

Cervical Spine Injury: An Evidence-Based Evaluation Of The Patient With Blunt Cervical Trauma

It's 2:30 AM and the bars have just closed. EMS brings an uncooperative, intoxicated 40-year-old male to your emergency department who was the driver of a vehicle that ran into a house. He has no complaints other than the need to urinate, and he wants the cervical collar off. He is verbally abusive, refuses to lie still on the backboard, is trying to take his collar off, and wants to leave. The nurse hands you an AMA form then wonders aloud why you are ordering a cervical spine film on a patient with no complaints; she also wonders how you plan to keep the patient still while he waits for the study.

The cervical spine, its contents, and its precarious interposition between a 70 kg body and a 10 kg head make it susceptible to mechanical failure. This can lead to catastrophic neurologic injury.¹ Emergency physicians have the unique responsibility among medical specialists in determining who is at risk for a cervical spine injury. A patient with neck pain and neurologic findings after a high-speed motor vehicle collision (MVC) clearly requires diagnostic evaluation. On the other hand, patients with altered mental status (eg, from dementia or drug intoxication) with a worrisome mechanism for cervical spine injury despite the absence of pain or tenderness on examination pose a more complicated clinical decision-making challenge, which can be made even more complicated if they are uncooperative. Part of the job

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CME Objectives

Upon completion of this article, you should be able to:

1. Identify the common signs of cervical spine trauma.
2. Optimize resource utilization and minimize identification failure in the treatment of cervical spine injuries.

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description for emergency physicians is to diagnose problems or injuries that do not seem apparent on first glance and proactively identify and treat these problems and injuries before they become catastrophic. This issue of *Emergency Medicine Practice* addresses cervical spine injuries by providing a systematic approach that optimizes resource utilization and minimizes identification failure.

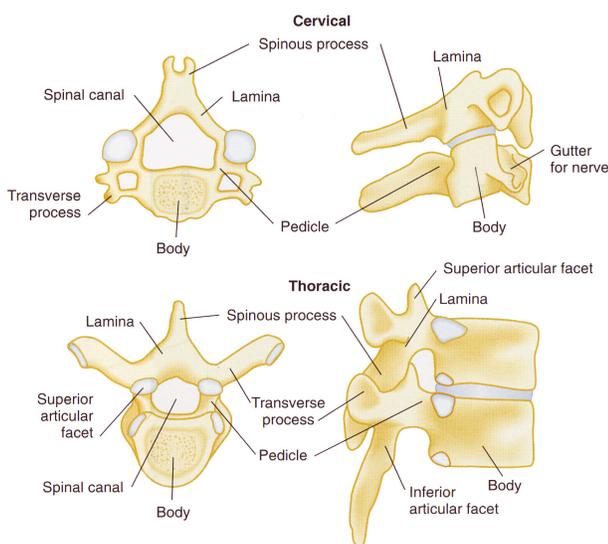
Critical Appraisal Of The Literature

A literature search was conducted using: Ovid MEDLINE and the Cochrane Library (including the Cochrane Database of Systematic Reviews and the Cochrane Controlled Trials Registry). Searches were limited to English language sources and human subjects. Search terms included cervical spine injuries, pediatric, missed, radiologic evaluation, and treatment. More than 250 articles were reviewed.

Epidemiology

Spinal cord injury is the dreaded result of cervical spine trauma. Spinal cord injury can occur in the absence of cervical spine fractures, and the presence of a cervical spine fracture does not necessarily result in spinal cord injury. The National Spinal Cord Information Database (NSCID) has been collecting epidemiologic data on spinal cord injuries in the United States since 1973.² According to the NSCID, the number of people living with spinal cord injuries is estimated to be approximately 253,000. The esti-

Figure 1. Diagram Of Typical Vertebrae From The Spinal Column



Reproduced with permission from: Rosen Hockberger RS, Kaji AH, Newton EJ. Ch. 40 Spinal Injuries (figure 40.1). In: Marx JA, Hockberger RS, Walls RM, et al. *Rosen's Emergency Medicine: Concepts and Clinical Practice*, 6th ed. 2006; Mosby:Philadelphia.

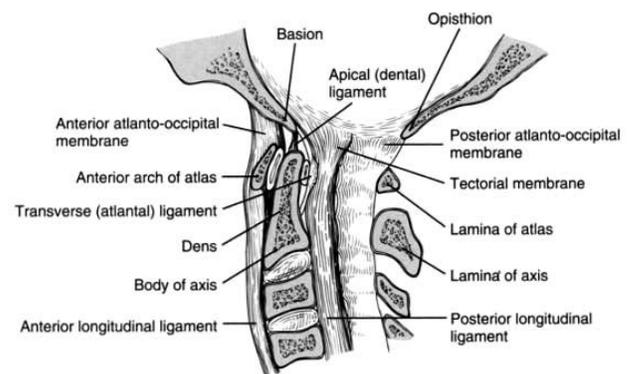
mated annual incidence of spinal cord injury (SCI), not including those who die at the scene of the accident, is approximately 12,000 new cases each year.²

Historically, spinal cord injuries have been most prevalent in young males. Males are at a much greater risk of suffering from a spinal cord injury than females due to increased risk-taking behavior and alcohol intoxication. Since 2000, 77.8% of spinal cord injuries have occurred in males.² The average age at time of injury for SCI from 1973-1979 was 28.7 years, with most injuries occurring in patients 16 to 30 years old.² In recent years, the number of older individuals who suffer from these injuries has been steadily increasing. Since 2005, the average age at the time of injury is 39.5 years, and the percentage of patients older than 60 years at the time of injury has increased from 4.7% before 1980 to 11.5% since 2000.² The incidence of cervical spine injuries among blunt trauma patients progressively increases with age.²

The pediatric population differs from adults both anatomically and developmentally, which seems to provide some protection against SCI. Children tend to have less exposure to high energy mechanisms of injury and high-risk behaviors when compared to older individuals, which is consistent with the dramatic rise in cervical spine injuries that occur in the late teenage years when most minors are beginning to drive. There are approximately 1000 reported SCIs annually in the pediatric population in the United States.² Young children are more susceptible to high cervical injuries than older children. Close to 80% of injuries affecting these areas occur in children less than 2 years old.²

Since 2005, the majority of patients with spinal cord injury are victims of motor vehicle collisions or falls. Motor vehicle collisions account for 42% of cases, falls account for 27%, sports-related injuries account for 7.4%, and acts of violence account for approximately 15% of SCIs.²

Figure 2. Sagittal Anatomy Of The Cervicocranium



Reproduced with permission from: Browner BD, Jupiter JB, Levine AM, et al, eds. *Skeletal Trauma: Basic Science, Management and Reconstruction*, 3rd ed. (figure 28.1). Elsevier: Philadelphia 2003.

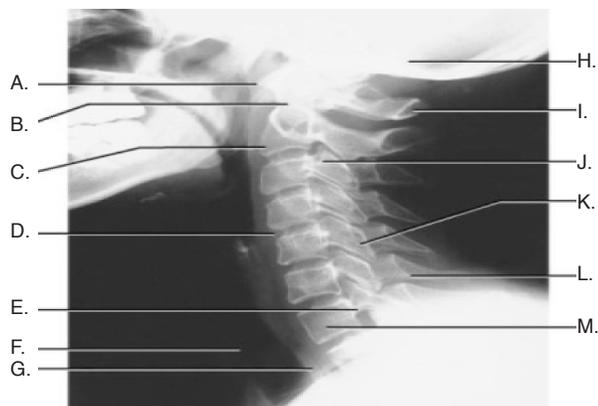
Anatomy

The cervical spine consists of 7 vertebrae that are separated from one another by intervertebral disks and connected by a complex network of ligaments. (See Figures 1-4.) It can be best visualized as consisting of an anterior and a posterior column. The anterior column is formed by vertebral bodies and disks held in alignment by the anterior and posterior longitudinal ligaments. The posterior column contains the spinal canal, which is formed by the pedicles, transverse processes, articulating facets, laminae, and spinous processes. It is held in alignment by the nuchal ligament complex, the capsular ligaments, and the ligamentum flavum. If both columns are disrupted, the spine will move as 2 separate pieces thus jeopardizing the integrity of the spinal cord. In contrast, if only 1 column is disrupted the other column resists further movement, and the likelihood of a spinal cord injury is less. The vertebral artery travels through the foramen transversarium throughout the course of the cervical spine. Because of the lack of intrinsic bony stability, integrity of the ligamentous anatomy is essential.

Prehospital Treatment

Spinal immobilization is one of the most frequently performed procedures in the prehospital care of trauma patients in North America. While clinical and biomechanical evidence suggest that spinal immobi-

Figure 3. Normal Anatomy Of The Cervical Spine In The Lateral Projection



- | | |
|---------------------------|--------------------------------------|
| A. Anterior arch of C1 | H. Occipital bone |
| B. Odontoid process of C2 | I. Posterior arch of C1 |
| C. Body of C2 | J. Inferior articulating facet of C5 |
| D. C4-5 disk space | K. Superior articulating facet of C5 |
| E. Pedicle of C7 | L. Spinous process of C6 |
| F. Trachea | M. Body of C7 |
| G. Esophagus | |

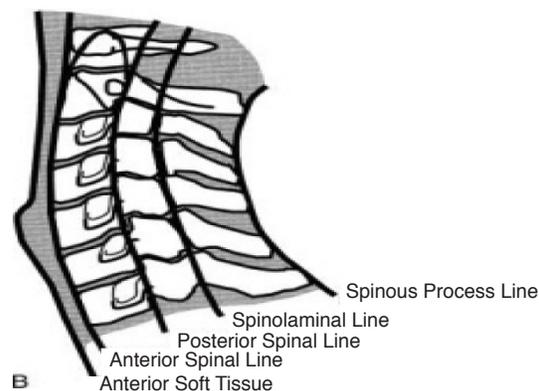
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lization limits pathologic motion of the injured spinal column, there is no rigorous evidence to support the need for spinal immobilization in all patients following trauma.³ In a 2003 Cochrane review, no randomized controlled trials that evaluated prehospital spinal immobilization in trauma patients were identified.⁴

In 2005, Kwan et al did a comprehensive review of randomized controlled trials of spinal immobilization on healthy participants. Seventeen randomized controlled crossover trials comparing the various types of spinal immobilization devices in 529 healthy volunteers 7 to 85 years of age were identified. Of note, substantial amounts of head and neck motion were reported regardless of whether rolled towels or foam wedges were used. A comparison of these 3 devices showed no significant difference in the efficacy of reducing head and neck movements.⁵

Despite its widespread use, the clinical benefits of prehospital spinal immobilization have been questioned. The current protocol for prehospital spinal immobilization has a strong historical rather than scientific precedent based less on objective evidence and more on the concern that a patient with an injured spine may deteriorate neurologically without immobilization.⁶ Spinal immobilization has never been proven to prevent secondary spinal injury.⁷ It has also been argued that considerable force is required to fracture the spine at initial impact and any subsequent movements by routine handling and transport are unlikely to cause further damage to the spinal cord. Estimates in the literature regarding the incidence of neurological injury due to inadequate immobilization may have been exaggerated.^{7,8} Approximately 5 million patients in the United States receive spinal immobilization every year, regardless of chief complaint, largely in response to the fear of doing harm due to unrecognized occult fractures.⁹

Figure 4. Normal Anatomy Of The Cervical Spine (Diagrammatically)



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Still, there are examples of patients whose spinal cord injury occurred after immobilization devices were removed and the patient was allowed to move his or her neck. While this may occur infrequently, it can be catastrophic when it does occur.

Helmet Removal

Although cervical spine injuries involving patients wearing helmets are relatively uncommon, when they do occur, they present a unique and sometimes difficult diagnostic and therapeutic challenge. In addition, shoulder pads worn by football, hockey, and lacrosse players further complicate the treatment of these patients. The management of the helmeted patient with a potential neck injury begins at the scene with proper immobilization and positioning. Immobilization of the neck in the neutral position restricts movement of the unstable vertebral column in an effort to prevent damage to the spinal cord and nerve roots. In almost all cases, the helmet and shoulder pads should not be removed prior to arrival in the ED; the facemask can be carefully removed to allow better visualization and access to the patient's airway.

The National Collegiate Athletic Association (NCAA) published helmet removal guidelines as part of a consensus statement by the Inter-Association Task Force for Appropriate Care of the Spine-Injured Athlete.²³ The NCAA has stated that, unless there are special circumstances such as respiratory distress coupled with an inability to access the airway, the helmet should never be removed during prehospital care of the student athlete with potential head/neck injuries unless:

- a. the helmet does not hold the head securely, such that immobilization of the helmet does not immobilize the head;
- b. the design of the sport helmet is such that even after removal of the facemask, the airway cannot be controlled or ventilation provided;
- c. after a reasonable period of time, the facemask cannot be removed; or
- d. the helmet prevents immobilization for transportation in an appropriate position.

If the helmet is removed prior to ED arrival, the shoulder pads should also be removed to prevent extension of the cervical spine.²³ (See Table 1 for a description of the helmet removal process.)

Emergency Department Management

When a patient with a potential cervical spine injury arrives in the ED, every effort should be made to protect the cervical spine until it is assessed. Sedation may be required in the combative patient. Patients should be removed from backboards as soon as the clinician determines that the spine is stable. If re-

moved from the board, the patient should be instructed to remain supine. Cervical collars should also be removed as soon as the clinician determines that no serious cervical injury exists.

Spine boards were developed as a means of extricating patients from a motor vehicle while maintaining spine precautions; they were not intended as an immobilization device.¹⁰ Leaving the patient on the board is not necessary for immobilization. Patients who arrive in the ED on a spine board should be evaluated immediately. If continued spinal immobilization is needed, the patient should be log rolled off the board and placed on a firm mattress. This transfer may be briefly delayed for initial stabilization and radiographs, but leaving the patient on the board for convenience is inappropriate.¹¹ Unfortunately, presently there is no non-radiographic method for determining the presence or absence of potentially unstable thoracolumbar fractures and some experts believe that the spine board is helpful in protecting this portion of the spine. Local practice varies with regards to whether the patient needs to remain on the spine board until their entire spine has been clinically or radiographically cleared. There is no published consensus on this matter.

Unwarranted spinal immobilization can expose patients to the risks of iatrogenic pain,^{12,13} increased intracranial pressure,^{14,15} skin ulceration,¹⁶⁻¹⁸ aspiration^{19,20} and ventilatory compromise,^{19,21} as well as longer hospital stays and increased costs. The

Table 1. Helmet Removal²³

1. Manually stabilize the head, neck, and helmet by using a single person's 2 hands inserted from below the head and into the helmet. Then cut the chinstrap.
2. While maintaining stability, remove the cheek pads by slipping the flat blade of a screwdriver or bandage scissor under the pad snaps and above the inner surface of the shell.
3. If an air-cell expanding system is present, deflate it by releasing the air at the external port with an inflation needle or large gauge hypodermic needle.
4. Rotate the helmet slightly forward. It should now slide off the occiput.
5. If the helmet does not move with this action, apply slight traction to the helmet as it is carefully rocked anteriorly and posteriorly. Take care not to move the head/neck unit.
6. The helmet should not be spread apart by the earholes, as this maneuver only serves to tighten the helmet on the forehead and on the occiput regions.
7. All individuals participating in this important maneuver must proceed with caution and coordinate every move.

potential risks of aspiration and ventilatory compromise are of concern because death from asphyxiation is one of the major causes of preventable death in trauma patients.²²

Allowing patients to remain on the backboard for prolonged periods of time adds to patient discomfort and can increase the risk of pressure ulcers, especially in patients with spinal cord injury.²⁴ If the patient needs to remain on the spine board past initial radiographs, pad the bony prominences. This significantly increases patient comfort and decreases the likelihood that the patient will move around on the board to achieve comfort.²⁵ It may be difficult for the patient to differentiate pain due to an injury from pain iatrogenically created by prolonged length of time on the board.²⁴

There is still some controversy regarding helmet and shoulder pad removal once the patient has arrived in the ED. It is possible to obtain initial cervical spine radiographs with the protective gear in place, but adequate films and visualization can be difficult in this setting. Football helmets and shoulder pads impair visualization of the 1st, 2nd, 3rd, and 6th cervical vertebrae.³⁹ If accurate visualization and interpretation of radiographs is not possible without removal of protective gear, remove the gear with extreme caution. Gather and coordinate as many people as necessary to provide proper immobilization during the removal process. An athletic trainer or team physician can provide valuable assistance in this process.²⁶

Airway Management Considerations

Direct laryngoscopy and orotracheal intubation with manual in-line stabilization has become the standard of care for airway management in the trauma patient. It is the simplest and most effective means for obtaining an airway in most trauma patients.²⁷

Spinal immobilization can complicate the ability to secure an airway. Credible case reports of neurologic deterioration as a result of direct laryngoscopy and orotracheal intubation with manual in-line stabilization are rare.^{28,29}

The currently available body of literature suggests that direct laryngoscopy and orotracheal intubation are not likely to cause clinically significant cervical spine movement. Manual in-line stabilization does not limit the movement that does occur and may actually increase subluxation at unstable segments.²⁷⁻³⁸ Additionally, in-line stabilization may worsen the laryngoscopic view, which can lead to failed intubation with associated hypoxia and secondary neurologic injury.^{31,40-44} Manoach and Paladino published an excellent review of this literature in 2007 and noted that the reported data on direct laryngoscopy and orotracheal intubation with manual in-line stabilization in injured people consisted of only 9 case series: 5 of the studies were adequately described and reported 120 patients with unstable injuries and salvageable cord function who underwent direct laryngoscopic orotracheal intubation

with no associated intubation related complications.²⁷ Despite the evidence, physicians are understandably hesitant to forgo manual in-line stabilization during even a difficult intubation as the potential for exacerbating an injury exists. Physicians should focus on minimizing cervical movement while securing definitive airway access as quickly as possible.

Direct laryngoscopy and orotracheal intubation will be successful in most cases of airway management in the patient with a potential cervical spine injury. However, when difficult airways are encountered and intubation fails, alternative approaches must be available. Nasotracheal intubation is less successful than orotracheal intubation and requires a spontaneously breathing patient. It is contraindicated when there is suspicion of craniofacial injuries.⁴⁵ Cricothyrotomy is the ultimate procedure for a failed airway. Equipment for this procedure must be readily available anytime an intubation is attempted.

History

An accurate history is particularly important in the evaluation of patients with blunt cervical trauma, as it is an important factor in deciding who needs cervical spine imaging.⁴⁶

If the injury is the result of a motor vehicle collision, it is important to determine where the patient was seated, if restraints were used, if airbags deployed, where the vehicle was hit, and if the patient was ejected from the vehicle. This information may help determine the severity of the mechanisms of injury. Note the use of any intoxicants by the patient, since an intoxicated patient may have an unreliable physical examination. It is often reported that the patient was or was not ambulatory at the scene. This fact is of limited importance within the setting of potential cervical spine injury, as patients with cervical spine fractures may be ambulatory, especially if their judgment of pain perception is impaired by alcohol. Despite being clinically intuitive, evidence of this phenomenon in large prospective trials demonstrating the effect of alcohol intoxication and missed diagnosis of cervical spine fractures is lacking.⁴⁷ If the mechanism of injury was from a fall, determine from what height the patient fell and if any events preceded the fall, such as syncope or seizure. Question the patient about the presence of pain. In addition, elicit associated signs and symptoms such as loss of consciousness or related medical complaints. Presence of weakness or paresthesias is of particular importance.

Physical Examination

Talk to the patient immediately and ask their name, what happened, and where they are hurting. This simple assessment provides information about the airway, the patient's mental status, and the patient's ability to ventilate. Ask if they have weakness or

numbness anywhere and have them move all 4 extremities. Inspect and palpate the entire neck and back for any obvious injury, taking care to maintain spinal precautions. Open the collar to examine the neck for crepitus, hematoma, or laceration. Any of these have the potential to compromise the airway and can easily hide under a cervical collar. Note whether the patient has focal vertebral tenderness or paraspinal muscle tenderness. However, the presence of only paraspinal muscle tenderness does not exclude vertebral injury. Posterior midline tenderness had only an 86% sensitivity for clinically important cervical spine injury in the study that framed the basis of the Canadian cervical spine rule.⁴⁶ This is in contrast to the NEXUS data. When a fracture is in a superficial position, there is focal tenderness on palpation. Palpation at a distance from the fracture may not cause tenderness. Additionally, tenderness may not be elicited if the fracture is in an area with there is greater muscle development. Direct palpation of a vertebral body is not possible. This may explain why palpation in the posterior midline, which may be at a considerable distance from a vertebral fracture, may fail to elicit focal tenderness in an occasional patient.⁴⁸

The neurological examination of a patient with any spine injury is key and should be performed as soon as possible. Serial examinations should be performed when indicated to assess the possibility of evolving spinal cord injury. Simple observation of the patient may provide important clues. Asymmetric movement or absence of movement of extremities, abdominal breathing, priapism, and involuntary loss of bladder or bowel contents may be noted.

The patient's motor function should be examined. The minimal motor function, whether it be full motor strength in all extremities or completely flaccid, should be determined. Even the slightest movement in a finger or toe is meaningful with regards to preserved spinal function.

For the sensory examination, a dermatomal map can be used to aid in identifying the area of deficit. This should initially be done with light touch, moving from an area of diminished sensation to an area of sensation as patients are more sensitive to the appearance of sensation than to its disappearance.⁴⁹ Appreciation of pinprick sensation should be assessed as well. Light touch affects the posterior column while pinprick affects the anterior column. In anterior cord syndrome, light touch appreciation is present despite

Table 2. NEXUS Criteria For Low Probability Of Injury

1. No midline tenderness
2. No focal neurologic deficit
3. Normal alertness
4. No intoxication
5. No painful distracting injury

serious cord damage. Areas of preserved sensation within an affected dermatome or below the level of apparent total dysfunction, even in patients with complete paralysis, indicate that the patient has a very good chance of functional motor recovery.⁴⁹ Repeat sensory examinations are important since progression of deficit occurs in a cephalad direction. Impending respiratory failure should be expected.

The presence or absence of reflexes and rectal tone should be noted. Spontaneous respirations with elevation and separation of the costal margins on inspiration indicate normal thoracic innervation.⁵⁰ An unconscious or intoxicated patient may be difficult to evaluate neurologically. Observation for spontaneous movement of the extremities or response to noxious stimuli is often the only initial option.

Cervical spine injuries are associated with other injuries, including maxillofacial injury, head injury, abdominal injury, and other vertebral injuries.⁵¹⁻⁵⁴ Therefore, a careful secondary survey is needed after initial stabilization is complete.

Indications For Imaging

NEXUS Criteria

In 1992, the National Emergency X-Radiography Utilization Study (NEXUS) was conducted to develop a clinical decision tool for cervical spine imaging. NEXUS was a prospective observational study which enrolled more than 34,000 blunt trauma patients in 21 U.S. emergency departments. The inclusion criteria included any patient with blunt trauma who had cervical spine imaging. This study sought to validate criteria for identifying patients who have a low probability for cervical spine injury.⁵⁵ NEXUS was the first decision tool to be validated for selected cervical spine imaging. (See Table 2.) The NEXUS criteria identified all but 8 of 818 patients who had a spinal injury. Only 2 of those 8 patients had a clinically significant injury, for which only 1 needed surgical intervention. The NEXUS investigators determined that the criteria were 99.6% sensitive for a clinically

Table 3. Radiographically Documented Cervical Spine Injuries Categorized By NEXUS As "Not Clinically Significant"⁵⁵

- Spinous process fracture
- Simple wedge compression fracture without loss of 25% or more of vertebral body height
- Isolated avulsion without associated ligamentous injury
- Type 1 odontoid fracture
- End plate fracture
- Osteophyte fracture, not including corner fracture or teardrop fracture
- Injury to trabecular bone
- Transverse process fracture

important injury but only 12.9% specific. **Table 3** presents those cervical spine injuries that NEXUS categorized as not clinically significant (ie, if not identified, these injuries would be extremely unlikely to result in harm to patients).^{55,56}

Canadian Cervical Spine Rule

In 2001, Canadian researchers published a study of 8924 patients with blunt cervical trauma from 10 adult emergency departments with different clinical evaluation criteria than NEXUS. The Canadian researchers reported that their criteria demonstrated greater sensitivity (100%) and greater specificity (42.5%) than the NEXUS criteria for detecting clinically important cervical spine injury. (See **Table 4**.)⁴⁶ The Canadian Cervical Spine Rule identifies trauma patients who require cervical spine radiography based on 3 clinical caveats:

1. Patients that are high risk due to age, dangerous mechanism of injury, or presence of paresthesias must have radiography.
2. Patients with any 1 of 5 low risk characteristics may safely undergo clinical assessment if active range of motion is possible. Low risk criteria include:
 - a. Ambulatory
 - b. Without midline tenderness or immediate onset of pain
 - c. Able to sit up
 - d. Simple rear-end motor vehicle collision
 - e. Can actively turn head 45 degrees in both directions
3. Patients who are able to actively rotate their neck 45 degrees to the left and right regardless of pain do not require imaging.

Comparing NEXUS And The Canadian Cervical Spine Rule

Application of a decision tool requires clinicians to be familiar with the defining criteria and to conduct careful assessments. The principle benefit of both instruments lies in their ability to safely identify patients who do not require imaging. They are much less efficient in determining which patients have cervical spine injury.⁵⁸ The NEXUS-based assessment of 5 criteria can be applied to all blunt trauma patients. The Canadian Cervical Spine Rule is more complex, relies on a series of evaluations, and has several inclusion criteria that limit its application in some patient groups, including children and pregnant women.⁵⁸

The Canadian Cervical Spine study enrolled all patients who had sustained neck trauma, including a significant percentage (69%) of patients who did not undergo radiographic evaluation, resulting in a higher specificity.⁵⁸ The NEXUS study enrolled only patients who had imaging and specifically excluded patients that did not. Canadian researchers found that the

NEXUS criteria had a sensitivity of less than 93% when retrospectively applied to their patient population.⁵⁹ However, these results are not consistent with the data collected during the development and validation of the NEXUS criteria and are in conflict with the large body of literature that investigated similar criteria prior to the NEXUS study.⁶⁰ This decrease in sensitivity likely resulted from the Canadian study's use of surrogate variables and retrospective methodology. Both studies have common strengths and weaknesses. Neither decision tool exhibits very high positive predictive value since the vast majority of non-low risk patients do not have a cervical spine injury.⁵⁸

Special Considerations In Cervical Spine Imaging

Distracting Injuries

The NEXUS investigators definition of a distracting injury included a "long list of various injuries that could potentially distract a patient from a cervical spine injury."⁵⁵ This list includes long bone fracture, visceral injury requiring surgical consultation, large laceration, degloving injury or crush injury, large burns, or any other injury producing acute functional impairment.⁵⁵ Distracting injury was given as the indication for more than 30% of all radiographic studies ordered in NEXUS.⁵⁵

The Canadian study's definition of distracting injuries was: "injuries such as fractures that are so severely painful that the neck examination is unreliable."⁴⁶

The concept that certain injuries may "distract" patients from other injuries is based on the gate theory of pain. In this theory, an injury such as a long bone fracture may induce enough signal through the spinal pathways that other smaller injuries, such as abrasions, may go unappreciated.⁶³ It has been shown that the proximity of the 2 painful stimuli to each other plays a major role in whether one stimulus may inhibit the other.⁶³ Hefferman et

Table 4. Canadian Criteria For Detecting Clinically Important Cervical Spine Injury⁴⁶

High Risk Factors	<ul style="list-style-type: none"> • Age > 65 • Fall > 1 meter • Axial loading injury • High speed MVC/ rollover/ejection • Motorized recreational vehicle or bike collision • Presence of paresthesias
Low Risk Factors	<ul style="list-style-type: none"> • Simple rear-end MVC <ul style="list-style-type: none"> • Not pushed into oncoming traffic • Not hit by large bus or truck • No rollover • Not hit by high-speed vehicle • Sitting position in the ED • Ambulatory anytime • Delayed onset of neck pain • No midline cervical tenderness

al evaluated 406 blunt trauma patients. Ten percent of these patients had a cervical spine fracture and 18% of those patients had a non-tender cervical spine and an associated upper torso injury. None of the patients with injuries isolated to the lower torso and a non-tender neck had a cervical spine fracture ($p < 0.05$).⁶⁴ This study is limited by small sample size so caution must be used in excluding a lower extremity injury as a distractor.

Intoxication

Intoxication is another complicating factor that may result in missed spinal injuries. Over 40% of patients injured in motor vehicle collisions and falls are intoxicated at the time of injury.⁴⁷ NEXUS defines intoxication as recent history by the patient or an observer of intoxication; intoxicating ingestion or evidence of intoxication on examination such as odor of alcohol, slurred speech or ataxia, dysmetria, or other cerebellar findings; or any behavior consistent with intoxication.⁵⁵ Liberman et al retrospectively studied 216 intoxicated patients with spinal column injury. Four out of 22 patients without cervical spine tenderness had cervical spine fractures. None of these injuries required operative fixation.⁶⁵

Elderly

Elderly patients (> 65 years) are at greater risk of fracturing their cervical spine as a result of a lower energy mechanism. The prevalence of cervical spine fractures in patients over the age of 65 is double that of younger patients.^{66,67} Degenerative changes tend to occur in the mid cervical spine and lower cervical spine, conferring a greater degree of mobility through the skull base to C2. C1 and C2 fractures account for approximately 70% of the cervical fractures in elderly patients with C2 being the most commonly fractured vertebra.⁶⁸ C1 and C2 fractures are the most often missed fractures on initial plain radiographs.⁶⁹ The combination of increased C1-C2 injuries and the frequent presence of degenerative changes in the elderly along with the known difficulty of detecting these injuries on plain radiographs suggests that CT of the cervical spine should be considered the imaging modality of choice in this patient population; see next section.

NEXUS criteria do not require imaging based on age alone, in contrast with the Canadian Cervical Spine Rule that mandates imaging in patients > 65 years. The NEXUS group addressed the validity of their decision rule in elderly patients by conducting a sub-group analysis of their data. Their conclusion was that the NEXUS decision instrument could be applied safely to these patients.⁶⁶ However, only 8.6% of the patients in the NEXUS study were elderly. This small number of patients in this sub-group negates the validation power achieved by the large size of the overall study. NEXUS requires a 'normal level of alertness.' Specifically, the NEXUS

investigators state that an altered level of alertness can include any of the following: 1) GCS 14 or less; 2) inability to remember 3 objects at 5 minutes; 3) delayed or inappropriate response to external stimuli.⁵⁵ Subtle cognitive defects that disqualify the patient from having 'normal alertness' may be difficult and time-consuming to tease out in the emergency department setting. In a small retrospective study by Scharg et al, cervical spine tenderness was only present in 45% of elderly patients with cervical spine fractures.⁷⁰ This data does not invalidate the NEXUS criteria but does demonstrate a potential problem with its application in the elderly.

Imaging Studies

Obliques and Flexion/Extension Views

Flexion/Extension (F/E) views are most often obtained for patients with an acceleration-deceleration mechanism who have neck pain/cervical tenderness but normal plain radiographs. In these patients, there is potential for ligamentous injury that may not be seen on a static, neutral view of the cervical spine.⁷¹ Small retrospective studies have suggested this approach might be of diagnostic benefit in certain patients.^{72,73} Patients must have a normal mental status, have a normal neurologic examination, and be able to cooperate with the neck movement that is required. Pollack et al reviewed the NEXUS data to attempt to determine if there is benefit to the use of F/E views in this setting.⁷¹ F/E views were obtained in 10.5% of the 818 patients in NEXUS who were ultimately found to have cervical spine injury. In only 4 of these patients, standard imaging failed to identify a cervical spine subluxation or dislocation, but in every such instance, these views were positive for some injury that routinely prompts additional imaging.⁷¹ Where there is concern about ligamentous instability, MRI is preferable to F/E. The overall use of F/E in the acute setting of blunt cervical trauma should be very limited; in fact, the ability of F/E views to reliably diagnose significant injury is questionable.⁷¹ A recent cadaver study demonstrated that, with less than 60 degrees of flexion or extension, intervertebral rotation or displacement was almost never greater than the 95% confidence interval established for asymptomatic people. Even with adequate motion, intervertebral rotation and displacement were within normal limits after excessive damage to the soft-tissues.⁷⁴

The addition of supine oblique views is thought to enhance the visualization of the lower cervical spine and posterior elements and to detect injury that may not be identified with standard views alone. However, Offerman et al demonstrated that the addition of oblique views did not increase the sensitivity and specificity for fracture detection.⁷⁵ While some centers may not have CT readily available, addition of oblique

views to the standard 3 view series does not always improve diagnostic accuracy. The clinician may have a false sense of security about the absence of a fracture when the oblique views are normal; therefore, these views are not recommended for regular use.

Interpretation Of Plain Radiographs

Ensure that the films are good quality and that the lateral view visualizes the C7-T1 junction. One of the most common reasons for missed cervical spine fracture is technically inadequate plain films. In one retrospective review of 216 trauma patients, failure to visualize C7 and the C7-T1 junction was the most common error made in the radiographic assessment of cervical spine injury.⁷⁶ In another retrospective review of 740 patients with cervical spine injuries, the diagnosis of cervical spine injury was delayed or missed in 34 patients (4.6%). In this study, the single most common error was failure to obtain an adequate series of cervical spine radiographs.⁷⁷ Interpretation of cervical spine radiographs should be undertaken in a systematic manner each time. A useful technique is to remember the ABCs of cervical spine film evaluation: A=alignment, B=bony abnormalities, C=cartilage/space assessment, and S=soft tissues. (See Tables 5 and 6.)

Alignment

Anterior and posterior cervical lines are imaginary

Table 5. The ABCs Of Cervical Spine Radiograph Interpretation

Alignment/Anatomy
<ul style="list-style-type: none"> • Disruption of A/P vertebral body lines • Disruption of spinolaminar line • Jumped and locked facets • Rotation of spinous processes • Widening of interpedicular spaces • Loss of lordosis • Kyphotic angulation
Bony Integrity
<ul style="list-style-type: none"> • Obvious fracture • Disruption of ring of C1 • Widening of interpedicular space • Disruption of posterior vertebral body line
Cartilage/Disk Space
<ul style="list-style-type: none"> • Widening of predental space • Abnormal intervertebral disk space/widened facet joints • Uncovered facet joints • Widening of interspinous or interlaminar distance
Soft Tissue
<ul style="list-style-type: none"> • Widening of retropharyngeal space • Widening of retrotracheal space • Displacement of prevertebral fat stripe • Soft tissue mass in craniocervical junction • Tracheal or laryngeal deviation

lines that connect the anterior and posterior margins of the vertebral bodies. The spinolaminar line connects the bases of the spinous processes extending to the posterior aspect of the foramen magnum. The 3 lines should form a lordotic curve without disruption. Any disruption suggests bony or ligamentous injury. An exception to this is pseudosubluxation in children at C2-C3, which will be discussed in a subsequent section.⁴⁹

Bones

Evaluate the bones for obvious fractures and loss of height of the vertebral bodies. Any small fragment may represent a fracture. Closely inspect the odontoid and its relationship to C1. Fractures commonly missed on plain films include fractures of C1, fractures of the odontoid, facet fractures, and C7-T1 injuries.⁷⁸

Cartilage

Anterior or posterior widening of the intervertebral space can be seen in a dislocation, but this may be subtle. Intervertebral disc spaces should be uniform in height and length. Narrowing of the disk space may represent acute disk herniation or adjacent vertebral fracture. Widening could represent injury of the posterior ligamentous complex.

Soft tissues

Abnormal size of prevertebral soft tissues suggests an adjacent fracture. To evaluate the size of the retropharyngeal space, measure from the anterior border of C2 to the posterior wall of the pharynx. This distance should be no greater than 6 mm in children and adults. The space from the anterior border of the body of C6 to the posterior wall of the trachea should not exceed 22 mm in adults and 14 mm in children < 15 years old or should be less than the width of the vertebral body at each level. In children less than 2 years old, the retropharyngeal space may normally appear widened during expiration, thus requiring an inspiratory film.⁴⁹ In a retrospective study of 106 study patients and 93 control patients, the patients were divided into 2 groups: those with fractures at C1-C4 and those with fractures at C4-C7. A C2 prevertebral soft tissue measurement of more than 6 mm had a sensitivity of 59% and a specificity of 84% for fractures at C1-C4. A C6 prevertebral soft tissue measurement of more than 22 mm had a sensitivity of 5% and a specificity of 95% for fractures at C4-C7. The authors concluded that the cutoffs of 6 mm at C2 and 22 mm at C6 as a marker of cervical spine injury fails to identify a large proportion of patients with cervical spine fractures.⁷⁹

On the lateral view, the predental space (distance between the anterior aspect of the odontoid process and the posterior aspect of the anterior ring of C1) should not exceed 3 mm in an adult or 5 mm in a child.⁶¹ Widening of this space is concerning for

Figure 5. Single Lateral View Of The Cervical Spine



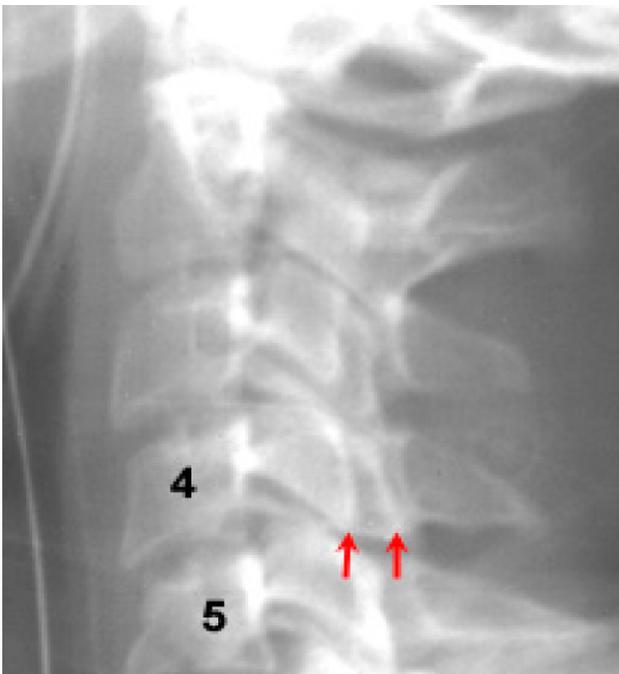
A single lateral view of the cervical spine demonstrates a flexion rotation injury of C4 upon C5 with anterior subluxation. This CT image shows right pedicolaminar fractures of C4 and C5 with anterolisthesis at C4-C5, concerning for ligamentous injury. Imaged used with permission from Lisa Freeman Grossheim, MD.

a Jefferson burst fracture.⁴⁹ Proper evaluation of the soft tissues in an intubated patient is not possible as the normal air and soft tissue interface is obscured.

Lateral View

First determine if the film is adequate. All 7 cervical vertebrae must be seen, including the top of the first thoracic vertebra. Check the alignment of the ante-

Figure 6. Double Facet Sign



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rior, middle, and posterior arcs. These arcs should be present in smooth unbroken lines. **Figure 5** demonstrates a single lateral view of the cervical spine.

Examine the bones; the vertebral bodies C2 through C7 and spinous processes should have uniformity and similar height. The anterior height of the vertebral body should be no more than 3 mm shorter than the posterior height. The “double facet” sign indicates a fractured articular facet. The sign is caused by a display of the anterior margin of the inter-faceted joints overlapping the horizontal rotation of the fractured facet. (See **Figure 6**.)

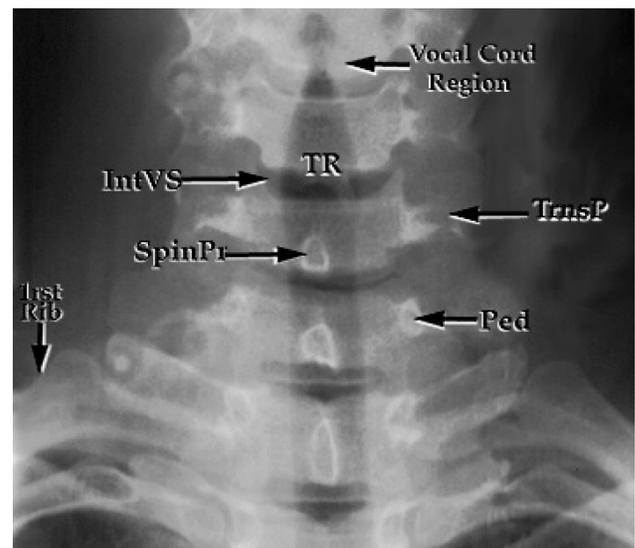
Examine the cartilage; the intervertebral disk space height and length should be uniform. Finally, examine the prevertebral soft-tissue width. Focal prevertebral or retropharyngeal soft tissue edema or hematoma can indicate an otherwise radiographically undetected fracture.⁴⁹

Missed injuries on lateral view film can include overlapping of bone (especially involving the cervicocranial junction, the articular masses, and the laminae) and non-displaced or minimally displaced fractures (especially C1 and C2).⁷⁸

Swimmer’s Lateral

This view is often obtained to visualize the cervicothoracic junction when it is obscured by the density of the shadows produced by the shoulders on the true lateral. Optimal positioning requires that one of the patient’s arms be abducted 180 degrees and extended above the head while the opposite shoulder is extended posteriorly to decrease the overlapping of skeletal structures. If a swimmer’s view cannot be obtained, oblique views or CT is needed.

Figure 7. Normal Anteriorposterior View



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Anteroposterior View

The AP view includes C3-T1 as the mandible obscures C1 and C2. (See Figure 7.) Evaluate the alignment of the spinous processes and the distance between the spinous processes as well as the uniformity and height of the vertebrae. The spinous processes should form a straight line down the middle of the vertebral body and should be equidistant apart. If one spinous process is out of line compared to the others, a jumped facet may be present.⁷⁸ The lateral masses should form smoothly undulating margins without abrupt interruption, and the disc spaces should be uniform in height from anterior to posterior.⁷⁸

Open Mouth Odontoid (Atlantoaxial View)

This view requires the cooperation from the patient for optimal studies. Problems with this view may occur due to overlap from the mandible or dentition. A normal open-mouth odontoid (OMO) view demonstrates the lateral margins of the C1 ring aligned within 1 to 2 mm of the articular masses of the axis. The articular masses of C2 should appear symmetric, as should the joint spaces between the articular masses of C1 and C2 as long as there is no rotation of the head. The distance between the odontoid and the C1 medial border (lateral atlantodental space) should be equal, but a discrepancy of 3 mm or greater is often seen in patients without pathology. A vertical line bisecting the odontoid process should form a 90-degree angle with a line placed across the superior aspect of the C2 articular masses.⁷⁸

CT Versus Plain Films

In the past decade, helical CT scanning with or without multidetector technology has been replacing radiography as the method of choice for cervical trauma screening in most large U.S. trauma centers among moderate-risk to high-risk patients.⁸⁰⁻⁸² This is due to CT's ease of performance, speed of study, and greater ability to detect fractures.^{83,84}

The sensitivity of plain films is inversely correlated with the severity of trauma sustained.^{9,85} Multiple studies have demonstrated the limitations of

plain radiography in the cervical spine, particularly at the craniocervical and cervicothoracic junctions.^{85,86} In a study of 102 patients, Widder et al reported plain films to have a sensitivity of 39% compared to CT.⁸⁶ In a retrospective study of 245 patients with 309 cervical spine injuries, Daffner et al demonstrated that plain radiography detected just 44% of injuries whereas CT detected 99.2% of injuries.⁸⁸

Many centers have reported CT scanning in moderate-risk to high-risk trauma patients to be a more cost-effective screening modality than plain radiography when the costs of missed injuries are taken into account.⁹⁰⁻⁹²

The main reasons to get a CT scan in blunt trauma patients include inadequate plain films, abnormal plain films, fractures or dislocations seen on plain films, or high suspicion of injury despite a normal plain film series. Patients with multi-system injuries who need CT of the brain often have CT of the cervical spine performed as well. Patients who are intubated cannot be evaluated with only plain cervical spine radiographs. Evaluation of the soft tissues of the upper cervical spine requires the presence of an air column in the trachea to help delineate the curvature and width of the soft tissues. The presence of an endotracheal tube diminishes the magnitude of this air column thus rendering the soft tissue evaluation inaccurate. If there is any doubt about an abnormality on the plain radiograph or if the patient has disproportionate neck pain, a CT is warranted. Be familiar with your scanner. CT cuts need to be 3 mm or less to reliably detect occult fracture.

Low-risk patients are those who have low prevalence of injury. Plain radiographs are an effective tool in these patients.⁵⁵ A 2.4% prevalence of cervical spine injury was reported in NEXUS. This low prevalence of injury makes it extremely unlikely that an individual patient with blunt trauma will have an injury missed on screening radiography.⁵⁵ Plain radiography has its limitations in the high-risk patient group. It is difficult to obtain adequate films in severely injured patients, especially those who are intubated. High-risk patients would include those who have a significant closed head injury, neurologic deficits, high-energy trauma, unreliable examination secondary to intoxication, and neck pain out of proportion to plain film findings.⁹³ These patients need CT evaluation.

Presently, the American College of Radiology's 2007 Appropriateness Criteria recommends that patients who need imaging have a thin-section CT examination that includes sagittal and coronal multiplanar reconstructed images. CT of the cervical spine with sagittal and coronal reformats is given a rating of 9, considered most appropriate. Three-view cervical spine plain radiographs are given a rating of 2, with 1 being least appropriate.⁹⁴

Table 7, on page 12 lists the 5 cardinal findings on CT that indicate instability.

Table 6. Measurable Parameters Of Normal Cervical Spines⁷⁸

Parameter	Adults	Children
Predental space	3 mm or less	5 mm or less
C2-C3 subluxation	3 mm or less	5 mm or less
Retropharyngeal space	< 6 mm at C2 < 22 mm at C6 age > 15 yrs	1/2 to 1/3 AP vertebral < 14 mm at C6 age < 15 yrs
Angulation of spinal column at any single interspace	< 11 degrees	< 11 degrees

MRI

How to detect significant cervical spine instability in the absence of bony injury remains a controversial issue. This injury is uncommon, with a reported incidence of 0.1% to 0.5% of patients with blunt trauma.^{77,85,95,96} MRI is considered to be the gold standard to make this diagnosis.

MRI is a highly sensitive non-invasive imaging modality that is unique in its ability to detect acute injury of the spinal cord as well as injury to the ligamentous structures and intervertebral disks. It is the study of choice for detecting neurologic injury secondary to trauma. The advantages of MRI include superior resolution in the detection of soft tissue injuries (such as contusions, hematomas, or laceration) and no requirement for IV contrast material or ionizing radiation.

Hemodynamically-unstable patients are not appropriate for MRI as intensive monitoring and resuscitation are difficult in the MRI suite. MRI is time-consuming, taking much longer than CT, and it is not universally available. In addition, some patients have medical implants that preclude the use of MRI. Additionally, cortical bone contains essentially no hydrogen atoms so it is not well visualized by MRI. Only major bone injuries are seen on MRI. The indications for emergent MRI include the presence of neurological deficits attributable to a spinal cord injury or suspicion of ligamentous injury as evidenced by subluxation on plain films or CT.

See **Table 8** for a list of MRI findings that indicate cervical spine ligamentous injury.

Classification Of Cervical Spine Injuries

Cervical spine fractures are classified based on their stability (stable versus unstable), the distorting force that caused the fracture (extension, flexion, rotation), and the level of the cervical fracture. The upper cervical spine (occiput, C1, and C2) is a functionally distinct unit compared to the lower cervical spine (C3-C7) as it is designed for rotary movement. Fractures involving C1 and C2 are generally considered anatomically unstable due to their location and paucity of supporting ligaments.

The Atlas – C1

Fractures of the first cervical vertebra comprise 2% to 13% of all acute cervical spine fractures.⁹⁸⁻¹⁰⁰ When

Table 7. Five Cardinal Findings On CT That Indicate Instability¹⁰⁸

1. Displacement
2. Wide interpedicle distance
3. Wide interspinal (interlaminar) distance
4. Widening of facet joints
5. Disruption of posterior vertebral body line

they do occur, the most likely injury is an isolated fracture of the posterior arch that occurs when the arch is compressed between the occiput and spinous process of C2 during hyperextension.¹⁰² These fractures are often bilateral, non-displaced, and considered stable. The exception to this rule is the Jefferson fracture, which is an extremely unstable injury that results from a force delivered to the top of the skull. Both the anterior and posterior arches break and the transverse ligament is disrupted. This injury is typically identified on the OMO view by a bilateral offset of the lateral masses of C1 relative to C2.^{49,78} Due to prevertebral hemorrhage and retropharyngeal swelling, the lateral film may show a widening of the prepedal space between the anterior arch of C1 and the odontoid. A prepedal space greater than 3 mm in adults and 5 mm in children is abnormal. If the fracture fragments are minimally displaced, the Jefferson fracture may be difficult to recognize and a CT is necessary.⁴⁹

Figure 9 on page 14 shows a fracture of the posterior arch of C1.

The Axis – C2

Fractures of C2 are quite common, especially in older patients, but they may be easily missed if they are non-displaced. The term “hangman’s fracture” has been used extensively in the literature to describe the injury produced by judicial hanging as well as axis pedicle fractures that are often seen in MVCs and falls. (See **Figure 8**.)⁵⁰ Hanging injuries produce bilateral axis pedicle fractures with complete disruption of the disc and ligaments between C2 and C3 by hyperextension and distraction. This differs from the mechanism to the injury produced by falls and MVCs, which results from various combinations of extension, axial compression, flexion, and varying degrees of disc disruption.

The neurologic consequences from C2 pedicle fractures are generally less severe than anticipated due to the cord occupying only about 1/3 to 1/2 of the AP diameter of the spinal canal at this level. In addition, the bilateral pedicle fracture produces a decompression of the canal with stability dependent on the amount of displacement, translation and angulation. Some types of C2 pedicle fractures require operative fixation while others do not.

Fractures of the odontoid (dens) of C2 are common and occur through a variety of mechanisms,

Table 8. MRI Findings That Indicate Cervical Spine Ligamentous Injury¹⁰⁹

- Abnormal vertebral body or facet joint alignment not explained by degenerative changes
- Ligamentous disruption with edema
- Facet joint fluid with facet joint widening
- Fluid between spinous process with splaying
- Paraspinal muscle edema not explained by rib fracture
- Abnormal intervertebral disc signal with disc space widening

including shearing, flexion, extension and rotation. These fractures are classified as Type 1, 2, or 3. Type 1 and 2 are “high” dens fractures and may be non-union, whereas Type 3 is a “low” dens fracture and typically heals well.¹⁰² (See Figure 10, page 14.) Spinal cord injury in odontoid fractures is uncommon.

A pure flexion injury of the C1-C2 complex can cause atlanto-occipital dislocation (OAD). Classically, OAD is thought to be a lethal injury. However, the contemporary treatment of trauma patients from the accident scene to the hospital has enabled as many as 33% of these patients to survive after the injury.¹⁰³ OAD is often associated with brain injury, which is a common cause of death. Patients with complete quadriplegia as a result of OAD have a poor prognosis. OAD is most common in the pediatric population, likely due to anatomic factors and ligamentous laxity.¹⁰³ Treatment of this condition is possible, so utmost care must be used when performing imaging and airway management, as the injury is extremely unstable.

The Lower Cervical Spine (C3-C7)

A simple wedge compression fracture occurs when a vertebra is compressed between adjacent vertebrae during flexion. The anterior height of the vertebra is compressed while the posterior height is maintained and the posterior elements are not affected. Neurologic impairment is not common.

A burst fracture occurs via an axial loading mechanism. The posterior as well as the anterior cortex of the vertebral body are violated as the vertebral body explodes outward. This causes a comminuted fracture of the vertebra that often leads to retropulsion of bony fragments into the spinal canal. This

Figure 8. Hangman's Fracture Seen On Sagittal Reconstruction Of CT Images



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may lead to spinal cord impingement or frank injury.

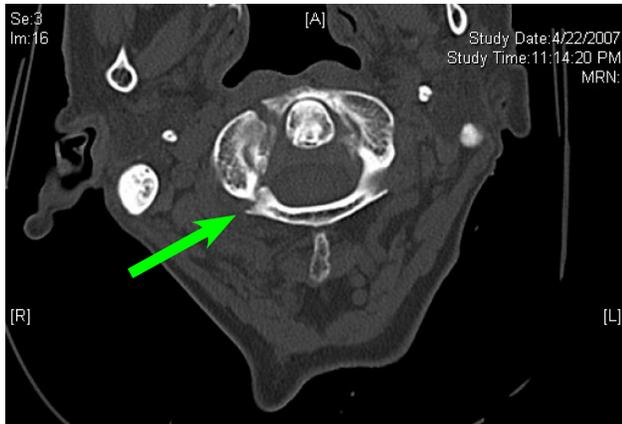
The tear-drop fracture is a fracture-dislocation due to flexion and axial loading such as from a diving injury. The flexion teardrop fracture is a fracture with resultant wedge-shaped fragment (resembling a teardrop) and loss of anterior vertebral body height. Ligamentous disruption is present, making this injury unstable and often associated with spinal cord injury.^{78,102}

A unilateral interfacet dislocation (UID), also known as unilateral locked facets, is caused by simultaneous flexion and rotation. (See Figure 11, page 14.) The dislocated facet comes to rest anterior to the subjacent facet. Associated articular mass fracture is common. Spinal cord injury is variable.⁷⁸

A bilateral interfacet dislocation (BID) occurs when both facet joints at the level of injury are dislocated. (See Figure 12, page 17.) All of the interosseous ligaments are disrupted, resulting in marked forward displacement of the involved vertebrae. The articular masses of the vertebrae lie completely anterior to the articular masses of the vertebra below. The dislocated articular masses pass upward, forward, and over the superior process of the subjacent vertebra coming to rest in the intervertebral foramina so that the inferior facet of the involved vertebra lies anterior to the superior facets of the subjacent vertebra. BIDs may be partial or complete. When the dislocation is incomplete, the dislocated vertebra is anteriorly displaced a distance less than one-half the AP diameter of the vertebral body. The posterior inferior margins of the inferior facet of the dislocated vertebra may come to rest atop the margins of the superior articular process of the subjacent vertebra (“perched” vertebra) or the dislocated articular masses may sit high in the vertebral foramina.¹⁰⁴ This injury is usually associated with fractures and spinal cord injury.⁷⁸

Hyperextension/hyperflexion (“whiplash”) injury is a traumatic injury causing cervical musculoligamentary sprain or strain due to hyperextension-flexion and excludes fractures or dislocations of the cervical spine.^{105,106} (See Table 9, on page 17.) This type of injury can be seen in rear-end or side-impact motor vehicle collisions or any trauma that causes rapid flexion-extension of the cervical spine. It is estimated that close to 1 million people suffer whiplash injury in the U.S. every year. Rear-end collisions are responsible for many of these injuries.^{105,106} Whiplash injury is not associated with significant MRI findings. In a case control study of 173 patients that consisted of groups of patients with neck pain after an MVC, patients with chronic atraumatic neck pain, and asymptomatic patients, no differences in the alar ligament were noted between the groups.¹⁰⁷ In another study of 178 patients who had an MRI an average of 13 days post-injury, no patient had traumatic findings that were associated with adverse outcome after 3 and 12 months.⁶²

Figure 9. Fracture Of The Posterior Arch Of C1



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Special Circumstances

Pediatric Patients

Cervical spine injury is rare in the pediatric population, accounting for 1% to 2% of all pediatric trauma patients and less than 10% of all cervical spine injuries.¹¹⁰

The pediatric cervical spine is more elastic compared to adults, especially in the first 8 years of life. The spinal ligaments and joint capsules can withstand significant stretching without tearing, which contributes to the occurrence of pseudosubluxation.¹¹¹

Preverbal children cannot be clinically cleared if sufficient mechanism for potential cervical spine injury exists. Verbal children should be approached with caution as well. Distracting injuries or anxiety are prominent concerns in children and should lead

Figure 10. Type 3 Dens Fracture

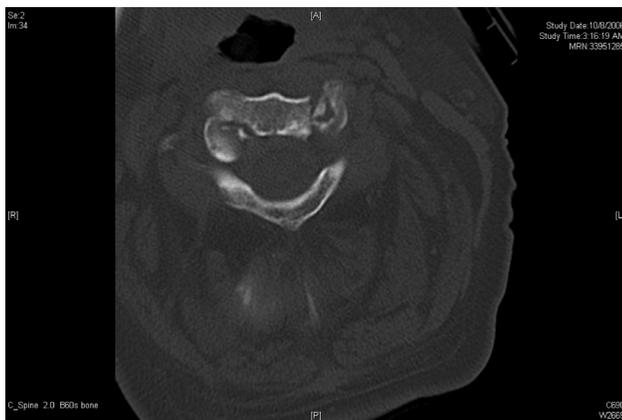


Image of 68-year-old man after a fall from standing that shows a comminuted type 3 dens fracture with bilateral involvement of the foramen transversarium at the level of C2 and on the right at C3. Also present were right C6 and C7 fractures. The cervical angiogram was normal. Reproduced with permission from Lisa Freeman Grossheim, MD.

to a conservative approach for plain film imaging in children. A child may deny neck pain out of fear of getting a shot or some other painful procedure if they state they have pain.

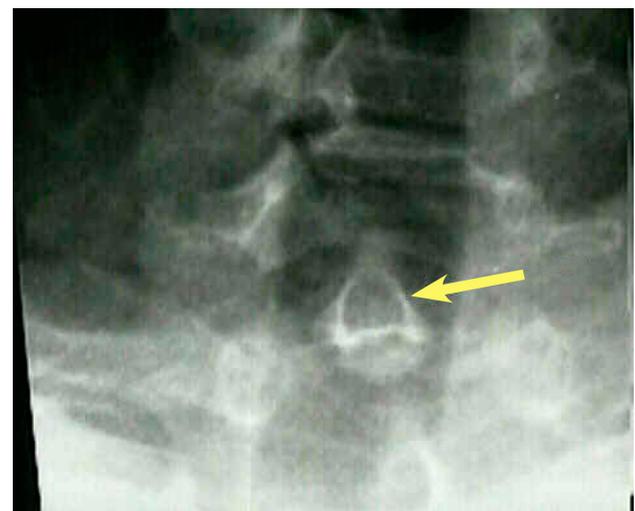
Clearing the cervical spine by physical or radiographic examination is complicated by many factors including physicians' infrequent exposure to children with cervical spine injury, communication barriers due to young age, and many normal variations in anatomy including pseudosubluxation, epiphyseal variations, unfused synchondroses, and incomplete ossification.¹¹⁴ Incomplete ossification, different vertebral configuration, and ligamentous laxity account for the different injury patterns compared to adults.

A recent prospective multicenter trial was performed to evaluate utility of the NEXUS criteria for identifying pediatric patients with blunt trauma in whom radiographs should be obtained. None of the 603 children designated as low risk in this trial had evidence of cervical spine injury on plain films.¹¹⁵ However, a weakness of the NEXUS study is the small number of infants and toddlers.

Interpreting Pediatric Cervical Spine Radiographs

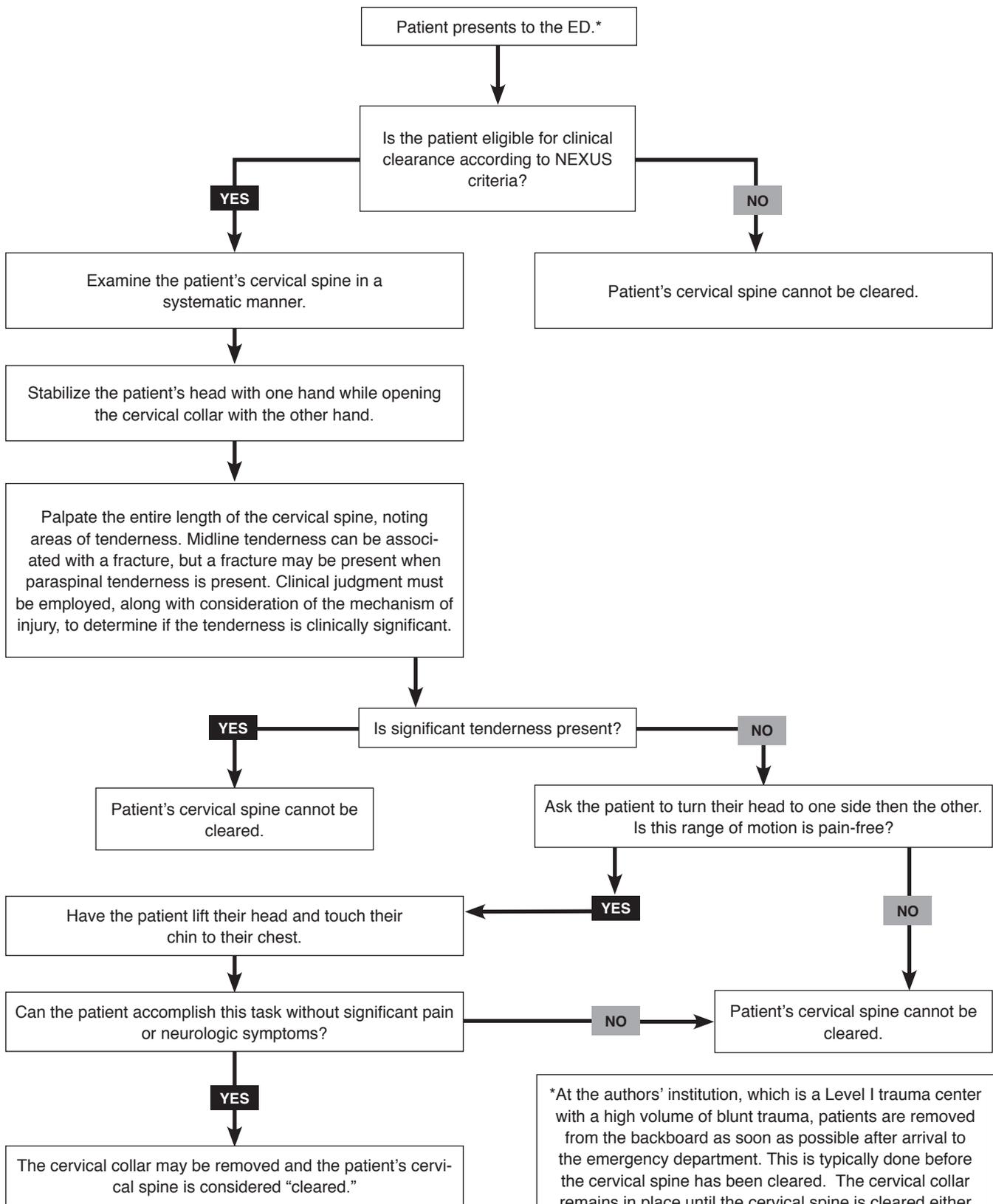
Difficulty reading plain radiographs of the cervical spine in children is the result of a variety of factors, lack of knowledge about the patterns of vertebral ossification, congenital anomalies, laxity of ligaments, and reader inexperience.¹¹⁶ One study found that 24% of children younger than 8 years of age are misdiagnosed initially when being evaluated for a cervical spine injury compared to 15% for older children.¹¹⁶ Nitecki and Moir demonstrated that subluxation

Figure 11. Unilateral Interfacet Dislocation As Seen On The AP View



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Clinical Pathway For Clearing A Patient's Cervical Spine



*At the authors' institution, which is a Level I trauma center with a high volume of blunt trauma, patients are removed from the backboard as soon as possible after arrival to the emergency department. This is typically done before the cervical spine has been cleared. The cervical collar remains in place until the cervical spine is cleared either clinically or radiographically. Even patients with cervical spine injuries are removed from the board while maintaining immobilization with the cervical collar.

injuries are common in young children (45% of all children < 8 years).¹¹⁷

Pseudosubluxation of C2-C3 is common. In children < 8 years old, 3 mm of anterior displacement is seen in 40% of patients at C2-C3 and 14% of patients at C3-C4.⁷⁷ This occurs up to age 14. There are strict criteria for pseudosubluxation. A line drawn through the posterior arches of C1 and C3 should touch, pass through, or lie within 1 mm anterior to the cortex of the posterior arch of C2. Otherwise, a true dislocation is suspected. Additionally, an atlantodens interval > 3 mm is seen in 20% of children. (See Figure 13, page 18.)¹¹⁸

For children < 10 years old, the usefulness of CT scan is limited because most injuries in this age group are ligamentous with no osseous component.^{112,119} If a child has persistent neurologic symptoms or pain with normal findings on x-ray or CT, MRI is recommended.

A collection of synchondroses in all cervical vertebrae, especially seen in the dens, may mimic a fracture. To distinguish dens-arch synchondroses

from a fracture, note that the synchondrosis is visible on an oblique view but not on a straight lateral film. Ossification centers vary depending on age. If there is any question with regards to an injury vs. an ossification center, consult a radiologist or obtain a CT scan. **Table 10** lists common mimics that may appear in cervical spine imaging.

For a detailed look at the Pediatric Cervical Spine, please see our July 2008 issue of *Pediatric Emergency Medicine Practice*, Emergency Evaluation Of The Pediatric Cervical Spine.

SCIWORA

Spinal cord injury without radiographic abnormality (SCIWORA) was defined in 1982 by Pang and Wilberger as "objective signs of myelopathy resulting from trauma without evidence of ligamentous injury or fractures on plain x-ray or tomographic studies."¹¹¹ Transient vertebral displacement with subsequent realignment to a normal configuration results in a damaged spinal cord with a normal-appearing vertebral column.¹²⁰ Historically, this has

Risk Management Pitfalls For Cervical Spine Injury

- "I did not think a broken arm would distract him from reporting tenderness to his neck."** Distracting injuries are subjective and based on the patient's interpretation of pain, not the physician's. If there is any doubt if an injury is distracting, obtain radiographs of the patient's cervical spine. One patient's distracter is not always the same as that of another.
- "The initial 3-view radiographs were negative so I cleared the patient from cervical precautions. I thought the midline cervical tenderness was secondary to a muscle strain not fracture."** If a patient continues to have significant cervical tenderness after plain films, obtain a CT scan to further evaluate the cervical spine.
- "The intoxicated patient had negative cervical radiographs and no cervical tenderness, so I cleared him from spinal precautions. Why is he paralyzed now?"** Do not remove an intoxicated patient from cervical precautions until you can perform and document a repeat examination with no midline tenderness in a sober patient.
- "I checked sensation during my initial examination but did not record the results."** Spinal cord injuries may be easily missed in a busy ED. The patient's lack of movement may be thought to be due to a lack of cooperation or intoxication. It is important to document a full neurologic examination during the initial evaluation and at time of disposition. Write it down. "Negative acute" or "WNL" is not adequate.
- "I wanted to see the cervical radiographs before I intubated the patient. I did not know that he would aspirate."** The primary survey and necessary interventions to stabilize the patient are ALWAYS preformed before radiographs. If the airway is in jeopardy assume the patient has a spine injury, apply in-line cervical stabilization, and intubate the patient.
- "Her mechanism was not consistent with a cervical spine injury, so I removed her from the cervical collar. She just fell from standing at her nursing home."** Always take a complete and detailed history before clinically clearing a patient from a cervical collar. Older patients are at increased risk for cervical spine injuries with seemingly minimal mechanisms. Have a high level of suspicion for cervical fractures in the elderly.
- "I thought that the radiographs were adequate to clear the patient from the cervical collar even though the cervical thoracic junction was not visualized."** Never settle for inadequate films. Significant pathology can be missed if the cervical thoracic junction is not visualized. Order a repeat swimmer's view or a CT scan. Inadequate films provide no legal protection.

been considered an entity seen mainly in children. The NEXUS data has called this idea into question.

The NEXUS definition of SCIWORA is the “presence of a spinal cord injury, as shown by MRI, when a complete and technically adequate plain radiographic series consisting of at least 3 views reveals no bony injury.”¹²⁰ In NEXUS, there were 3065 pediatric patients (< 18 years) who sustained SCI, but there were no pediatric cases of SCIWORA in this large series. There were 27 SCIWORA patients (all adults) in the study and all had MRI evidence of injury or spinal stenosis and all had at least one NEXUS criteria present. SCIWORA was an uncommon injury pattern in general, occurring in only 3% of cervical spine injury patients and 0.08% of all patients enrolled.⁵⁵ SCIWORA has become a misnomer because most patients actually have a “radiographic abnormality” detectable on MRI.^{66,119}

The true incidence of SCIWORA is unknown. NEXUS and other data suggest that spinal stenosis and intervertebral disc disease play a prominent role in the development of SCIWORA in adults.^{122,123} Risk factors for SCIWORA in children include more tenuous spinal cord blood supply and greater elasticity in the vertebral column than in the spinal cord.¹¹¹ Findings on MRI include ligamentous or disc injury, complete cord transection, and spinal cord hemorrhage.¹²⁴

Figure 12. Severe Flexion Rotation Injury At C5 With Bilateral Facet Dislocation



21-year-old male with quadriplegia after bull riding accident. CT reveals a severe flexion rotation injury at C5 with bilateral facet dislocation. MRI revealed near complete cord transection. Angiogram of the neck revealed vascular injury in bilateral vertebral arteries at the level of the injury. Reproduced with permission from Lisa Freeman Grossheim, MD.

Without documentation that an adequate series of plain radiographs was interpreted by an experienced reader as being negative, it is uncertain that all such cases were truly without radiographic abnormality. Also, in the absence of MRI or documentation of actual cord injury, it is possible that some of these cases may have had brachial plexus, nerve root injury, or peripheral nerve injury rather than SCI. Referral bias may be a factor as well in case reports or case series from tertiary referral centers.

The presence of cervical ligamentous injury without radiologic evidence is rare, but delayed instability has been reported.¹²⁵ Most cervical imaging is performed with the patient in the physiologically ‘unloaded’ position and it is possible that cervical instability is not evident until the patient is upright.¹²⁵ It is reasonable to recommend follow-up imaging for persistent pain.

Management And Disposition

Treatment Of Cervical Strain/Whiplash/Non-Specific Soft Tissue Injury

Few prospective controlled studies of whiplash treat-

Table 9. Injuries Associated With Hyperflexion¹¹³

Injuries Associated With Hyperflexion	
Anterior subluxation	potentially unstable
Bilateral interfacetal dislocation	unstable
Simple wedge compression fracture	stable
Clay shoveler's fracture	stable
Flexion tear drop fracture	extremely unstable
Atlanto-occipital dislocation	unstable
Odontoid fracture with lateral displacement fracture	unstable
Transverse process fracture	stable
Injuries Associated With Hyperflexion And Rotation	
Unilateral interfacet dislocation	stable
Injuries Associated With Hyperextension	
Avulsion fracture of anterior arch of C1	varies
Posterior arch of C1 fracture	unstable
Extension teardrop fracture	unstable
Laminar fracture	varies
Traumatic spondylolisthesis (“Hangman’s fracture”)	unstable
Vertical Compression (Axial Load)	
Burst fracture at any level (except C1)	stable
Jefferson burst fracture at C1	extremely unstable
Isolated fracture articular pillar or vertebral body	stable

ment exist. Routine treatment for acute injuries often consists of pain medications, NSAIDs, and muscle relaxants. Range of motion exercises, physical therapy with a variety of modalities, trigger point injections, and transcutaneous electrical nerve stimulator units also may be beneficial but are not usually prescribed from the ED. Collars are generally unhelpful. In a randomized parallel-group trial of 458 patients, patients were treated with immobilization, mobilization, or no specific treatment ('act as usual'). No significant differences were seen with regards to prevention of pain, disability, and work capability one year after injury.¹²⁶ Dehner et al compared 2 days of immobilization with a soft cervical collar versus 10 days of immobilization and found no difference in terms of pain, range of motion, or disability.¹²⁷

Patients with an unstable cervical spine injury will either be admitted or transferred to a higher level of care. Patients with stable injuries such as those with an isolated transverse process fracture or other isolated clinically unimportant injury with no evidence of neurologic impairment whose pain is not severe may be discharged in a cervical collar with clear follow-up care arranged.

Controversies And Cutting Edge

Following negative cervical spine imaging in intoxicated patients with no other injuries, some physicians recommend to keep these patients in the ED until the effects of the drugs or alcohol wear off in order to be able to "clinically clear" the spine prior to discharge. The need to retain these patients after ruling out all other injuries contributes to ED overcrowding, increased costs, and increased burden on treating physicians.⁶⁵ This practice is generally not necessary as CT imaging of the cervical spine is available in most facilities and has been shown to be sensitive in the detection of cervical spine injury, including indirect evidence of ligamentous injury. CT is not flawless

Figure 13. Pseudosubluxation As Seen On CT



Sagittal construction CT image of a 3-year-old boy who fell 10 feet showing demonstrated physiologic pseudosubluxation of C2 on C3. Note that the posterior elements are in alignment. No injuries were identified in the study. Reproduced with permission from Lisa Freeman Grossheim, MD.

in detecting injury of course, so when in doubt, obtain an MRI or examine the patient when sober.

The ideal method for clearing the cervical spine in trauma patients who do not have a normal mental status and are in the ICU is controversial. Two opinions predominate: CT is adequate to clear the cervical spine or CT coupled with MRI is necessary to clear the cervical spine in this patient population. The literature contains multiple studies supporting both opinions. For example, Tomycz et al reviewed the records of 690 patients who had both cervical spine MRI and CT after blunt trauma. Of these patients, 180 had a GCS of 13 or greater and had no neurological deficit. All CTs were read as normal. The average time between CT and MRI was 4.6 days. Among these 180 patients, MRI identified 38 patients (21.1%) with acute traumatic findings in the cervical spine. None of these patients had a missed unstable injury and no patient required surgery or developed evidence of delayed instability.¹²⁸ Conversely, Stassen et al recommended both CT and MRI for obtunded trauma patients, noting that 30% of patients in their prospective study with a negative cervical spine CT had positive findings on MRI for ligamentous injury.¹²⁹ More research is needed to settle this controversy.

Vascular Injuries

Vertebral and carotid artery dissection can occur with blunt cervical trauma. Blunt cerebrovascular injury is uncommon, with a reported incidence between 1% and 3%;¹³⁰⁻¹³³ 37% to 58% of these patients have a permanent neurologic deficit on discharge.^{130,131,134} The classic presentation of a carotid injury is that of a neurologically intact victim of a motor vehicle collision who subsequently develops hemiparesis.¹³⁵ Patients included in most studies who are considered to be at risk are those with facial fractures, cervical

Table 10. Common Mimics In Interpretation Of Pediatric Cervical Spine Radiographs^{87,97,116}

Diagnosis	Mimic
Odontoid fracture	Odontoid does not fuse with the body of the axis until age 6-8
Compression fracture	Vertebrae during childhood are normally wedge-shaped
Chip or teardrop fractures	Ring apophysis in anterior-superior or anterior-inferior corners of vertebral body
Ligamentous injury	C2-C3 pseudosubluxation
Lack of lordosis	Ligamentous injury
	Angulation at individual intervertebral spaces
	Pronounced vascular channels in an ossification center

fractures, low GCS, or signs of vascular or neurologic injury. Mechanisms associated with high risk of blunt carotid and vertebral injury include direct blows to the neck and deceleration injuries producing high shearing forces from a stretching or twisting motion of the neck, such as motor vehicle collisions or falls.^{101,121,138} Symptoms may be immediate or delayed for days. Almost half of the patients with vascular injury have a normal initial neurologic examination.¹³⁶ A retrospective review of the National Trauma Database of >700,000 patients demonstrated that the presence of a cervical fracture produces an odds ratio (OR) for carotid or vertebral artery injury of 8.4 (95% CI, 6.8-10.3), an OR for carotid injury of 2.6 (95% CI, 1.9-3.6), and an OR for vertebral artery injury of 30.6 (95% CI, 21.8-42.8). The presence of a transverse process fracture alone has an OR for vertebral artery injury of 19.5% (95% CI, 12-30.5).¹³⁷

Cothren et al determined that 3 injury patterns were associated with an increased risk of cervical vascular injury: subluxations, C1 to C3 body fractures, and fractures with extension through the transverse foramen.¹³⁹ MR angiography has shown promise as an imaging modality for evaluation of vascular injury. It will detect mural hematoma and dissection, pseudoaneurysms, and arteriovenous fistulae. Digital subtraction angiography remains the gold standard to make the diagnosis of cerebrovascular injury. However, multislice CT angiography is often more readily available than angiography but may not be as sensitive. In a prospective study of 216 patients, the combination of CT and MR angiography was directly compared to standard angiography. CT angiography was 47% sensitive for CAI and 53% sensitive for VAI. MR angiography was 50% sensitive for CAI and 47% sensitive for VAI.¹³⁴ **Figure 14** shows a CT of the neck and discusses the findings on the follow-up CT angiogram. CT angiography may lack sensitivity secondary to the associated scatter from bone, especially near the carotid canal, which is an area with high prevalence of injury.¹³⁵

Table 11 lists indications for screening for vascular injury.

Pharmacotherapy For Acute Spinal Cord Injury

A number of agents have been studied in an attempt to improve neurologic outcome following spinal

Table 11. Indications For Screening For Vascular Injury¹³⁴

- Unexplained neurologic deficits in patients with hyperextension/hyperflexion injuries
- Severe blunt trauma to neck or seat belt injury
- Cervical spine or skull base fractures adjacent to or involving vascular foramina
- Le Fort II or III facial fractures

cord injury, including naloxone, glucocorticoids, nimodipine, tirilazad mesylate, and GM1 ganglioside. The National Acute Spinal Cord Injury Studies (NASCIS) suggested an outcome benefit of high dose methylprednisolone therapy when given within 8 hours of spinal cord injury.¹⁴⁰ The recommendation was the result of a secondary analysis of the data and the overall methodology of the trials have received considerable criticism.¹⁴¹ A randomized trial in France using an identical treatment protocol failed to show a benefit of corticosteroid therapy.¹⁴² The American Academy of Neurologic Surgeons performed a critical analysis of the trials on steroids in spinal trauma and questioned the benefit of treatment.¹⁴³ Currently, steroids in spinal trauma are a treatment option and the negligible potential benefit must be carefully weighed against the potential for harm, ie, increased risk of infection.

Case Conclusion

Despite repeated attempts at verbal reassurance, soft restraints, and benzodiazepine sedation, the patient remained uncooperative with his ED evaluation. He was intubated so as to protect him from self-harm until his imaging was completed. His cervical spine CT revealed a burst fracture at C6 with retropulsion of bone fragments into the spinal canal.

Figure 14. CT Of The Neck



This CT shows a severe distraction injury at C5-C6 and fractures of the C5 and C6 transverse processes with involvement of the transverse foramen. A follow-up CT angiogram of the neck revealed possible focal dissection of the vertebral artery at C3. Reproduced with permission from Lisa Freeman Grossheim, MD.

Summary

Low-risk patients for cervical injury, as defined by the NEXUS or Canadian criteria, generally do not need any imaging. For patients who require imaging, many can be evaluated with plain radiographs alone. Patients with multi-system injuries are best evaluated with CT as their initial imaging modality. MRI is indicated for suspected cervical ligamentous injury or spinal cord injury. CT angiogram and MR angiogram have utility in identifying cervical vascular injury.

Note

Higher resolution versions of all images in this article can be found online at www.ebmedicine.net/topics.

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Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

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CME Questions

1. **The majority of cervical spine injury patients are the victims of:**
 - a. Sports related injury
 - b. Motor vehicle accident
 - c. Falls
 - d. Battery
 - e. None of the above
2. **The upper cervical spine acts as a distinct unit from the lower cervical spine, with distinct injury patterns. Which of the following statements is FALSE regarding C1 and C2 injuries?**
 - a. C1 fractures are uncommon.
 - b. The Jefferson fracture does not involve ligamentous disruption.
 - c. The open mouth odontoid view is useful to identify fractures.
 - d. C2 fractures are common in older patients.
 - e. Hangman's fracture is also known as traumatic spondylolysis C2.
3. **Which condition is NOT usually associated with spinal cord injury?**
 - a. Simple wedge compression fracture
 - b. Atlanto-occipital dislocation
 - c. Bilateral interfacet dislocation
 - d. Flexion teardrop fracture
 - e. All of the above are usually associated with spinal cord injury
4. **Which of the following clinical indicators is NOT a NEXUS criteria for low probability of cervical spine injury?**
 - a. No midline tenderness
 - b. No focal neurological deficit
 - c. Normal alertness
 - d. No painful distracting injury
 - e. All of the above are NEXUS criteria
5. **Which injury is considered a clinically significant cervical spine fracture?**
 - a. Spinous process fracture
 - b. Transverse process fracture
 - c. Osteophyte fracture
 - d. Type II odontoid fracture
 - e. Simple wedge compression fracture

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