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"I think a hero is an ordinary individual who finds strength to persevere and endure in spite of overwhelming obstacles. "

Christopher Reeves

Outline of Chapter

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I. Cervical Spine Trauma

Neurology, instability and deformity are the core reasons for any spinal intervention. Perhaps one of the most devastating afflictions that an individual may experience is a traumatic cervical spine cord injury. The major determinant of neurologic prognosis is dependent on the severity of the primary injury itself. Addressing the secondary injury mechanism and stability issues, becomes the paramount concern of spinal intervention. Most of the advances in further injury prevention, and complication avoidance has shown to improve the mortality and morbidity rates of patients with spinal cord injuries.

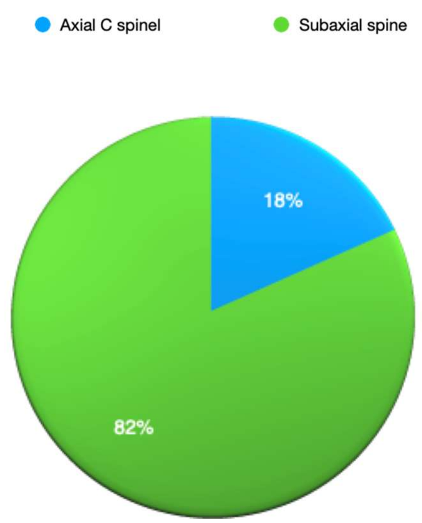
An insult to the cervical spinal cord that leads to temporary or permanent deficit with regard to motor, sensory or autonomic function is a spinal cord injury (SCI). Direct injuries are injuries to the spine caused by penetrating trauma or missile injuries. Indirect spinal trauma occurs when supraphysiologic loads act on the spine causing injury to the spinal cord. The resultant of forces causes subsequent failure of the spine most especially in the transitional zones. Cervical spine injury should be excluded for all patients with a history of blunt trauma. This high index of suspicion can prevent devastating complications that may arise if stability issues are not adequately addressed. Since most cervical spine injuries result from an indirect force applied to a segment of the spine, hence the transitional zones, such as the occipital cervical and cervicothoracic junction will be affected.

a. Epidemiology

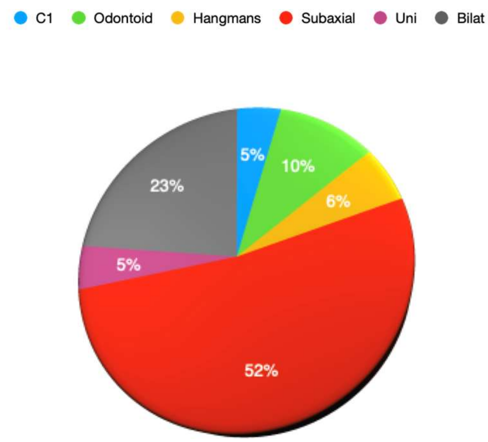
In the USA, there are 7,000 to 10,000 patients with cervical spine injuries who present for treatment annually. An estimated 5,000 additional patients with cervical spine injuries die at the scene of the accident. Almost half of cervical spine injuries are associated with spinal cord injury. Spinal cord injury most often occurs in teenagers and young adults.

Overall about 82% of all patients are males. The three most common causes of spinal fractures are motor vehicle accident (50%), falls (25%), and sports injuries (10%).

In a 10-year review (2009-2019) of spinal trauma admitted at the PGH, cervical spine trauma comprises 40 percent of all spinal cord injury admissions. Majority of the admissions were sub-axial cervical spine injuries 82%. The injuries to the atlantoaxial complex was 18%. The mechanism for injuries were mainly vehicular accidents and falls.



The axial injuries were 18 percent of all cervical spine injuries (n=18) and the rest were subaxial injuries (N=80). Among the axial spine injuries, there were 4 C1 fractures, 9 odontoid fractures and 5 Hangman's fractures. Sub-axial fractures were seen in 46 patients, 4 unilateral facet dislocations and 20 bilateral facet dislocations. There were 10 unspecified cervical fractures.

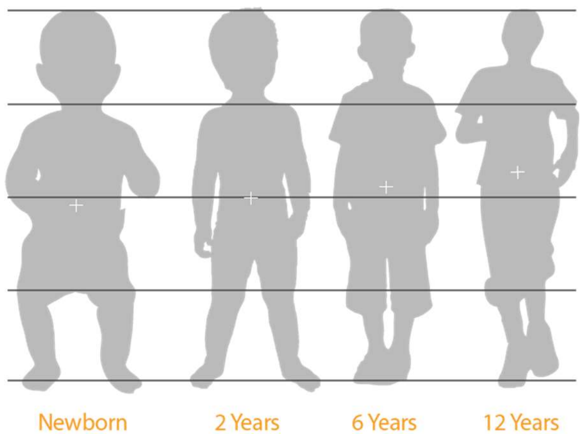


b. Patho-mechanics

Trauma to the cervical spine may produce different clinical syndromes. Spinal cord pathology on dependent on two points: The initial or primary trauma and the subsequent secondary insult from ischemia, hemorrhage and edema. The primary injury to the spine is dependent also on two things: The amount of force applied and the position of the neck upon application of the force. The specific anatomical structure and location of injury that the cervical spine sustains is dependent in the mechanism of injury applied. It is also sensitive to the initial position of the head relative to the neck, the rate of loading and the degree to which the neck is constrained also affect the tolerance. Individual parameters, including the presence of preexisting pathology or deformities, as well as the geometry and bone density, also affect biomechanics.

Multiple mechanisms of injury to the cervical spine have been defined. The more common mechanism of injuries includes: Flexion, extension and lateral rotation; hyper flexion and axial loading.

Pediatric cervical spines behave differently from adult on due to anatomic features including proportionately heavier heads as well as material differences including greater ligament laxity and growth centers that are susceptible to shear forces. The injury may occur with the continuous motion of the head relative to the stabilized thorax. It is with sufficient force to load the cervical spine beyond its tolerances that injury occurs. Injury may occur even without contacting the vehicle interior this forceful movement.



This picture shows the difference in head proportion as a child develops

II. Immediate care:

Immediate or emergent care for traumatic injuries of the cervical spine should not differ from the care given to all trauma patients. It must be assumed that the victims have cervical trauma if they are unconscious and during extrication. The hierarchy of airway breathing, and circulation remain the cornerstone of initial management. The cervical spine should be stabilized by a rigid collar during extrication.

Airway management of cervical spine patients is challenging but should addressed. A patient who is combative or with a high risk for aspiration, extra care is needed when performing intubation. Endotracheal intubation should be performed via the oral route with a rapid sequence induction with manual in-line stabilization. The airway management team demands a physician who is experienced in airway control techniques.

Hypotension occurs in the cervical spine injury patient. This usually caused by hemorrhage or neurogenic shock. Maintenance of normal blood pressure also prevents secondary ischemic changes. A target MAP of 85 mmHg should be maintained in the first 5 days. Vital signs are often confusing in acute spinal cord injury because of an increased incidence of associated injuries. A diligent search for occult sources of hemorrhage must be made. The common areas where occult hemorrhage maybe present include the chest, abdomen, retroperitoneum and fractures of the pelvis or long-bones. Appropriate investigations, including radiography or computed tomography (CT) scanning, are required. In the unstable patient, diagnostic peritoneal lavage or bedside FAST (focused abdominal sonography for trauma) ultrasonographic study may be required to detect intra-abdominal hemorrhage.

Once hemorrhage is ruled out as a cause for hypotension, initial treatment of neurogenic shock focuses on fluid resuscitation. Judicious fluid replacement with isotonic crystalloid solution to a maximum of 2 L is the initial treatment of choice. Overzealous crystalloid administration may cause pulmonary edema, because these patients are at risk for the acute respiratory distress syndrome (ARDS).

Once the primary resuscitation is complete and stable, splinting and transport of the injured patient becomes a critical part of avoiding long term disabilities. The current recommendation is that a cervical collar should be put on a suspect cervical injury patient.

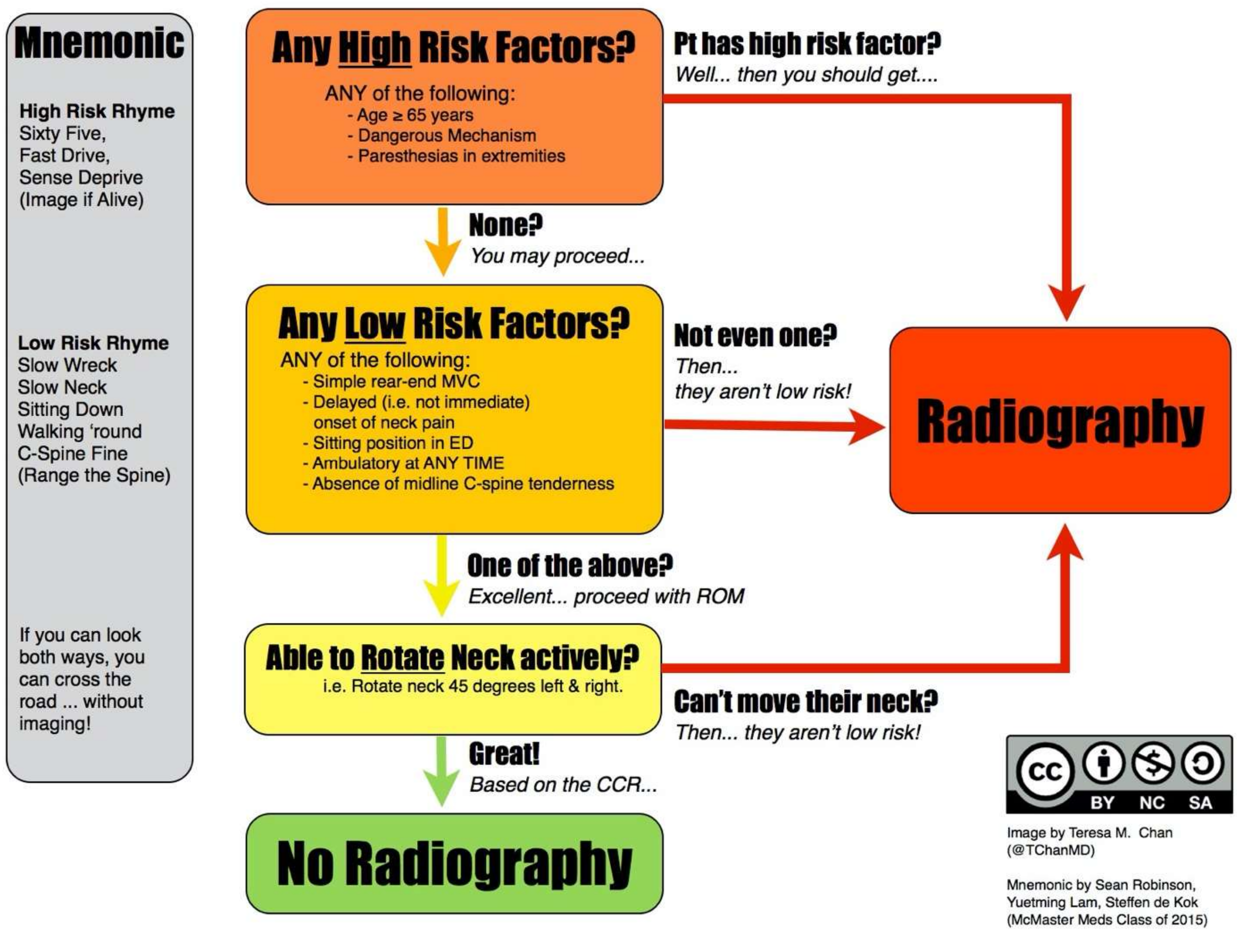
The head is initially stabilized by the first person on the scene. A collar is then applied with supportive blocks on either side of the head. The head can be immobilized further with adhesive. Sandbags, newspapers and cartons maybe used to stabilize the patients neck though the stability it offers at best is questionable.

While the head is stabilized by the initial person on the scene, the patient should be transferred to a rigid spine board. Transfer can be accomplished either using a log roll with subsequent spine board insertion or a 6-person lift (lift-and-slide) technique. When the patient is seen supine, the 6-person lift is recommended, using a scoop stretcher placed under the patient, who is lifted about 4 to 6 in (10 to 15cm) while the spine board is slid underneath. The patient is then lowered down onto the spine board and strapped to it. At least 3 straps should be used to secure the torso, pelvis, and legs. The head should be secured with towels, blankets, or commercial head immobilizers and then secured to the board with tape. Once the patient is secured to the spine board and strapped down (body first, followed by the head), transport can begin.

III. Imaging modalities

When to order x-rays

Effectively ruling out a cervical spine injury is important to all trauma patients. Routine radiographs, however, is not advisable. Radiographs to the C spine are relatively cheap, but because of its inefficient use, patients are subjected to unnecessary radiation, as well as an additional burden to the healthcare system. There are two decision making algorithms available for deciding whether cervical spine x-ray should be taken, the Nexus and the Canadian C spine rule. The Nexus criteria offers the advantage that it relies mainly on the history and no manipulation is done to the patient. The Canadian C spine rule uses history combined with a few physical examination maneuvers. Recently, it was demonstrated that the Canadian C spine rule was more sensitive (99.7 %) to its American predecessor.



What to Order

A standard C spine series should include the Cervical Lateral, AP and Open mouth views. The Lateral views are usually taken first, and can be done without removing the collar. All 7 cervical vertebrae and C7-T1 junction must be visualized because the cervicothoracic junction is a common place for traumatic injury. The visualization of C7-T1 may be limited by the amount of soft tissue in the shoulder region especially in the obese individuals. These can be rectified by Pulling or traction on arms if no arm injury is present, or, swimmer's view (taken with one arm extended over the head).

Interpretation

Initial evaluation of the radiographs requires an organized checklist to make sure nothing is missed. The author frequently uses the Mnemonic AABCDE. A1 is adequacy of radiographs, A2 is alignment, B is bone, C is Cartilage space and S is soft tissue.

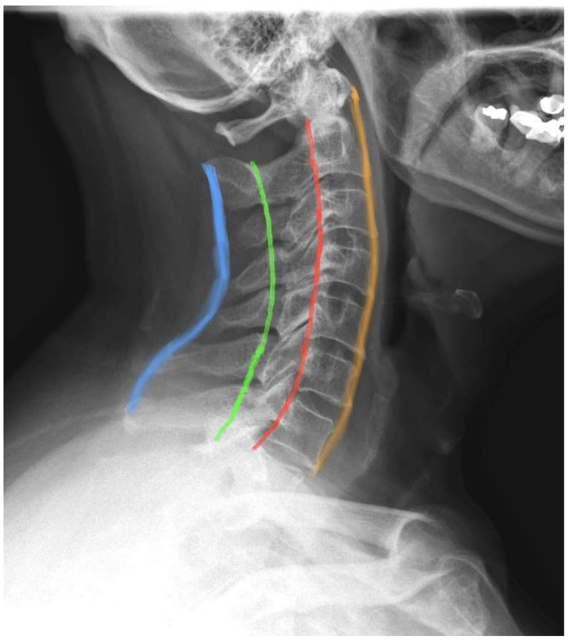
An ***A****dequate* C spine xray should show all 7 vertebrae. The contrast between bone and soft tissue should be appreciated. Evaluation of the ***A****lignmen*t should focus on several lines from anterior to posterior of the C spine. A harmonious relationship should be demonstrated. Any subluxation should be closely analyzed.

B*ony landmarks* should be evaluated. The Anterior vertebral height should almost be equal with the posterior vertebral height. The spinous processes, facet joints, lateral masses and pedicles should be inspected. The ***C****artilage space* should be evaluated. In the C1C2 area there is a normal distance between the anterior arch of C1 and the Odontoid process of C2 , this is the atlanto dens interval (ADI) . This should not measure more than 3 mm in adults and 5 mm in children.

D*isk Spaces* should approximately be equal and symmetric. In the elderly individuals these maybe sclerotic.

Evaluation of soft tissue: Careful inspection of the retro pharyngeal space and the retrotracheal space may reveal prevertebral swelling. This correlates poorly with the injured segment but provides us clues that there is injury in a specific area. Anterior to C2 to C4, the retro pharyngeal space often measures less than 5 – 7 mm.

Anterior to C5 to C7 the retro tracheal space measures less than 14 mm (in



Cardinal lines for X-ray evaluation
Yellow Anterior vertebral line
Red Posterior vertebral line
Green Spinolaminar line
Blue. Posterior spinous line

children) and less than 22 mm (Adults).

Imaging beyond conventional x rays

Up to one fifth of all injuries maybe missed with plain radiographs. Additional techniques utilized for the evaluation of the Cervical spine patient may be utilized. These include dynamic views, CT scans and MRIs.

Dynamic views are utilized the determine the in vivo stability of the C spine. In patients without instability in passive xrays, these maybe utilized. It is done in the lateral position and patient is advised to voluntarily flex and extend his neck.

CT scans are extremely useful in the evaluation of bony pathology. An adequate CT scan should be at the most have 1.5 mm interval cuts. It should also have sagittal and coronal reconstruction. It has limited use in the evaluation of soft tissues.

Magnetic Resonance Imaging (MRI) is an ancillary test that can provide superior imaging of soft tissue. It has become the gold standard for imaging patients with neurologic deficits. Its high cost is the main deterrent for its use. Magnetic resonance imaging (MRI) is best for suspected spinal cord lesions, ligamentous injuries, or other soft-tissue injuries or pathology. This imaging modality should be used to evaluate non-osseous lesions, such as extradural spinal hematoma; abscess or tumor; disk rupture; and spinal cord hemorrhage, contusion, and/or edema. Neurologic deterioration is usually caused by secondary injury, resulting in edema and/or hemorrhage. MRI is the best diagnostic image to depict these changes.

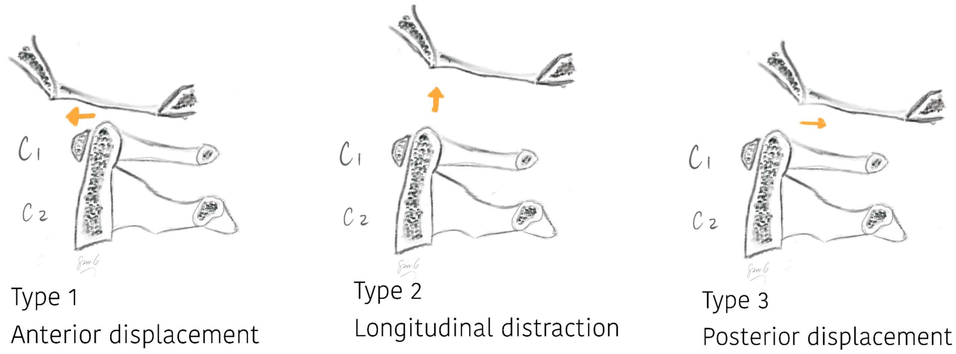
IV. Injuries to the atlanto-axial complex

Atlanto-axial complex injuries comprise about 1/5 of all cervical spine injuries seen at the PGH. The joints that connect the skull to the spine have to react to an increased amount of stress in a traumatic situation. The weight of the head compared to the relatively small size of the joints, together with the long lever arms that act upon it, subsequently cause a failure in the atlanto-axial complex. These have a potential to cause high spinal injuries that can compromise the respiratory physiology of the patient. While most patients can be managed initially with a rigid collar and traction, there are 2 instances when traction is contraindicated. These include: Type 2 atlanto-occipital dissociation and Type 2a traumatic spondylolisthesis of C2 over C3.

a. Atlanto-occipital dissociation

Atlanto-occipital dissociation (AOD) represent a highly unstable injury. The damage is directed to the bones and soft tissues that connect the spine to the skull. It is the most common cervical spine injury that results in 5 to 8% of on-site mortality. It also accounts for a third of all cervical spine injury mortality. Children are most at risk for these injuries owing to the flatter shape of the occipito-atlantal joint and a relatively higher mass of the head compared to the body.

Patients may present, in addition to spinal cord injury, cranial nerve deficits and vertebral artery syndrome. Initial radiologic exam will show swelling of the posterior pharyngeal shadow at C3. The injury patterns for AOD was discussed by Treynelis and classified as Type 1 anterior displacement of the , Type 2 longitudinal displacement and type 3 posterior displacement. Traction should never be applied to type 2 injury as this can

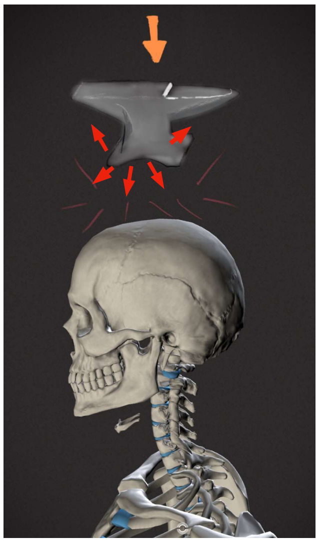


worsen neurologic status.

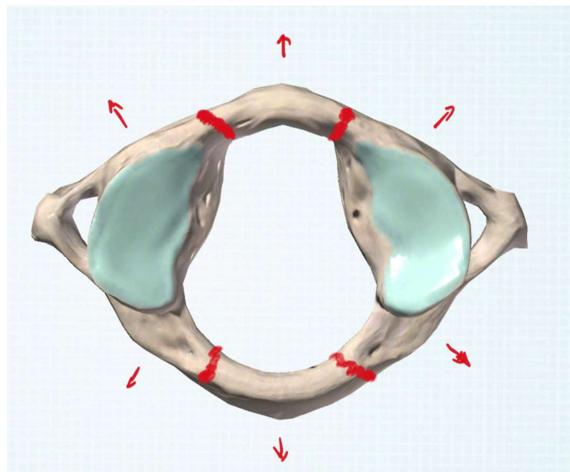
b. Atlas ring fractures

This was classically described by Jefferson in 1921. It is caused by sudden axial loading to the head can cause a compressive downward force of the occiptal condyles to the atlas. The fracture is caused by a failure of the lateral masses of C1 and forces them to burst out laterally. Further compression causes the anterior and posterior arches to fail, with possible disruption of the transverse ligament. Subsequent fracture of the ring occurs in a burst manner. Half of the patients with this fracture would present with other cervical spine injuries.

Patients would present with sub-occipital pain often and neurology injury is rare. On open mouth radiographs the lateral masses are seen extending beyond the articular pillars of C2. Lateral radiographs show angular displacement of the posterior arch.



The common mechanism of a burst fracture of C1 is axial loading.



The axial load is transmitted thought the ring, causing failure along the circumference of C1.

c. **Odontoid fractures**

The odontoid process allow the C1 vertebra to pivot over the C2. It is the most commonly fractured bone in the occipito-cervical area. Fortunately the abundance of space present in the canal account for a relatively low incidence of neurologic injury in this area. Prognosis is primarily determined by the anatomical area that is fractured.

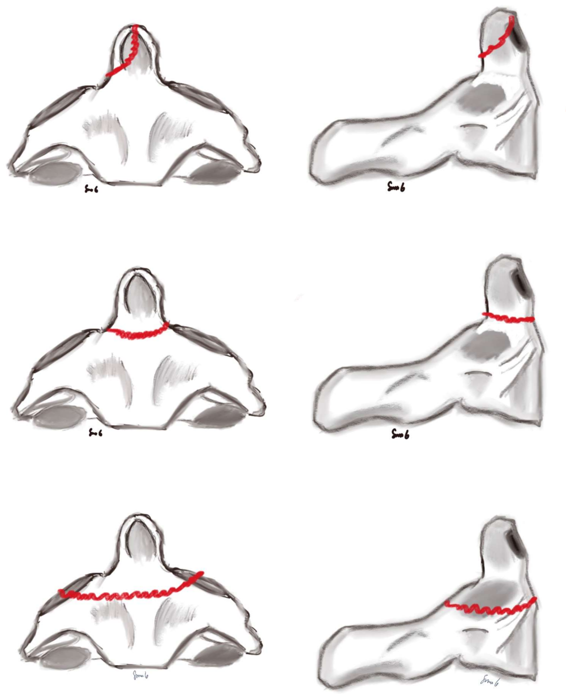
Type I odontoid fracture is an avulsion of the tip of the dens at the insertion site of the alar ligament. A type I fracture is mechanically stable, but it may be associated with atlanto-occipital dislocation. It must be ruled out because of this potentially life-threatening complication.

Type II fractures occur at the base of the dens and are the most common odontoid fractures. This type is associated with a high prevalence of nonunion due to the limited vascular supply and small area of cancellous bone.

Type III odontoid fracture occurs when the fracture line extends into the body of the axis. Nonunion is not a major problem with these injuries because of a good blood supply and the greater amount of cancellous bone.

With types II and III fractures, the fractured segment may be displaced anteriorly, laterally, or posteriorly. Since posterior displacement of segment is more common, the prevalence of spinal cord injury is as high as 10% with these fractures.

Initial management of a type I dens fracture is use of a rigid cervical orthosis. Management of types II and III odontoid fractures is initially done by applying traction. Once stable and reduced, surgical stabilization is done.



Type 1 odontoid fracture
Treated with rigid orthosis

Type 2 odontoid fracture
Treated with surgical stabilization
Prone to non union

Type 3 odontoid fracture
Treated with rigid orthosis and surgery

d. Traumatic spondylolisthesis of C1 over C2(Hangman's fractures)

The name of this injury is derived from the typical fracture that occurs after hanging. Presently, it commonly is caused by motor vehicle collisions and entails bilateral fractures through the posterior half of the C2 due to hyperextension.

Radiographically, a fracture line should be evident through the neural arch of C2, along with obvious disruption of the spinolaminar contour line. Although considered an unstable fracture, it seldom is associated with spinal injury, since the anteroposterior diameter of the spinal canal is greatest at this level, and the fractured pedicles allow decompression.

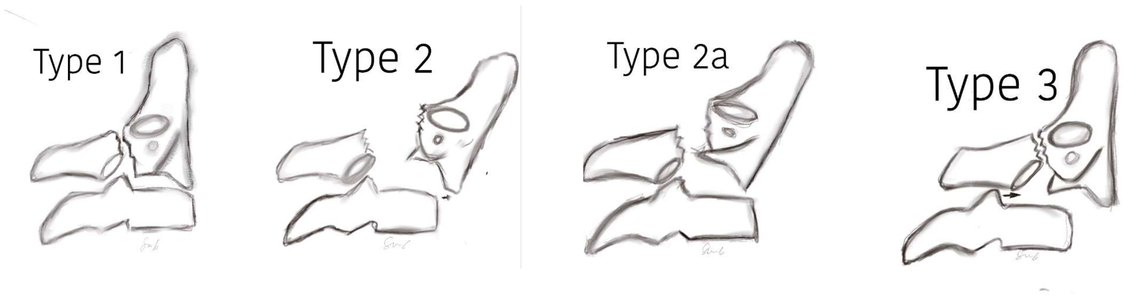
Eismont created a classification system for these injuries.

Type 1 The fracture line crosses the pars interarticularis bilaterally and has no more than 3 mm of anterior displacement. These fractures are treated with a rigid cervical collar for 8 to 12 weeks.

Type 2 The fracture line crosses through the pedicles. Translation is more than 3 mm and angulation of the C2 over the C3. These are treated initially with traction and subsequently with application of halo vest.

Type 2a The fracture shows severe angulation of the C2 over the C3 but with less than 3 mm of anterior displacement. All posterior structures are disrupted, hence only the anterior longitudinal ligament remains as the primary stabilizer. Traction should never be applied to these patients. Treatment is usually includes immediate application of halo vest traction.

Type 3 The fracture occurs with unilateral or bilateral facet dislocation. Severe anterior displacement is usually seen. These patients are treated with traction subsequently with fusion.



Classification system of Hangman's fracture by Eismont

V. Subaxial Spine

Majority of cervical spine injuries occur at the subaxial spine . The subaxial vertebra is tasked with providing neck mobility while protecting the spinal cord, nerve roots and the vertebral artery. It progressively increases in size as the spinal unit casually has to carry a higher mass. There are numerous classification system for sub-axial spine assessment. As of this writing the Subaxial Spine Injury Classification System (SLIC) is the most useful in our opinion. Three domains are evaluated namely fracture morphology, Disco-ligamentous complex and Neurologic function. A score of less than 4 is treated non operatively, more than 4 operatively and a score of 4 can be treated either with surgery or conservatively. Special attention must be given in assessing the posterior ligamentous structures as injury confirmed injury to this usually determines the subaxial cervical spine as unstable and thus should be managed surgically.

	SLIC Classification	
1	**Fracture morphology**	**Score**
	None	0
	Compression	1
	Burst	2
	Distraction	3
	Rotation/Translation	4
2	**Disco-Ligamentous Complex**	
	None	0
	Indeterminate	2
	Disrupted	3
3	**Neurologic Function**	
	Intact	0
	Root injury	1
	Complete cord injury	2
	Incomplete cord injury	3
	Ongoing compression with deficits	1

a. Anterior Compression

This is an injury which causes the vertebral body to fail secondary to a force applied in flexion with axial loading. This is usually a stable injury if the posterior disco ligamentous complex is intact. Care must be take to analyze the stability of the posterior disco ligamentous complex for the presence of distraction, rotation or translation.

b. Burst Fracture

Subsequent propagation of the deforming forces described in the anterior compression injury leads to a burst fracture. The hoops stresses arising from the rapid force propagation causes the vertebral body to fail. Usually these injuries are stable if patients have no neurology injury. An intact posterior disco ligamentous complex is a good prognostic factor in favor for conservative management in most cases.

c. Facet dislocations

Unilateral facet dislocation occurs when flexion, along with rotation, forces one inferior articular facet of an upper vertebra to pass superior and anterior to the superior articular facet of a lower vertebra, coming to rest in the intervertebral foramen. Although the posterior ligament is disrupted, vertebrae are locked in place, making this injury stable. Radiographically, the lateral view shows an anterior displacement of the spine at the involved level of less than one half the diameter of the vertebral body. This is in contrast to the greater displacement seen with a bilateral facet dislocation, as discussed above. The anteroposterior view is useful in diagnosis of unilateral dislocation because it shows a disruption in the line connecting the spinous processes at the level of the dislocation.

Bilateral facet dislocation is an extreme form of anterior subluxation that occurs when a significant degree of flexion and anterior subluxation causes ligamentous disruption to extend anteriorly, which causes significant anterior displacement of the spine at the level of injury. This injury involves the annulus fibrosus, anterior longitudinal ligament and posterior ligamentous complex. At the level of injury, ie, the upper vertebrae, inferior articulating facets pass superior and anterior to the superior articulating facets of the lower involved vertebrae because of extreme flexion of the spine. Radiographically, this is seen as a displacement of more than half of the anteroposterior diameter of the vertebral body in the lateral view.

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