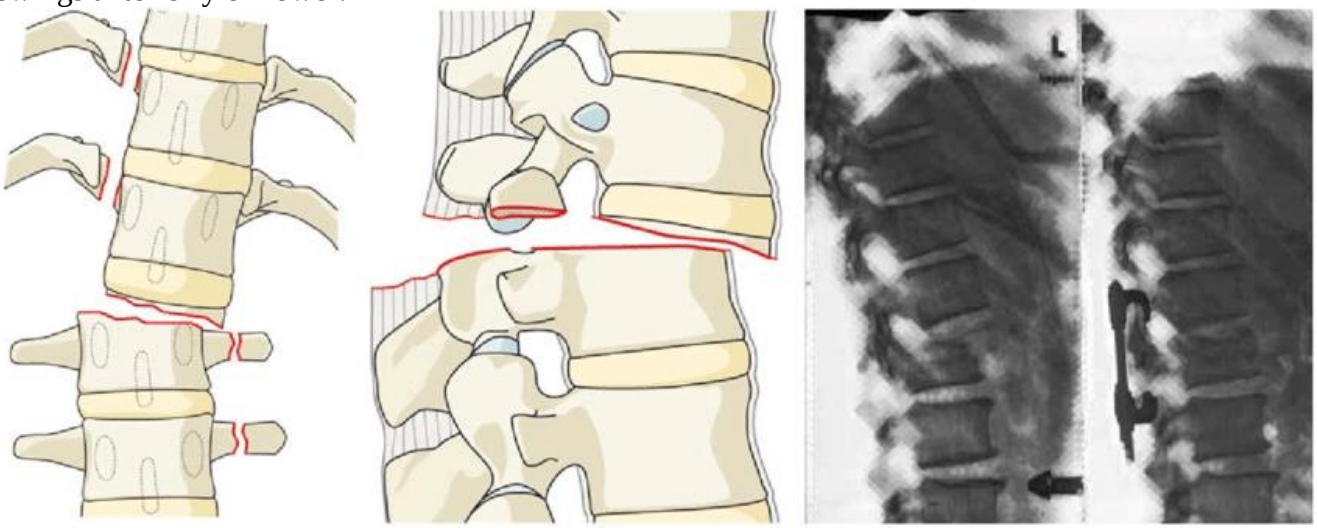


N.B. *percutaneous internal stabilization is contraindicated* if ligamentous complex and disc are disrupted!

- open reduction of locked facets – bilateral Smith-Peterson osteotomies to remove medial facets (reduction happens spontaneously).

"SLICE" FRACTURE-DISLOCATION, S. TORSIONAL / ROTATIONAL INJURY, HOLDSWORTH SLICE FRACTURE

(unstable)
- occurs in (thoraco)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:



- An unstable fracture dislocation of the thoraco lumbar junction of the spine.
- The injury comprises a fracture through a vertebral body, rupture of the posterior spinal ligaments and fractures of the facet joints.

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!)
  2) chronic ***steroid*** use
  3) vertebral ***malignancies*** (metastases, multiple myeloma)
  4) vertebral ***osteomyelitis*** (incl. tuberculous → gibbus).
  5) hyperparathyroidism
  6) prolonged immobilization
- most often - **thoracolumbar compression (wedge) fractures**.
  N.B. compression fracture → seek for treatable risk factors!
  – compression fractures above midthoracic region are suggestive of malignancy.

- many remain undiagnosed - present with ***progressive painless kyphosis or scoliosis***.
- others present with ***back pain*** and ***tenderness***.
- kyphoplasty is ideal for pain due to pathologic fractures due to metastases!!!

GUNSHOT WOUNDS TO THE SPINE

- SCI due to **civilian** GSWs are primarily due to direct injury from the bullet (unlike **military** weapons which may create injury from shock waves and cavitation).

INDICATIONS FOR SURGERY

1. Progressive neurologic deterioration – suggests **epidural hematoma**.
2. Compression of nerve root / cauda equina (whether complete or incomplete injury)
3. CSF leak.
4. Bullet lodged in disc space → plumbism (anemia, encephalopathy, motor neuropathy, nephropathy, abdominal colic)
5. To remove a copper jacketed bullet: copper can cause intense local reaction.
6. Debridement to reduce the risk of infection:
    - military GSW (massive tissue injury)
    - bullet has traversed GI or respiratory tract
7. **Spinal instability**: very rare with isolated GSW to the spine.
8. **Incomplete SCI**: very controversial - some series show improvement with surgery, others show no difference from unoperated patients.