

Cervical Spine Injury: A State-Of-The-Art Approach To Assessment And Management

4:00 a.m.: The young woman is barely out of high school. She and her boyfriend were wrestling when she fell backwards onto her head. Suddenly everything stopped. Her strong limbs became limp; she felt nothing below her breasts. The boyfriend, almost paralyzed with fear, called 911.

The medics applied a cervical collar, placed her on a backboard and brought her to your ED. She looks at you with fear, and says, "Am I going to be all right? What's happened to me?"

An essential part of early trauma care involves the assessment and management of the patient with potential injury to the spine. This often-devastating injury can have lifelong implications for the patient and, if poorly managed, the treating physician as well. As specialists in emergency medicine, it is not good enough to be "familiar" with the management of these high-risk patients—we must become experts! This requires a thorough understanding of the biomechanics of trauma, refined clinical examination skills, current knowledge of the indications for spinal radiography, and a sophisticated approach to the interpretation of these x-rays. A zero-tolerance policy for missed spinal injury will protect patient and physician alike.

Epidemiology

The National Spinal Cord Injury Database (NSCID) has compiled epidemiologic data on spinal cord injury patients in the United States since 1973.¹ An estimated 13% of new spinal cord injuries are entered into the database each year; as of April 2001, information is available for 20,527 cases.² Data from the NSCID and other studies suggest that the annual incidence of spinal cord injury, not including those who die at the scene, is roughly 40 cases per

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CME Objectives

Upon completing this article, you should be able to:

1. explain the indications for cervical spine imaging and which diagnostic studies to order in the trauma patient;
2. interpret a standard three-view cervical film series in a thorough, systematic manner;
3. discuss evidence-based methods relating to special situations in cervical injury, such as airway management, pediatric considerations, and spinal cord injury without radiographic abnormality; and
4. describe treatment with methylprednisolone in patients with spinal cord injuries.

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See "Physician CME Information" on back page.

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million population, or approximately 10,000 new cases each year.^{1,3-5} Four times as many vertebral column fractures occur without neurologic sequelae.

Spinal cord injury is predominantly a disease of productive young adults. Fifty-five percent of cases occur among people in the 16- to 30-year age group. Overall, 81.7% of patients are male. Since 1973, there has been a gradual increase in the mean age at time of injury and the proportion of victims over the age of 60 years.^{1,6} This trend is not surprising, since the median age of the general population has experienced a similar increase during the same period.

Most patients with spinal cord injury are victims of vehicular trauma. Since 1990, motor vehicle crashes and pedestrians struck account for 37.4% of cases. Speeding, alcohol intoxication, and failure to use restraints are major risk factors. The next largest contributors are acts of violence (gunshot wounds and assaults—25.9%), followed by falls (21.5%) and recreational sporting activities (7.1%). Data from the NSCID show the proportion of injuries due to motor vehicle crashes and sporting activities has declined, while the proportion of injuries from acts of violence has climbed steadily since 1973.¹

*The incidence of cervical spine fracture in most series of blunt trauma patients is between 1% and 6%, while fractures of the thoracolumbar spine occur in 2%-3%. Roughly 65% of vertebral injuries involve the cervical spine, 20% involve the thoracic spine, and 15% involve the lumbar spine.*³⁻⁵

The most common site of fracture in the cervical spine is C2 (including the odontoid), which accounts for roughly 24% of fractures. C3 is the least likely vertebra in the cervical spine to be fractured. Dislocations occur most commonly at C5-C6 or C6-C7 and uncommonly at C7-T1 and the atlanto-occipital complex. Children (<12 years) and the elderly (>50 years) usually sustain injury to the upper cervical spine (C1-C3); approximately 43% of injuries in patients older than 50 years involve the atlanto-axial complex.⁷ Teens and young to middle-age adults (12-50 years old) usually sustain injury to the lower spine (C6-T1).

Initial Stabilization/Prehospital Care

As with all patients suffering significant trauma, the clinical imperative during the initial assessment is to rapidly identify and manage injuries posing a threat to life. Airway management, hemodynamic stabilization, and the maintenance of adequate tissue perfusion are the priorities of initial care. During this frenetic time period, the physician should assume the neck to be broken and take appropriate spinal precautions. Once the ABCs have been addressed, the clinician can then turn to a careful physical exam, including examination of the vertebral column and neurologic function, and then set management priorities.

Spinal Immobilization

Assume that all blunt trauma patients have spinal cord

injury until proven otherwise. The spine must be adequately protected until injury has been identified and stabilized or reliably excluded. In most patients with spinal injury, neurologic impairment is clinically apparent early in the course of evaluation.^{8,9} However, mechanically unstable spines are especially vulnerable to additional injury from external forces. Excessive manipulation may cause or worsen spinal cord injury. Attention to detail, careful protection of the spine, and frequent examinations will decrease this risk.

Many studies have examined techniques for optimal cervical immobilization using a variety of cervical collars, backboards, and extrication devices.¹⁰⁻¹² These efforts have resulted in the universal practice of spinal immobilization with a rigid cervical collar (which incorporates the upper thorax), sandbags or taped blocks, and a long spine board (padded or unpadded). The rationale for this intervention dates back to the report by Rogers in 1957 that showed that 10% of spinal cord injuries occurred or were exacerbated following the initiation of professional medical care.¹³

Spinal immobilization is not without consequence. The patient with inadequate protective reflexes can easily aspirate while strapped in the supine position. Others with minor brain injury or intoxication may become combative when tied to the board. Pharmacologic control of the patient may be required until spinal injury can be reliably demonstrated or excluded.

In addition, prolonged immobilization may cause significant discomfort and pressure necrosis. For these reasons, the patient should be removed from the spine board as soon as possible in the context of the case at hand. A “backboard protocol” can decrease the length of time a patient remains immobilized. In EDs with such a protocol, the triage nurse will immediately alert an emergency physician when a patient is brought in on a backboard. The physician will then examine the patient to decide whether immobilization should be continued or whether x-rays are needed.

In the patient with a clear-cut spinal cord injury, prompt removal from the spine board is even more critical—not less. Impaired sensation and sympathetic tone put these patients at increased risk for pressure sores, rhabdomyolysis, and compartment syndrome. When and how to remove the backboard from a spine-injured patient should be based on either an established protocol or consultation with a neurosurgeon.

Airway Management Considerations

In most victims of major trauma requiring urgent airway management, intubation will be done *before* a full assessment of the cervical spine is possible. The safety of oral intubation in the setting of known or suspected cervical spine injury was once controversial. It was argued by some that laryngoscopy causes significant movement of the neck, putting the patient with cervical fracture at increased risk for neurologic injury. Proponents of this theory recommended blind nasotracheal

intubation or surgical cricothyrotomy as the airway management of choice. While it has been demonstrated that laryngoscopy does indeed cause movement of the destabilized cervical spine,¹⁴⁻¹⁷ it has also been shown that this can be minimized by meticulous in-line stabilization^{16,17} (*stabilization*, not traction). Numerous studies show that endotracheal intubation with in-line stabilization *does not* significantly increase the risk of neurologic injury in patients with unstable cervical spine fractures.¹⁷⁻²⁵ Most authorities now believe that endotracheal intubation using rapid-sequence induction (RSI) is the preferred method of airway management in the patient with the potential for cervical injury. It should be noted that careful documentation of the procedure is crucial to risk management (i.e., "...in-line cervical spine immobilization maintained during intubation...").

When RSI is impossible or unsuccessful, alternative airway management techniques become necessary. There is no "perfect" airway rescue technique, and the spine should be manually stabilized regardless of which device is selected. The decision on which approach to use in the setting of a failed airway should be guided first and foremost by the experience of the operator and the resources available. While there are no large prospective trials in the literature evaluating the use of alternative airway devices in patients with cervical injury, cadaver-model studies and small case series suggest that fiberoptic-guided intubation is least likely to move the destabilized cervical spine.^{16,26} The utility of this approach may be limited by operator experience and the presence of blood or gore in the airway. The intubating laryngeal mask (Fastrack™) is also a reasonable alternative and may be more available and familiar to most emergency physicians.^{27,28} Available data suggest that the Combitube™ is potentially dangerous in the setting of an unstable cervical spine, as it is difficult to insert with the neck held in-line and is more likely to cause undesirable spinal movement.²⁹ While surgical cricothyrotomy does cause measurable movement of the injured spine, this is not felt to be clinically significant.³⁰

ED Evaluation

*"A lover forsaken A new love may get,
But a neck when once broken can never be set."
—William Walsh (1663-1708), British poet*

History

Historical information can often provide clues to help the emergency physician identify cervical spine injuries. The patient, prehospital providers, family members, and witnesses may provide valuable information about the events that will help guide the evaluation, diagnosis, and disposition.

The mechanism of injury should also be explored during the patient interview. As is discussed later in the text, some fractures are commonly associated with particular mechanisms. All patients with potential injury

should have a complete primary and secondary survey performed. A history of neck pain, numbness, burning, or weakness (whether present in the ED or having resolved prior to arrival) may signal cervical spine injury.

The past medical history is likewise important because certain medical conditions may predispose patients to cervical injury. Patients with rheumatoid arthritis may rupture the posterior odontoid ligament with minimal trauma, while children with Down's syndrome are predisposed to atlanto-occipital dislocation.

Physical Exam

After life threats have been addressed, the physician can then focus on the secondary survey. Several important steps should be performed and documented. First, an assessment of the patient's mental status is crucial, as this will influence the decision to obtain radiographs. Many minimally brain-injured patients (GCS 14) appear to have a normal mental status on superficial examination. When there is any doubt about the patient's mental status, the physician should have a low threshold to image the cervical spine.

Second, the physician must inspect and palpate the entire spine for evidence of ecchymosis, deformity, or focal tenderness. Determine whether the patient has focal vertebral tenderness as opposed to paravertebral muscle tenderness. Obtain radiographs if the patient has point tenderness over the bone, or if this distinction cannot be made. Finally, the physician will have to decide whether a distracting painful injury is present. As is discussed later in the text, this problematic issue depends on clinical judgment.

Essentials Of The Neurologic Examination

A detailed and precise neurologic examination is critical. Serial examinations are of equal importance in order to identify evolving neurologic pathology or associated vertebral injuries that may require surgical decompression or stabilization.

The American Spinal Injury Association (ASIA) has established guidelines for motor and sensory evaluations.³¹ In the awake, interactive patient, light-touch sensation may be assessed by dermatome to localize the most cephalad extent of the spinal cord injury. Remember, on the anterior chest, dermatome levels abruptly change from C4 to T2 just above the nipple line. Pain sensation can be used to test contralateral spinothalamic tract function. Motor function, indicative of ipsilateral corticospinal tract integrity, is assessed on a 0 to 5 scale. Dorsal column testing will differentiate between a complete lesion and an anterior cord syndrome. This is best examined with proprioception or vibration in the distal extremities. A quick and simple test of vibration is by using your beeper (set on vibrate) and placing the end to the area to be tested.

If the patient has a neurologic deficit, pay special attention to rectal tone, sacral sensation, and bowel and

bladder function in order to avoid missing injuries to the conus medullaris and cauda equina, as well as documenting complete vs. incomplete cord injury. Male patients with a cord injury may have priapism. In the presence of a spinal deficit, test the bulbocavernosus reflex. Insert one finger in the rectum and then either tug gently on the Foley, pinch the glans penis, or press on the clitoris. This should elicit an involuntary contraction of the anal sphincter (the so-called “anal wink”).

Also remember that spinal shock may eliminate all spinal function and reflexes for the first 24-48 hours following injury. Reversal of spinal shock is heralded by the return of the bulbocavernosus reflex.

Classification Of Cervical Spine Injuries

For purposes of injury classification, the cervical spine can be anatomically divided into *anterior* and *posterior columns*. The posterior longitudinal ligament acts as a fulcrum between the two. Cervical spine injuries are described according to the mechanism of injury and resultant radiographic alterations of these columns.³¹ Flexion, extension, axial load, and rotational mechanisms each predispose patients to particular fracture patterns. (See **Figure 1.**)

Flexion Injuries

Flexion injuries cause *compression of the anterior column and distraction of the posterior column*. This results in varying degrees of crush to the anterior aspect of the vertebral body, and ligamentous disruption and widening of the posterior column (“crushed in the front and wide in the back”). Simple wedge fractures, flexion teardrop fractures, unilateral facet dislocations, and bilateral facet dislocations represent a progression of severity (and instability) of flexion injuries.

Extension Injuries

Extension injuries cause *distraction of the anterior column and compression of the posterior column*. There is variable disruption and widening of the anterior ligaments and varying degrees of crush of the posterior elements (“wide in the front and crushed in the back”). Extension injuries include the hangman’s fracture and extension teardrop fractures.

Axial Load Injuries

Axial load injuries cause *compression of both the anterior and posterior columns*. These are the result of forces from above (skull) or below (pelvis) that are applied to the vertebral column in neutral position at the time of impact. Adjacent vertebral bodies are forced against each other with overwhelming force. The resultant vectors cause the vertebral body to shatter outward, resulting in a “burst fracture.” A burst fracture is usually stable because the ligamentous structures of the vertebral column remain intact.

One unstable burst fracture involves C1 (Jefferson fracture). It occurs when vertical forces are applied to the skull and transmitted through the occipital condyles to the lateral masses of the atlas. This results in disruption of the anterior and posterior arches of C1. On the lateral view, look for a widened pre-dental space (between the dens and the anterior arch of C1) and soft-tissue swelling anterior to C2. On the odontoid view, the lateral masses of C1 extend beyond, and overhang, the lateral masses of C2. This extremely unstable injury requires immediate neurosurgical consultation.

Rotational Injuries

Rotational injuries cause varying degrees of *rotation of both the anterior and posterior columns, usually around a facet*

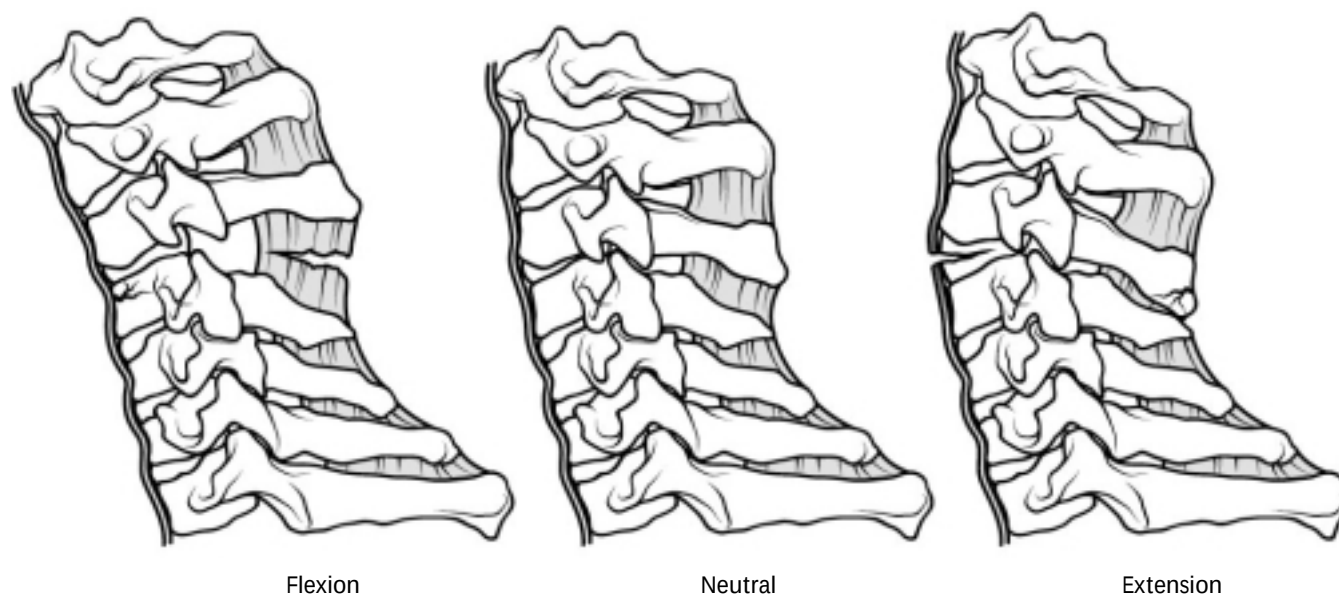


Figure 1. Mechanism of flexion and extension injuries.

dislocation. This occurs when one of the facets acts as a fulcrum, and rotation plus flexion allows the contralateral facet to dislocate. The superior facet jumps above and anterior to the inferior facet. Thus the superior facet comes to rest in the intervertebral foramen, resulting in a “locked in” position and a stable injury (even though the posterior ligaments are somewhat disrupted). The AP radiograph will reveal the spinous process above the injury angled away from the midline in the direction of the rotational injury. On the lateral projection, a subluxation of the vertebra above the facet dislocation will be present. In addition, the jumped facet will be blurred compared to the sharp line that defines the other facets.

*“If thou examinest a man having a dislocation
in a vertebra of his neck, shouldst thou find him
unconscious of his two arms and his two legs
on account of it, while his phallus is erected
on account of it, and his urine drops from
his member without his knowing it;
His flesh has received wind;
his two eyes are bloodshot;
It is a dislocation of a vertebra of his neck.”
—The Edwin Surgical Papyrus³²*

Neurologic Syndromes

While most spinal cord injuries are complete, a significant number of patients present with well-defined neurologic syndromes corresponding to specific incomplete neuro-anatomic lesions. These include the central cord syndrome, anterior cord syndrome, and Brown-Séquard syndrome.³³

The most common of these is the central cord syndrome. This syndrome is the result of a forced hyperextension injury, which causes the ligamentum flavum to buckle into the cord, resulting in a central contusion. The most medial portions of the spinothalamic tract, corticospinal tract, and dorsal column are affected. The syndrome is especially common in elderly patients.

Patients with the central cord syndrome typically have more upper-extremity motor and sensory loss than they do in the lower extremities. It is often called the “burning-hand syndrome,” for obvious reasons. The majority of these patients will regain neurologic function to some degree.

The anterior cord syndrome involves bilateral injury in the distribution of the anterior spinal artery—that is, the corticospinal and spinothalamic tracts, with sparing of the dorsal columns. Hyperflexion is the most common mechanism of injury. This results in the loss of sensory and motor function below the level of injury with preserved position and vibration sense. Because this syndrome may be due to a correctable vascular injury, obtain immediate neurosurgical consultation.

The Brown-Séquard syndrome, also known as hemisection of the spinal cord, is extremely uncommon in blunt injuries and is usually the result of penetrating trauma. When present in a patient with a blunt mecha-

nism, a lateral mass fracture should be suspected. This syndrome results in the contralateral loss of pain and temperature sensation as well as ipsilateral motor paralysis and ipsilateral loss of position and vibratory sensation (all distal to the lesion). This produces the notable physical finding in which the patient can feel a pinprick on his or her paralyzed side. Recovery is sporadic, although most regain the ability to ambulate.³⁴

Indications For Cervical Spine Radiography

The indications for cervical spine radiography have evolved considerably during the past 20 years. In the 1980s, the American College of Surgeons recommended cervical radiography in “any patient with major blunt trauma.”³⁵ While this approach was effective in excluding injury, it came at the expense of a large number of negative radiographs. In addition to the obvious financial implications, this strategy resulted in unnecessary exposure to radiation and potential delays in trauma patient evaluation and stabilization. In the decade that followed, several authors attempted to identify clinical criteria that could be used to reliably exclude cervical injury in adults³⁶⁻⁴² and children.^{43,44} While these studies suggested that low-risk criteria could be successfully employed, none had the statistical power to reliably support their conclusions.

These efforts culminated with the National Emergency X-Radiography Utilization Study (NEXUS).⁴⁵ All emergency physicians should be intimately familiar with the results of this trial. NEXUS was a prospective, multicenter, observational study of a decision rule used to identify patients at low risk of cervical spine injury and who did not need cervical radiography. The decision instrument required patients to meet five criteria in order to be classified as having a low probability of injury:

1. no midline cervical tenderness;
2. no focal neurologic deficit;
3. normal alertness;
4. no intoxication; and
5. no painful distracting injury.

The authors evaluated 34,069 patients at 21 academic and non-academic medical centers. Physicians were asked to assess each of the clinical criteria *before* radiographs were available. No efforts were made to influence physician ordering of radiographs, which were obtained at the discretion of the treating clinician. The decision rule identified all but eight of 818 patients who had cervical spine injury (sensitivity 99.0% [95% CI, 90.0%-99.6%]; NPV 99.8% [95% CI, 99.6%-100%]; specificity 12.9%; PPV 2.7%). Only two of the patients classified as unlikely to have an injury according to the decision rule met the preset definition of a clinically significant injury, and one of these two patients required surgical stabilization. Using the decision instrument, radiographic imaging could have been avoided in 4309 (12.6%) of the 34,069 patients.

Any patient who is not classified as low risk by the

NEXUS criteria (see **Table 1**) should be considered a candidate for cervical spine imaging. In the absence of these findings, radiography can be safely deferred. The inter-rater reliability of these criteria is substantial, although it should be remembered that they are subjective.⁴⁶

Similar indications have recently been validated for assessment of the thoracic and lumbar spine (by different investigators); however, these studies are much smaller.^{47,48} Since it is unlikely that a study the size of NEXUS will ever be repeated to assess the thoracolumbar spine, it seems reasonable to use their criteria to evaluate the entire spine.

Recently, the test performance of the individual NEXUS criteria was evaluated by the study investigators.⁴⁹ None of the low-risk criteria were present in a majority of patients with cervical injury, although posterior midline tenderness and distracting injury were relatively common (403 [49.3%] for each). A substantial number of patients (236 [29.9%]) with cervical injury were classified as non-low risk only because they failed to meet *one* of the five criteria. Posterior midline tenderness was the only non-low-risk finding in more than half of these patients (144/236 [61%]). Of interest, 45 patients (5.5%) had distracting injury as the only criterion; 24 patients (2.9%) had altered alertness or intoxication as the only criterion; and 23 patients (2.3%) had focal neurologic changes as the only criterion. Beware the blunt trauma patient who is “just drunk” or who “only has a femur fracture.” These may be the only triggers for indicated cervical radiographs.

The assessment of a “distracting” injury is particularly subjective and problematic. A recent article by the NEXUS study group cites that a significant fraction of blunt trauma patients may have an injury considered to be distracting.⁵⁰ Ullrich prospectively evaluated 778 patients and found that 264 (34%) had distracting painful injuries (DPIs).⁵⁰ Fractures accounted for the majority of DPIs (154 [58%]); 42 (16%) were soft-tissue injuries or lacerations and 86 (34%) were due to a variety of other entities, including visceral, crush, burn, or other miscellaneous injuries. Among the 37 (5%) patients with cervical fractures, 20 (54%) had a DPI, including three (8%) who had DPI as the only indication for cervical radiography. The determination of whether a particular injury is sufficient to “distract” the patient is one made by clinical judgment.

There are occasional case reports of clinically occult cervical spine injuries in the literature.⁵¹⁻⁵⁵ A careful

review of these cases by Saddison et al revealed that these injuries were not truly asymptomatic.⁵⁶ Several patients *did* have cervical pain or tenderness, and those without clinical findings were either brain-injured, under the influence of drugs or alcohol, or victims of severe multisystem trauma.

Children

What about children? A preliminary review of the pediatric patients in the NEXUS study has been published.⁵⁷ There were 3065 patients (9% of all NEXUS patients) who were less than 18 years old, 30 (0.98%) of whom sustained a cervical spine injury. Relatively few (88 or 2.9%) of these children were younger than 2. While approximately a quarter (817 or 26%) were between the ages of 2 and 8, the majority of enrolled children were between 8 and 17 years old (2160 or 70.4%). The decision rule correctly identified all pediatric cervical spine injury victims (sensitivity 100% [95% CI, 87.8%-100.0%]) and properly designated 603 patients as low risk (NPV 100% [95% CI, 99.4%-100%]). While the decision rule performed well, the small number of infants and toddlers in the study suggests caution in applying NEXUS criteria to this particular age group.

“I find the great thing in this world is not so much where we stand, as in what direction we are moving: To reach the port of heaven, we must sail sometimes with the wind and sometimes against it—but we must sail, and not drift, nor lie at anchor.”
—Oliver Wendell Holmes

Which X-Ray Views Should Be Obtained?

In 1989, Mirvis et al surveyed 125 North American trauma centers to assess practice parameters for the evaluation of cervical spine injury.³⁹ Two-thirds of the centers had established protocols for obtaining cervical radiographs, which varied widely among the centers. Thirty-five percent of respondents cleared the cervical spine with a cross-table lateral (CTL) alone; 29% used a standard “three-view” series (CTL, anteroposterior [AP], and open-mouth odontoid view [OMO]), and 24% routinely performed the “five-view” series (oblique views, in addition to the CTL, AP, and OMO). So, which views are needed to reliably exclude injury?

Is The Cross-Table Lateral View Sufficient?

No! It has been demonstrated that the use of a cross-table lateral view alone is *inadequate* to rule out cervical spine injury; it has a sensitivity of between 57% and 85%.⁵⁸⁻⁶⁰ MacDonald et al found that the addition of the anteroposterior and open-mouth odontoid views to the cross-table lateral increased the sensitivity from 83% to 99%.⁶¹ For this reason, at least three views should be obtained in all cases.

It has been argued that a cross-table lateral may be useful to “clear” the cervical spine prior to endotracheal

Table 1. Indications For Cervical Radiography Following Blunt Trauma.

- Neck pain and midline cervical tenderness
- Altered mental status
- Intoxication
- Focal neurological deficits or complaints
- Distracting painful injury

intubation. This approach has several important pitfalls:

1. it may delay definitive airway management;
2. it does not exclude cervical injury, and thus may provide the operator with a false sense of security; and
3. there is no evidence to support an increased risk of neurologic injury during endotracheal intubation, provided effective immobilization is maintained at all times.

Three Views Or Five Views?

The issue of whether the oblique views are routinely needed remains an area of controversy. These views are held by some to be essential because they provide superior visualization of the posterior column (pedicles, articular pillars, neural foramina, and lamina).⁶² Turetsky et al found that the oblique views demonstrated certain fractures not detected on the three-view series.⁶³ Conversely, Freemyer et al found no fractures or dislocations detected on the five-view series that were not identified on the three-view series.⁶⁴ The authors did point out that the oblique views did provide superior anatomic definition of laminar fractures and unilateral facet dislocations. While there is no consensus concerning the necessity for routine oblique radiographs in cervical trauma, these views may be useful in evaluating poorly visualized areas of the posterior column. In addition, the supine oblique view provides excellent definition of the cervicothoracic junction (C7-T1) and may be used instead of the often-inadequate swimmer's view.^{65,66} Ireland et al compared 60 patients whose cervical spines were imaged with swimmer's views to evaluate the cervicothoracic junction to those of 62 patients whose junctions were imaged with bilateral supine oblique radiographs.⁶⁷ Oblique views identified the junction adequately in 38% compared to 37% in the swimmer's view group. However, the facet joints and posterior elements were fully visualized in 70% of those imaged obliquely compared to only 37% in the swimmer's view group. It is reasonable to use the oblique view selectively, after a three-view series has been evaluated.

What Is The Role Of Flexion-Extension Views?

Some authorities recommend that neurologically intact patients with persistent neck pain and tenderness despite normal plain radiographs undergo flexion and extension views to exclude ligamentous injury.⁶⁸ However, the exact role and timing of these views is currently a controversial subject. Numerous recent investigations demonstrate that these views do not increase the sensitivity of standard radiographs in detecting spine abnormalities and may produce false-negative results in acute trauma victims because of associated muscle spasm.⁶⁹⁻⁷³ Flexion-extension films are sometimes used in the evaluation of minor subluxations seen on the lateral x-ray when the abnormality is presumed to be secondary to degenerative joint disease. However, the safety and utility of this practice has not been well-studied.

The use of flexion-extension views was recently reviewed by the NEXUS investigators.⁷⁴ Of the 818 patients ultimately found to have cervical injury, 86 (10.5%) underwent flexion-extension testing. Two patients sustained stable bony injuries detected only on these views. Four patients had a subluxation detected only on the flexion-extension views, but all four had other injuries apparent on routine imaging. These data suggest that flexion-extension views add little to the acute evaluation of patients with blunt trauma.

If flexion and extension films are used, they may be more appropriate in the days and weeks following injury, when muscle spasm has abated. If they are obtained in acute trauma victims, it is essential that the patient be alert and cooperative, as all neck movement must be initiated by the patient and discontinued immediately should pain occur. Manipulation of the neck by the physician or radiology technologist to overcome spasm is absolutely contraindicated. Some authors suggest filming in the erect position to enhance the detection of ligamentous instability.⁷⁵

Also controversial is the use of dynamic fluoroscopy in the obtunded, uncooperative, or intubated patient with normal radiographs. Proponents claim the technique can safely assess ligamentous stability in a group of patients that may be particularly difficult to evaluate.⁷⁶ Opponents argue the technique is unproven and risky, and urge caution until reliable studies are completed.⁷⁷ Existing work reveals that the procedure has a low yield (0.7%) and can result in rare but devastating injuries in some patients.⁷⁸ This technique should not be considered routine ED practice and, if done, is best performed under the guidance of a neurosurgeon or orthopedic spine surgeon.

Interpretation Of Cervical Spine Radiographs

When cervical spine fractures are missed by emergency physicians, it is usually due to one of four basic reasons (see also **Table 2**):

Table 2. Interpretation Of Cervical Spine Radiographs.

A. Lateral view—is the film adequate?

- Alignment: anterior, middle and posterior arcs
- Bones: vertebrae and spinous processes uniformity and height
- Cartilage: intervertebral disk space height and length
- Soft tissue: prevertebral soft tissue width

B. Anteroposterior view

- Alignment of spinous processes
- Distance between spinous processes
- Uniformity and height of vertebrae

C. Open-Mouth Odontoid View

- Spacing of dens and lateral masses
- Lateral alignment of C1 and C2
- Uniformity of bones

1. failure to obtain indicated radiographs;
2. inadequate radiographs;
3. misinterpretation of the radiographs; or
4. radiographs fail to adequately visualize the injuries.

If you adhere strictly to the indications for radiography outlined in this article, you can avoid pitfall #1, and if you *always* demand adequate radiographs, you can avoid pitfall #2. Avoiding pitfall #3 is more challenging but is equally achievable, provided you follow a few basic steps:

- *Be systematic.* Develop an approach for interpreting these radiographs that works and use it on every case until the day you retire.
- *Be patient.* Flipping rapidly through a stack of films can only get you into trouble. Remember, the overhead lights in the ED were not made for reading x-rays!
- *Be a skeptic.* If you see something that “doesn’t look quite right,” don’t blow it off. Get more views and perhaps further imaging studies. This will help you avoid pitfall #4.

While it is clearly beyond the scope of this article to provide all of the information required to master cervical-spine x-ray interpretation, following are a few useful tips.⁷⁹

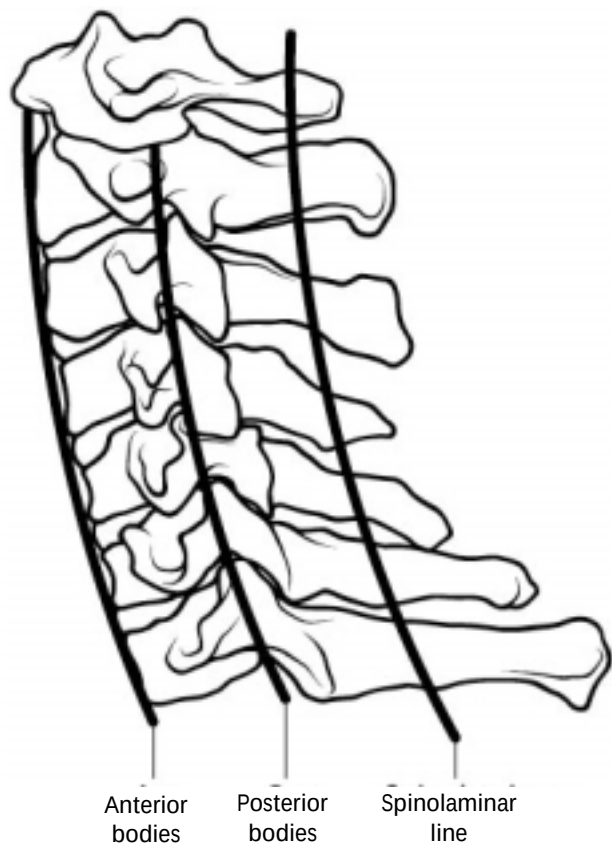


Figure 2. Lateral alignments.

Lateral View

Because approximately 70% of detectable abnormalities will be visible on the lateral view, this radiograph should be inspected first. An *adequate* lateral film must demonstrate all seven cervical vertebrae as well as the top of the first thoracic vertebra. If these are not seen, undertake other measures to obtain an adequate view of the lower cervical spine. If the film is adequate, use the mnemonic “ABCS” to examine the film:⁷⁹

- **A**lignment (see **Figure 2** and **Figure 3**): Three arcs should be easily traced on the lateral radiograph. The first is composed of the anterior margins of the vertebral bodies. The second is defined by the posterior margins of the vertebral bodies. The third is along the bases of the spinous processes (the spino-laminar line). These arcs should be traced as smooth, unbroken lines. If there is a step-off in any of these arcs, suspect a fracture or ligamentous disruption. The only exception to this rule is that occasionally the line along the bases of the spinous processes appears to have a posterior step-off at the C2 level.



Figure 3. Abnormal alignment of C4/5 level following direct strike to neck.

Used with permission from W.B. Saunders Company. In: *Trauma Management: An Emergency Medicine Approach*. Ferrera P, Colucciello SA, Verdile V, et al, eds. St. Louis, MO: Mosby; 2001. Fig. 13-3.

This step-off should be 2 mm or less posterior to a line drawn from the C1 to C3 spinous bases.

- **Bones:** Inspect all of the vertebral bodies, which should have a uniform square or rectangular shape from C2 and below. (See **Figure 4.**) Any small fragment may represent a fracture. Examine all laminae and spinous processes carefully for uniformity and smooth edges. Any loss of height or wedging either anteriorly or posteriorly may be a clue to a compression fracture. The anterior height should be no less than 3 mm shorter than the posterior height. Carefully examine C2, especially the odontoid, which articulates with C1. The odontoid should form a smooth arch just behind the anterior portion of C1 and should be closely applied to the posterior portion of C1. This space between the anterior dens and the anterior ring of C1 is the predental space and should be 3 mm or less in adults and 5 mm in children.

There are a number of radiographic signs distinct to C2. Oblique fractures of the second cervical vertebra below the odontoid may cause the body of C2 to appear enlarged or “fat” compared to C3 (known, not surprisingly, as the “fat” C2 sign).⁸⁰ There is also a radiographic “ring” on C2 best seen on the cross-table lateral view. If this ring is broken, suspect a type III odontoid fracture.⁸¹



Figure 4. Lateral radiograph shows Hangman's fracture.

Used with permission from W.B. Saunders Company. In: *Trauma Management: An Emergency Medicine Approach*. Ferrera P, Colucciello SA, Verdile V, et al, eds. St. Louis, MO: Mosby; 2001. Fig. 13-13.

- **Cartilage** (see **Figure 5**): The next step is to examine the cartilaginous structures. The intervertebral disc spaces should be uniform in height and length. Narrowing of a disc space may be a clue to acute disc herniation or an adjacent vertebra fracture. Widening of a disk space may suggest rupture of the annulus fibrosis or longitudinal ligamentous structures. Give careful attention to the spaces between the spinous processes. Any widening or “fanning” of these spaces could represent significant disruption to the posterior ligamentous complex.
- **Soft Tissues:** Finally, examine the soft-tissue spaces of the lateral radiograph. Abnormal swelling of the prevertebral soft tissue suggests a vertebral fracture. The soft tissue immediately anterior to C1-C4 should be 7 mm or less and, for C5-T1, 22 mm or less. Any



Figure 5. Widely separated C1 and C2 vertebrae (atlantoaxial dislocation) in a pedestrian-motor vehicle crash.

Used with permission from W.B. Saunders Company. In: *Trauma Management: An Emergency Medicine Approach*. Ferrera P, Colucciello SA, Verdile V, et al, eds. St. Louis, MO: Mosby; 2001. Fig. 13-4.

widening of these tissue planes should prompt careful scrutiny for subtle fracture and may suggest the need for consultation or CT scan of the involved area. (Ballooning of the prevertebral tissue may be normal in children depending on the timing of the film during the respiratory cycle; see below.) It should be kept in mind, however, that absence of soft-tissue swelling *does not* exclude injury.

Anteroposterior View

An AP radiograph is necessary to evaluate the cervical spine. This view should include C3 to T1 due to the fact that the mandible obscures C1 and C2. The alignment of the vertebrae and spinous processes is crucial to interpreting the film; the spinous processes should form a straight line down the middle of the vertebral body. (See **Figure 6.**) If one spinous process appears to be out of line compared to the rest, the patient probably has suffered a jumped facet. The distance between the spinous processes should be roughly equal; none of the spaces should be 50% wider than the one immediately above or below. Abnormalities in alignment or spacing could be an indication of unifacet dislocation or fracture of the lateral articulating surface. These findings should prompt you to carefully scrutinize the lateral view and perhaps order oblique films. CT scanning may be helpful when an

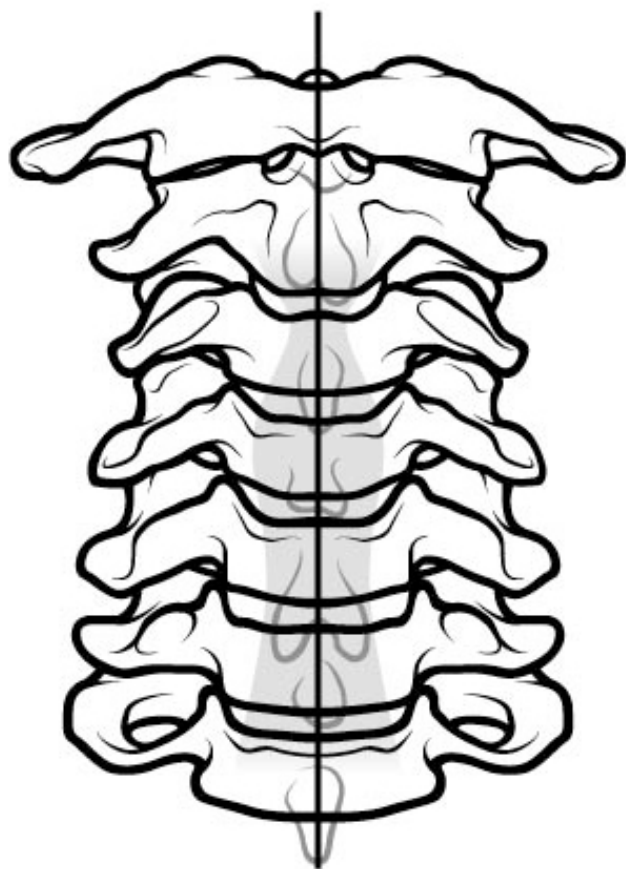


Figure 6. AP spine. Note alignment of spinous processes.

abnormality is found.

Odontoid View

This view identifies fractures involving C1 and the odontoid process of C2. This radiograph can be difficult to interpret due to the overlapping shadows and densities from the occiput and central incisors. *It is imperative to scrutinize this film carefully, as fractures of the first two cervical vertebrae are easily missed.* The dens should be parallel with the lateral masses of C1. The space on each side of the dens (between the dens and lateral masses) should be equal. If this space is asymmetric, it may indicate a fracture. You should then inspect the lateral alignment of C1 and C2. (See **Figure 7.**) If the lateral margins of C1 and C2 are normally aligned (the lateral masses of C1 should not overlap the lateral margins of C2), then the asymmetry at the odontoid space is probably due to patient rotation. (You can also look to see whether the upper central incisors are centered over the dens [head in neutral position] or if they are off to one side [head was turned while the film was taken].)

If the lateral alignment is not normal, you should suspect a fracture. It is common to see a thin black line at the base of the dens. This generally does not represent a fracture but results from overlapping shadows of adjacent structures (Mach effect). Look to see if the line extends *beyond* the margins of the dens, as this is characteristic of a shadow and not a fracture. A vertical split down the dens usually represents the notch between the upper central teeth (look for the faint outline of the teeth overlapping the odontoid). If you are unsure of a finding, you should seek advice before dismissing it as an artifact or rotational abnormality.

Despite optimal technique and careful interpretation, plain-film imaging is incapable of detecting all cervical spine injuries. In the NEXUS study, nearly 40% of patients with fractures were missed with a “standard” three-view series, although the majority of these occurred in cases in which plain radiographs were interpreted as inadequate or abnormal but not diagnostic. However, 23 patients (0.07% of all patients and 2.81% of the fracture group) had 35 injuries (including 3 potentially unstable

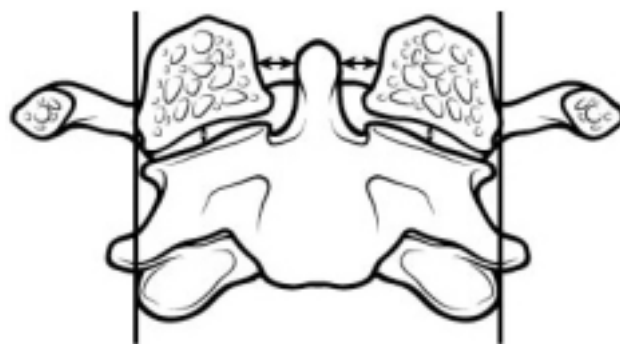


Figure 7. Open mouth view. Note alignment and symmetry of lateral masses.

injuries) that were not visualized on adequate plain-film imaging.⁸² The message is clear:

1. *Never* settle for inadequate films;
2. *Never* ignore subtle findings; and
3. *Always* be suspicious in the patient with persistent significant neck pain and “normal” plain films.

The limitations of plain-film imaging have prompted investigators to evaluate the selective use of advanced imaging techniques that may improve our ability to identify serious injuries, while still minimizing cost and radiation exposure.^{83,84}

When Should CT Or MRI Be Performed?

Computed Tomography

CT scanning is an excellent method for evaluating cervical spine fractures and dislocations. Its advantages

include speed, wide availability, and excellent cortical detail. The primary limitation of CT imaging is that it provides only partial anatomic definition of the spinal cord or adjacent soft-tissue structures.

Contemporary high-resolution scanners detect between 95% and 100% of cervical fractures—a significantly higher sensitivity than plain-film radiography. So, when should this effective, albeit expensive, technology be used? The traditional approach would reserve CT imaging to delineate bony anatomy at the level of identified or suspected fractures and dislocations, in those cases where the upper or lower cervical spine cannot be adequately visualized, in comatose trauma patients, and in patients with persistent pain and / or neurologic deficit despite normal plain films.⁸³⁻⁹⁰ A more aggressive strategy suggests that complete cervical helical scanning may be appropriate and cost-effective in

Continued on page 14

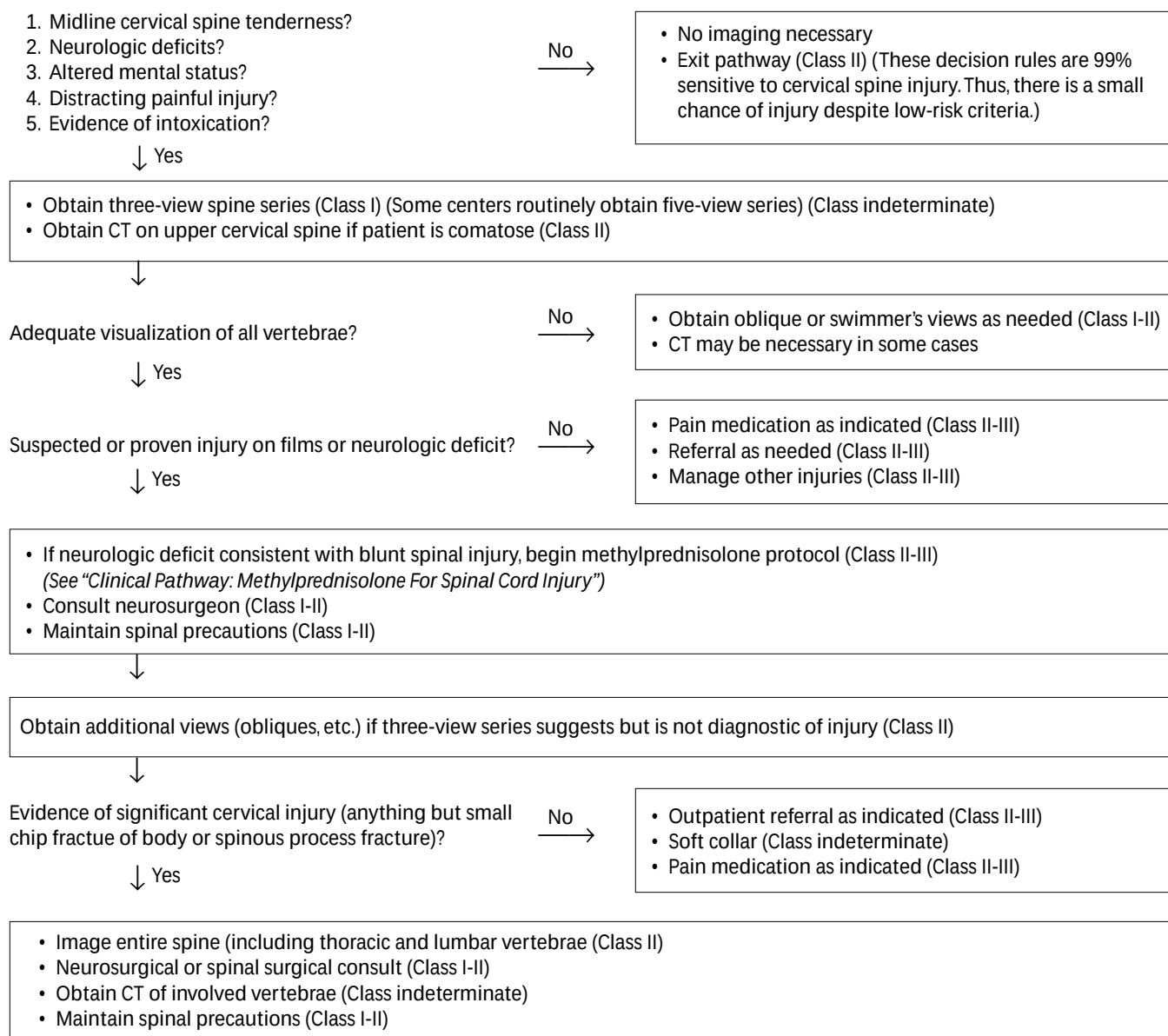
Pearls And Pitfalls In Cervical Spine Trauma

- Increase awareness of the cause of missed and delayed diagnosis of spinal injury, including: misreading of spine films, inadequate radiographs, head injury with altered level of consciousness, alcohol intoxication, multiple concurrent injuries, and two or more levels of spinal injury.
- Always perform a detailed and precise neurologic examination on any patient with potential cervical spine injury.
- Neurological manifestations of spinal injury are known to change rapidly over time. Performing and documenting serial neurologic examinations will be the best tool at your disposal to identify and document evolving pathology.
- Cervical radiography is unnecessary in alert patients without spinal tenderness who are neurologically intact, not intoxicated, and do not suffer from other distracting painful injuries.
- Never rule out cervical injury with a single cross-table lateral radiograph.
- Oral endotracheal intubation and effective in-line immobilization of the cervical spine is the safest method of securing an airway in a patient with suspected cervical pathology.
- Three-view radiographs of the cervical spine is the standard approach for initial evaluation. Order the oblique and swimmer's views selectively as needed.
- The emergency physician must *never* settle for inadequate

radiographs, and a thorough, systematic approach to radiograph interpretation is *absolutely essential* in all cases.

- Treatment with methylprednisolone should be considered for all patients with known or suspected spinal cord injury from blunt trauma, providing that it can be initiated within eight hours from the onset of injury. While the benefits are uncertain, the risk of administration is low.
- Manage the alcohol-impaired patient with a potential spine injury aggressively. Immobilize the patient and either perform serial examinations or obtain radiographs. *Do not* assume that symptoms are related to intoxication.
- When transferring a patient with a known cervical spine injury to another institution, immobilization should *always* be performed with a rigid cervical collar as well as sandbags or taped blocks and a long spine board.
- History-taking should screen for pre-existing conditions that increase the risk of spinal injury, including ankylosing spondylitis, rheumatoid arthritis, previous cervical injury, and previous cervical surgery.
- Remember SCIWORA. If there is any evidence of neurologic impairment at any point in time from the moment the accident occurred, the physician should assume that there is a spinal injury until proven otherwise.
- Judicious use of CT will be of major benefit in evaluating the laminae, pedicles, and spinal canal in a select group of blunt trauma patients. ▲

Clinical Pathway: Diagnostic Algorithm For Suspected Cervical Injury

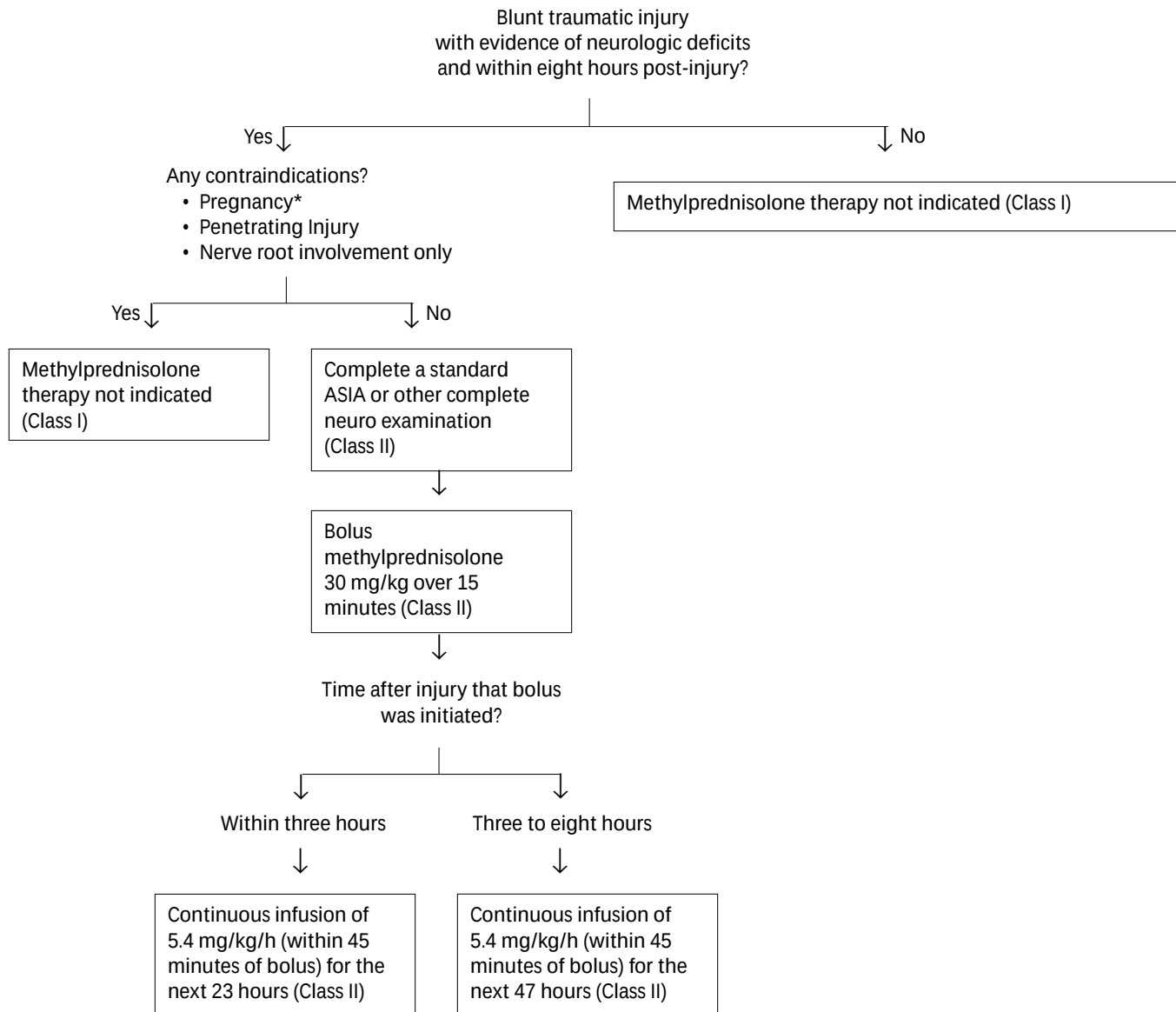


The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Clinical Pathway: Methylprednisolone For Spinal Cord Injury



*Pregnancy is not necessarily an absolute contraindication. Pregnant women were excluded from the NASCIS trial.

The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

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all severely injured patients at high risk for cervical fracture.⁹¹ We believe that in the majority of cases, a selective approach is reasonable. Emergency physicians, trauma and spine surgeons, and radiologists should drive local practice in a collaborative fashion.

Special mention should be made of the intubated trauma patient. Because the presence of an endotracheal tube may alter the radiographic appearance of upper cervical anatomy, a significant number of high cervical injuries may be missed on plain films. Several authors have suggested that patients undergoing cranial tomography for the evaluation of traumatic brain injury should have CT imaging extending through the upper cervical spine (C1 and C2).⁹²⁻⁹⁴ In one study of 100 intubated trauma patients, routine CT scanning of the craniocervical junction demonstrated an 8% incidence of occult C1-C2 and occipital condyle fractures not visualized on cross-table lateral films.⁹³ In another study of 202 patients with severe head injury, cervical CT scanning showed fractures in 28 patients even though plain x-rays were negative in 11 of these 28 (39%).⁹² Other studies show similar results.⁹⁴

Magnetic Resonance Imaging

The MRI is playing an increasing role in spinal cord injury evaluation. It has currently replaced myelography for intra-canal assessment in the evaluation of spinal trauma patients.⁹⁵ Advantages of MRI include its lack of ionizing radiation, multiplanar imaging capabilities, and most importantly its ability to delineate soft-tissue structures (i.e., cervical discs, anterior and posterior ligamentous structures) as well as the spinal cord.⁹⁶ MRI is indicated for:

1. complete or incomplete neurologic deficits to search for and quantify the degree of root or cord injury;
2. deterioration of neurologic function; or
3. suspicion of ligamentous injury despite negative flexion-extension films.

Notable disadvantages of MRI include:

1. a prolonged acquisition time;
2. unavailability at many institutions; and
3. contraindications, including patients with pacemakers, ferromagnetic aneurysm clips, metallic fragments in the spinal cord, and claustrophobia.

In general, MRI is less valuable in evaluating bony structures than CT, but better at determining soft-tissue injury and cord compromise. In most institutions, the neurosurgeon orders this study as opposed to the emergency physician.

*"You will cease to pry into my personal matters, Doctor, or I shall certainly break your neck."
—First Officer Spock, in the "Amok Time" episode of the television series "Star Trek"*

Clinical Issues

Are Head And Maxillofacial Injuries Predictive Of Cervical Spine Injuries?

No. The old dictum that "any patient with an injury above the clavicle needs cervical spine radiography" has not held up to scientific scrutiny. Several studies indicate that there is little if any relationship between head and facial injury and cervical spine injury. Williams et al reviewed 5021 consecutive trauma patients and found that the incidence of spinal injury in patients with maxillofacial trauma was 4%-5%—no greater than the overall population of trauma patients.⁹⁶ Sinclair et al reviewed 168 cases of facial fractures and found the incidence of cervical injury to be 4%,⁹⁷ while O'Malley et al compared 664 blunt trauma patients with significant head injury to 608 patients without head injury and found no difference in the incidence of cervical spine injury.⁹⁸ Davidson et al reviewed 2555 patients admitted with facial fractures following motor vehicle crashes and found the incidence of cervical spine injury to be 5.5%.⁹⁹

In other words, maxillofacial and head trauma in and of itself is not an indication for spinal radiography. As with all other blunt trauma patients, NEXUS criteria should be used to determine the need for cervical radiography. Painful distracting facial injuries or altered mental status as a result of head trauma are clear indications for cervical radiography.

There is also growing evidence that patients with isolated gunshot wounds to the head are not at significant risk for cervical injury, provided the missile trajectory does not involve the neck.¹⁰⁰⁻¹⁰² At first blush, this may seem like a trivial concern in a patient with such a devastating injury—in other words, what's the downside with getting cervical radiographs in a patient with a hole in his or her skull? On the other hand, knowledge that the neck can be safely manipulated may be crucial in the setting of emergent airway management.

Gunshot wounds to the *face*, as opposed to the cranium, are more likely to jeopardize the cervical spine. In one study of 247 patients with gunshot wounds to the face, cervical spine fracture occurred in 20 (8.1%).¹⁰³

Pediatric Considerations

Cervical spine injuries are infrequent in children; fewer than 1% occur in patients less than 12 years of age. In contrast to adults, a larger percentage of pediatric injuries involve the occipito-atlanto-axial segment.¹⁰⁴⁻¹⁰⁷ (See **Figure 8** on page 15.) Several anatomic factors predispose to this level of injury.¹⁰⁵

1. a proportionally heavier head and a higher fulcrum of flexion;
2. lax ligaments, allowing for more mobility at C1-C2;
3. un-fused physes; and
4. horizontally inclined articular facets that facilitate sliding.

There are also a number of anatomic characteristics unique to the pediatric cervical spine that may mimic injury. One of the most common of these is pseudo-subluxation at either C2-C3 or C3-C4.¹⁰⁸ (See **Figure 9.**) It usually occurs in children younger than 10 but may be seen in older children as well.¹⁰⁹ In cases of pseudosubluxation, a straight line can be drawn through the spino-laminar junctions of C1, C2, and C3 (Swischuk line). In addition, it should not be associated with soft-tissue swelling. Other normal variants include anterior wedging of vertebral bodies; secondary ossification centers that may mimic avulsions; variable interspinous distances; widening of the predental space (up to 5 mm); and lateral displacement of the lateral masses of C1 on C2.

Children also have loose prevertebral tissues that balloon outward during expiration.^{110,111} If soft-tissue swelling of the prevertebral space is the only radiographic abnormality, ask the radiology technician to obtain a lateral film timed to the child's inspiration. If timed correctly, the soft tissue will then appear normal.

Spinal Cord Injury Without Radiographic Abnormality

Spinal cord injury without radiographic abnormality



Figure 8. Atlanto-occipital dislocation.

(SCIWORA) is a syndrome of neurologic injury without evidence of bony injury or malalignment on plain radiographs or CT. SCIWORA is common in the pediatric population, making up 4%-67% of all pediatric spinal injuries. These injuries in children are felt to be due to highly elastic ligaments, increased mobility of the immature axial skeleton, and the relatively larger size of the head. Combinations of these factors leave the spinal cord vulnerable during high-velocity trauma.¹¹²⁻¹¹⁶

Recently, several authors have reported SCIWORA in the adult population. These injuries are attributable to different characteristics than in the pediatric population. Many adults with SCIWORA have pre-existing spondylitic changes of the cervical spine resulting in narrow diameters of the cervical canal. Thus, hyperextension and direct blow injuries result in more significant damage than can be appreciated on plain radiograph.^{115,116}

The presentation of SCIWORA ranges from complete paralysis to subjective complaints of numbness. The failure to recognize this injury can result in recurrent and deteriorating neurologic deficits.¹¹⁴⁻¹¹⁹

Patients with SCIWORA often have positive MRI findings ranging from cord hemorrhage or edema to intervertebral disk herniation or cord transection. MRI findings seem to correlate well with outcome; most patients with a normal MRI have an excellent prognosis, while those with dramatic findings usually have a bad outcome.

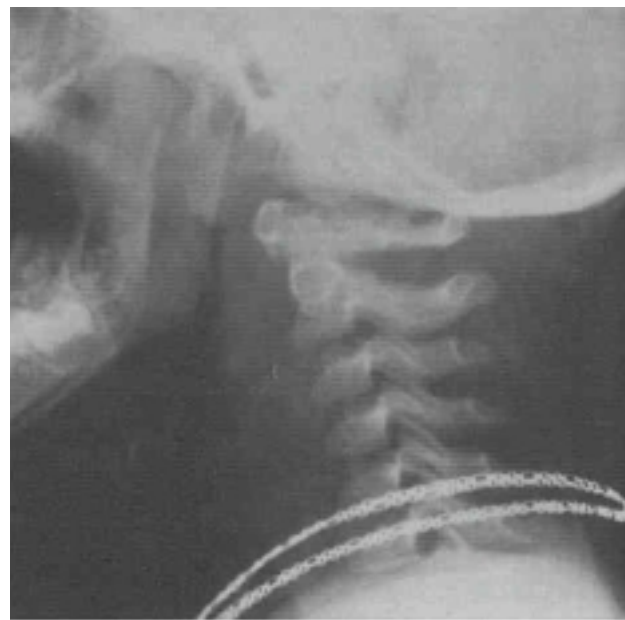


Figure 9. Pseudosubluxation of C2 on C3.

Used with permission from W.B. Saunders Company. In: *Trauma Management: An Emergency Medicine Approach*. Ferrera P, Colucciello SA, Verdile V, et al, eds. St. Louis, MO: Mosby; 2001. Fig. 13-13.

Why Are Cervical Spine Fractures Missed?

With over 10,000 spinal injuries each year, and with jury verdicts in the millions, emergency physicians should carefully analyze the causes of missed or delayed spinal injuries. Despite an improved understanding of injury patterns, advances in diagnostic imaging, and a heightened awareness among well-trained emergency physicians, these injuries continue to be missed.

In 1979, Bohlman reported that 100 of 300 cervical fractures were missed during ED evaluation.¹²⁰ The author found that delay in diagnosis involved misreading of cervical spine films, brain injury with altered level of consciousness, alcohol intoxication, and multiple concurrent injuries. While the proportion of missed injuries in this study is unusually high and perhaps reflects a time when physicians staffing EDs were not as well trained as they are today, some lessons still hold true for recent reports.

In a review of 32,000 trauma patients, Davis et al found delayed or missed diagnoses of cervical spine injuries in 34 of 740 patients (4.6%).¹²¹ Over 70% of these missed injuries were unstable. The authors report major neurologic consequences in 10 of the 34 patients (29%) as a result of the missed or delayed diagnoses. The neurologic consequences included two deaths, four quadriplegic or paraplegic patients, and four patients with perma-

nent limb paresis. The two most common reasons for missing a fracture were inadequate radiographs and misinterpretation of radiographs. The authors point out a recurring problem—the lack of even a minimum standard cervical spine series. They concluded that most errors (94%) leading to the missed or delayed diagnosis did not require sophisticated interpretive skills or advanced diagnostic technology.

Orenstein et al reported on several cases of delayed diagnosis of pediatric cervical spine injury.⁴⁴ In a study of 72 patients with cervical spine injury, nine patients had delays ranging from one day to two months before a correct diagnosis was established. Five of the nine (56%) patients had positive or suspicious x-ray findings that were initially misread as being normal. These errors resulted from misinterpretation of subtle findings on standard cervical spine views. In one case, the fracture was missed because the physician ordered a single lateral view. Two children with falls in the home did not have x-rays ordered despite neck pain.

Reid et al studied 274 patients with spinal injuries and found that 22.9% of cervical injuries and 4.9% of thoracolumbar injuries had a delayed diagnosis.¹²² The causes of the delays included the failure to take x-rays, fractures misread on the x-rays, and the failure of patients to seek medical attention. Associated factors

Ten Excuses That Don't Work In Court

1. "I felt the radiograph was adequate even though I couldn't see the C7-T1 junction."

A laminectomy was performed the next day after the patient presented to another ED for continued neck pain and a swimmer's view was ordered. Never settle for inadequate films. You must see all seven cervical vertebrae and the first thoracic vertebra on the lateral film.

2. "I'm not comfortable starting steroids without a neurosurgical consult."

Methylprednisolone therapy for spinal cord injury is considered the standard of care by many (despite conflicting evidence). You take a significant medicolegal risk if you withhold steroids in the presence of generally accepted indications.

3. "The c-spine films were normal—there could not have been a spinal cord injury."

Spinal cord injury without radiographic abnormality is well-described, especially in the pediatric population. You must take a detailed history from everyone involved, including prehospital personnel. Normal cervical spine films don't exclude spinal cord injury; however, a detailed history of no neurologic symptoms

and repeatedly normal neurologic exams do.

4. "I wanted to get a lateral c-spine film before intubation. I had no way of knowing he would aspirate."

The patient was extubated two months later after treatment for aspiration pneumonia and sepsis. Oral endotracheal intubation has been proven to be safe in the setting of known or suspected cervical spine injury. The rapid-sequence technique with atraumatic laryngoscopy and endotracheal intubation is the best way to prevent a restrained, injured patient from aspirating.

5. "I didn't immobilize his neck because he was drunk and uncooperative."

The intoxicated patient has an unstable cervical fracture until proven otherwise. Immobilization must be accomplished using methods ranging from sedation to the use of paralysis and intubation. Intoxicated trauma patients should either be immobilized and re-evaluated when sober, or they should undergo radiography.

6. "I checked sensation grossly with my car keys but did not record the results."

Continued on page 17

such as intoxication, multiple injuries, decreased level of consciousness, or two levels of spinal injury (8% of patients had 2 or more fractures) contributed to the delayed diagnosis of these injuries. In 17 cases, there was a failure to take x-rays, and in 20 patients, the fracture was missed despite adequate films. The researchers found the development of secondary deficits was significant in the delayed diagnosis group (10.5% in the delayed diagnosis group vs. 1.4% among those whose fractures were identified). Frequent causes of x-ray misreads included a failure to identify subluxation, significant soft-tissue swelling in front of the spine, or simply overlooking very obvious fractures, probably because of inadequate attention to the film. In 20% of cases, the films were of such poor quality that even careful scrutiny did not identify the fracture.

Gerrlets et al retrospectively reviewed 1331 injured patients, among whom cervical injury occurred in 61 (4.6%).⁸⁸ A delay in diagnosis occurred in 10% of survivors—all the result of inadequate radiographs. The sensitivity of plain-film radiography was 85.2%, whereas the sensitivity of CT was 97.2%. These authors recommended early use of CT imaging when plain films were inadequate.

These results highlight two crucial concepts:

1. the emergency physician must never settle for

inadequate radiographs; and

2. a thorough, systematic approach to radiograph interpretation is absolutely essential.

It is also important to remember that 5%-20% of spinal fractures are multiple.¹²³⁻¹²⁵ *The identification of a single fracture should always prompt a search for injury at all spinal levels with appropriate radiographs.*

Management Of Cervical Spine Injuries In Helmeted Patients

Improper handling of an unstable cervical spine injury in the prehospital setting may lead to neurologic damage. The prehospital management of a potential cervical spine injury in a helmeted football player differs drastically from that of other trauma patients. The presence of a helmet and shoulder pads makes the use of a hard cervical collar impossible. The prehospital removal of the protective football gear has previously been a controversial area in patient management. Several studies have shown that leaving protective gear in place in the prehospital setting (provided that the equipment does not interfere with resuscitation) and immobilizing the patient on a long spine board with blocks and straps is a safe method of cervical spine management. This approach is endorsed by the National Collegiate Athletic

Ten Excuses That Don't Work In Court^(continued)

Spinal cord injuries are easily missed with the exam: Neuro WNL (we never looked). Precise neurologic exam initially and repeated prior to disposition is essential. Document your findings carefully, especially if a deficit is found.

7. "I didn't think an open femur fracture would distract him from reporting tenderness on his neck exam."

Classifying an injury as distracting is a subjective decision. Patients perceive pain differently, so you'll need to evaluate each case individually. If you ever have a doubt if an injury is distracting, it is best to order radiographs and immobilize the patient. Remember, the majority of distracting injuries will be fractures or trauma to soft tissue.

8. "Since the three-view c-spine films were negative, I thought the continued neck pain was from a pulled muscle."

Nice try. Patients with persistent neck pain may harbor unstable ligamentous injuries. Whether such patients need MRI, immediate or delayed flexion-extension films, or just a soft collar and follow-up remains unclear. If flexion-extension films are ordered, the patient must perform the maneuvers in order to prevent further injury.

9. "I didn't think transportation with cervical spine immobilization was necessary since his neck wasn't tender."

The patient didn't report neck tenderness because he had a traumatic brain injury. While en route to the trauma center, he developed neurologic deficits and is now a quadriplegic. Remember—never clear spines on a patient with a brain injury in the ED. If transfer to another facility is arranged, always transport the patient with full cervical immobilization, including hard neck collar, sandbags, and long spine board with the patient strapped to the board. This will potentially avoid further injury and ensure detailed evaluation at the receiving facility.

10. "His mechanism was not concerning for a c-spine injury. I didn't know he had a history of ankylosing spondylitis."

A detailed history is extremely important when evaluating a patient with a potential cervical injury. Conditions such as ankylosing spondylitis, rheumatoid arthritis, and previous cervical injury or surgery can predispose patients to serious injuries. Relatively minor mechanisms in these patients can cause injury, and a concerning history should prompt a meticulous evaluation. ▲

Association (NCAA).^{126,127} Removal of the facemask portion of the helmet prior to transport may allow better access to the airway.

Assessment of the patient in protective gear while in the ED remains an area clouded with controversy. Removing either the helmet or the shoulder pads in isolation causes an intolerable amount of movement to the cervical spine.¹²⁸ Imaging the patient with protective gear still in place (a method the NCAA endorses) is cumbersome, time-consuming, and studies have shown that the equipment is an impediment to adequate radiographic visualization.¹²⁹ Therefore, we recommend removal of protective equipment (helmet and shoulder pads) in the ED by a team of trained individuals with cervical immobilization prior to cervical imaging.

Others, however, endorse the opposite approach and suggest attempting to obtain cervical spine films prior to removing protective equipment.¹³⁰ Unfortunately, there is no strong empirical data to refute (or support) either approach.

Pharmacotherapy For Acute Spinal Cord Injury

A number of agents have been studied in an attempt to improve neurologic outcome following spinal cord injury, including naloxone, glucocorticoids, nimodipine, tirilazad mesylate, and GM₁ ganglioside. Of these, only methylprednisolone (MP) is currently recommended for use in humans. The exact mechanisms through which steroids exert their effects following spinal cord injury are still unknown. The leading theory is that steroids inhibit lipid peroxidation after spinal cord injury and enhance recovery by inhibiting the injury-induced degenerative cascade that follows.¹³¹

The First,¹³¹ Second,¹³² and Third¹³³ National Acute Spinal Cord Injury Studies (NASCIS) provided prospective, randomized data that patients receiving MP therapy had improved motor recovery (see **Table 3**³¹) at six weeks, six months, and one year. (Pregnant women were excluded from the NASCIS trials.)

These studies suggest that treatment with MP is indicated for all patients with known or suspected spinal cord injury from blunt injury, providing therapy can be initiated within eight hours post-insult. (See **Table 4**.) If

Table 3. American Spinal Injury Association Impairment Criteria.

- **Grade A:** Complete motor and sensory loss below level of lesion
- **Grade B:** Complete motor loss with some sensory sparing below level of lesion with sacral sparing
- **Grade C:** Motor function intact including key muscles below the lesion level with muscle grade less than 3
- **Grade D:** Motor function intact including key muscles below the lesion level with muscle grade greater than or equal to 3
- **Grade E:** Motor and sensory function normal

therapy with MP is initiated within three hours post-injury, the total duration of therapy should be 24 hours. If initiation is 3-8 hours post-injury, the duration of therapy should be extended to 48 hours. There is no benefit to initiating treatment more than eight hours after the injury, and, in fact, these patients may do worse with steroids than without.

Contraindications to treatment include penetrating injury, nerve root involvement only, or cauda equina lesions. In one study, patients with penetrating spinal cord injury who were given MP seemed to do worse than those who did not receive the drug.¹³⁴

Recently, the results of the NASCIS have been challenged.¹³⁵ Independent review of study results has questioned the methodology and conclusions of the NASCIS investigators.^{136,137} A randomized French trial using an identical treatment protocol failed to show a benefit of corticosteroid therapy.¹³⁸ Two evidence-based literature reviews (one by the lead author of NASCIS) have produced conflicting results.^{139,140} The challenge to the NASCIS recommendations has important implications not only because corticosteroid therapy is now arguably considered the “standard of care,” but also because therapy is associated with a significant risk of infectious complications.^{131-133,141,142}

Transfer Issues

When transferring a patient with a known cervical spine injury to another institution, immobilize the patient with a rigid cervical collar as well as sandbags or taped blocks. Immobilization with a cervical collar alone is considered inadequate.

For transport, the patient should be secured on a long spine board. This facilitates stabilization and maintains the ability to turn the patient on his or her side should vomiting occur. In order to prevent pressure sores, the receiving institute must minimize the time the patient spends strapped to the long board.

Many trauma centers prefer the patient to be transported with full cervical immobilization, even if the spine was “cleared” radiographically or clinically at the transferring hospital. This provides protection during transport and ensures meticulous evaluation at the receiving facility in the event of a missed injury. Send the original radiographs (or high-quality copies) with the patient when possible. Precise documentation of the neurologic status of the patient immediately prior to transfer is essential for both medical and medicolegal reasons. Strict adherence to these points will reduce the

Table 4. Dosing Of Methylprednisolone For Spinal Cord Injury.

- Bolus 30 mg/kg over 15 min
- Continuous infusion 5.4 mg/kg/h (within 45 minutes of bolus) for 23 hours or 47 hours*

* See “Clinical Pathway: Methylprednisolone For Spinal Cord Injury”

incidence of further patient injury and potentially costly litigation.

Summary

A review of the medical literature demonstrates several opportunities for the emergency physician to avoid missing or exacerbating a spinal injury. The prompt recognition of spinal injury often determines the ultimate outcome for the patient.

All emergency physicians should use the NEXUS criteria to determine who needs cervical radiographs and consider the use of CT of the upper spine in the intubated blunt trauma victim. Emergency physicians should also periodically review the approach to interpreting the spine x-ray and demand the highest-quality radiographs (which always image all seven cervical vertebrae). Perform a careful physical examination with particular attention to any neurologic complaints, and document the patient's condition initially and any changes over time. A "zero-tolerance" philosophy for missed cervical spine injury will avoid potentially devastating complications and minimize litigation. ▲

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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.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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Physician CME Questions

49. Spinal cord injury:

- a. primarily occurs in children.
- b. primarily occurs in those in the 16- to 30-year age group.
- c. occurs in four times as many women as men.
- d. has been decreasing among the elderly.

50. Most cases of spinal cord injury:

- a. are caused by vehicular trauma.
- b. are caused by gunshot wounds.
- c. are caused by falls.
- d. are caused by sports.

51. The most common site of fracture in the cervical spine is:

- a. C7.
- b. C5.
- c. C3.
- d. C2 (including the odontoid).

52. Optimal cervical immobilization is achieved with:

- a. a rigid cervical collar.
- b. sandbags or taped blocks.
- c. a long spine board.
- d. all of the above.

53. Possible complications of spinal immobilization include:

- a. aspiration.
- b. discomfort.
- c. pressure necrosis.
- d. all of the above.

54. The preferred airway management technique in cervical-spine injured patients is:

- a. rapid-sequence induction with in-line stabilization.
- b. surgical cricothyrotomy.
- c. laryngoscopy.
- d. the Combitube.

55. Potential pitfalls in identifying cervical spine fractures include:

- a. failure to obtain indicated radiographs.
- b. inadequate radiographs.
- c. misinterpretation of radiographs.
- d. radiographs fail to adequately visualize the injuries.
- e. all of the above.

56. The NEXUS trial:

- a. was a prospective multicenter study of five criteria used to identify those at low risk of cervical spine injury.
- b. has not influenced decision-making regarding the need for cervical radiography among United States emergency physicians.
- c. has not been validated by other studies.
- d. did not include pediatric patients.

57. Which of the following conditions may predispose patients to cervical injury?

- a. Rheumatoid arthritis
- b. Down's syndrome
- c. Ankylosing spondylitis
- d. All of the above

58. Simple wedge fractures, unilateral facet dislocations, and bilateral facet dislocations are types of:

- a. flexion injuries.
- b. extension injuries.
- c. axial load injuries.
- d. rotational injuries.

59. Hangman's fracture is a type of :

- a. flexion injury.
- b. extension injury.
- c. axial load injury.
- d. rotational injury.

60. The Brown-Séquard syndrome:

- a. is often called the "burning-hand syndrome."
- b. is caused by hyperflexion.
- c. is usually the result of penetrating trauma.
- d. always produces permanent paralysis.

61. In patients in whom cervical injury is suspected:

- a. a cross-table lateral view can be used to rule out injury.
- b. a lack of midline cervical tenderness can be used to rule out injury.
- c. the patient history rarely yields useful diagnostic information.
- d. the NEXUS criteria can be used to help assess the need for radiography.

62. All of the following concerning lateral view radiographs of the cervical spine are true except:

- a. They must demonstrate all seven cervical vertebrae plus the first thoracic vertebra.
- b. They should be used to screen all victims of blunt trauma.
- c. They can detect about 70% of detectable abnormalities.
- d. Of the views obtained in patients in whom cervical spine injury is suspected, the lateral view should be inspected first.

63. SCIWORA:

- is less common in children than in adults.
- is a syndrome of neurologic injury without evidence by CT or radiographs.
- cannot be identified by MRI.
- always produces complete paralysis.

64. In patients with spinal cord injury, methylprednisolone:

- should be used in cases of penetrating injury.
- provides substantial benefit if initiated more than eight hours post-injury.
- has shown a benefit in some studies provided therapy is begun within eight hours of injury.
- is only helpful in pregnant patients.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives an alpha-numerical score based on the following definitions.

Class I

- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:

- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II

- Safe, acceptable
- Probably useful

Level of Evidence:

- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case-control studies
- Less robust RCTs
- Results consistently positive

Class III

- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:

- Generally lower or intermediate levels of evidence

- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate

- Continuing area of research
- No recommendations until further research

Level of Evidence:

- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA* 1992;268(16):2289-2295.

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