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Acute Spinal Injuries: Assessment and Management

It's a rainy Saturday night, and your urban emergency department is starting to get busy. There are multiple patients who have been brought in by EMS on backboards. As a trio of residents gets ready to roll one of the patients, the one at the head of the bed tells the others to be careful because the patient has vomited and urinated on himself. You tell the residents to hold off rolling him for a second. The patient is a 62-year-old male back-boarded, c-collared, in a ripped suit. You ask him how he's feeling. He says he's OK, but his left leg seems "funny." You ask him to try to lift it off the bed, but he can not. He says he has pain, and he asks you if he is going to be OK. After reassuring the patient, you tell the residents to move the patient to the trauma room as you begin to prioritize your concerns with this patient. You are also thankful you had the presence of mind to consider spinal injury in this patient.

ACUTE spinal cord injuries (ASCIs) remain a devastating consequence of traumatic injuries around the globe. These injuries cause permanent, profound disabilities and lead to changes in lifestyle ranging from employment to marital status. They can also greatly diminish quality of life and decrease life expectancy. The initial hospital charges approach \$100,000.[1] Lifetime costs range from \$525,000-950,000.[2, 3] This in turn costs the United States approximately \$9 billion per year.[4] Early recognition and management of these injuries is essential to minimizing their consequences. It is crucial that emergency physicians anticipate ASCIs and familiarize themselves with skills that prevent, identify, and treat these injuries as they present to the emergency department.

This review offers an up-to-date discussion and an evaluation of the latest approach to blunt trauma patients with potential acute spinal cord injuries. There have been numerous new developments to all four foci of this paper: immobilization, emergency department (ED) clinical spine clearance, imaging modality to evaluate spine injuries, and the treatment of spinal cord injuries if present. Inspired by the success of ED cervical spine clearance criteria, there have been attempts to develop prehospital

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CME Objectives

Upon completing this article, you should be able to:
1. Identify the different types of spinal cord injuries.
2. Understand the evidence for spine immobilization in the setting of blunt trauma.
3. Be aware of the risks associated with spine immobilization.
4. Familiarize yourself with the NEXUS low-risk criteria and the Canadian Cervical-spine Rules for clearance of the cervical spine.
5. Know the limitations of these clinical decision rules.
6. Understand the advantages and limitations of x-rays, multi-detector computed tomography, flexion and extension films, and magnetic resonance imaging in the evaluation of blunt trauma patients at risk for acute spine and spinal cord injuries.
7. Know the risks and benefits of administering high dose methylprednisolone to patients with acute spinal cord injuries.

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See "Physician CME Information" on back page.

immobilization criteria. There have been new approaches suggested on how to clinically evaluate ED patients who have been immobilized. The Canadian C-spine Rule (CCR) was recently developed to supplant the National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria because of their perceived weaknesses when used outside the United States. Within the US, EDs are increasingly using multi-detector computed tomography (MDCT) instead of traditional x-rays as the first imaging modality to evaluate the spine. Perhaps one of the most significant changes is that after the re-evaluation of the National Acute Spinal Cord Studies, high dose methylprednisolone sodium succinate (MPSS) has been downgraded by many organizations from the recommended therapy to a treatment "option." These profound developments require a change in the traditional paradigm used to manage ASCI patients, and this review updates the emergency department approach to them.

Critical Appraisal Of The Literature

This literature review used Pub-Med and OVID Medline searches for articles on the approach to ASCIs published between 1980 and 2006. Prehospital immobilization, evaluation and diagnosis in the emergency department, imaging, and treatment of spinal cord injuries were the four main foci of this review. Terms used in the searches included spinal cord injuries, blunt injury, prehospital immobilization, cervical spine clearance, and methylprednisolone. Over 300 total articles were reviewed, and 159 of these are included here for the reader's reference. A search of the Cochrane Database of Systematic Reviews found two pertinent articles: Spinal immobilization for trauma patients (last updated in 2003), and Steroids for acute spinal cord injury (last updated 2002).[5, 6] The American Association of Neurological Surgeons developed guidelines for the approach to spinal cord injuries and published them in a special supplement of the journal *Neurosurgery* in 2002.[7] The Cochrane Database of Systematic Reviews was searched, and articles relating to immobilization and methylprednisolone were retrieved. A search of www.guidelines.gov offered no existing guidelines about prehospital immobilization, cervical spine clearance, or steroids for the treatment of ASCIs. The Canadian Association of Emergency Physicians (CAEP) has developed a position statement regarding the use of methylprednisolone in acute spinal cord injury. The American Academy of Emergency Medicine has endorsed the Canadian guidelines for methylprednisolone. The American College of Emergency Physicians provided no clinical guidelines regarding these issues.

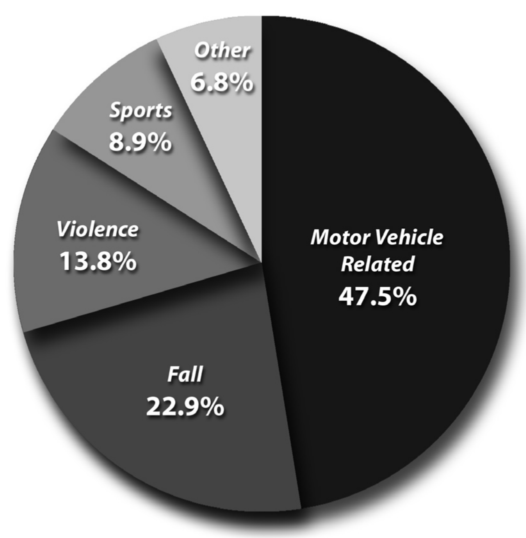
Depending on the sub-topic, the quality of the ASCI literature varies. There is almost no evidence in favor of spinal immobilization because the practice is largely based on tradition. Decreases in blunt trauma mortality rates have been largely attributed to immobilization, but no study exists that specifically demonstrates immobilization as the factor responsible for this. The spinal immobilization literature that exists addresses the different forms of immobilization and some of the dangers of the practice. There are several robust prospective randomized studies that demonstrate the safety of clinical cervical spine clearance criteria. There is less solid evidence that supports clinical clearance criteria to evaluate the thoracic and lumbar spines, but these areas are infrequently injured. In regard to imaging modalities, there is retrospective evidence to suggest that MDCT is a more sensitive imaging modality than plain films, and that it picks up injuries that would otherwise be overlooked. Interestingly, the literature addressing the use of steroids for ASCI is not new, but it has been re-evaluated. No subsequent study has replicated the benefit of MPSS in ASCI, and the benefits shown in the National Acute Spinal Cord Injury Study (NASCIS) trials have been questioned. Although the NASCIS trials were prospective and randomized, doubts have arisen about their conclusions because of statistical interpretive errors in those trials.

Epidemiology And Etiology

The United States National Spinal Cord Injury Database (NSCID) was created in 1973 to track spinal cord injuries. It derives national figures by extrapolating the data from a database of about 13% of new SCI cases in the US. The estimated rate of trauma-related spinal column injuries is approximately 30,000 per year in the US alone.[8] According to the NSCID, there are 11,000 new cases of ASCI per year caused by these spinal column injuries. This translates into roughly 40 new cases per million people in the US annually. As of December 2003, it is estimated that there are anywhere from 219,000 to 279,000 persons living with SCIs in this country.[4]

SCIs primarily affect young male adults. Over half (53%) of the yearly injuries occur in persons aged 16-30 years old. Since 1973, there has been an upwards trend in the mean age of injury from 28.6 to 32.6. An increase

Figure 1. Etiology of acute spinal cord injuries since 2000



in the proportion of SCIs in patients older than 60 years has been largely responsible. Spinal fractures may follow apparently minor trauma in people with arthritic and osteoporotic disease. Since the inception of NSCID, males have consistently accounted for 81.2% of all ASCIs. This incidence trend continues until one examines people older than 65, and likely reflects the disparate effect of osteoporosis in this population.[9]

The ethnic distribution patterns of SCIs have remained largely unchanged except in two groups. From 1973 to 1977, Caucasians comprised 76.8% while African-Americans comprised 14% of SCIs. Since 1992, the proportion of African-Americans has increased to 26%, while proportion of Caucasians has decreased to 63.1%.

The most common cause of ASCIs is motor vehicle accidents (MVAs), accounting for 40.9% of all injuries. Falls and acts of violence are the next most common causes. Acts of violence as a cause peaked in the 1990s and has been steadily declining.[4] Sports injuries account for another 7.5% of all ASCIs. Some of the higher-risk sports include football, gymnastics, skiing, hang gliding, equestrian activities, and diving. Diving in particular causes a disproportionately high number of sporting ASCIs and characteristically cause fractures in the cervical spine. In contrast, mining, logging, and parachuting injuries tend to damage the thoracolumbar region.[10] The causes are detailed in **Figure 1**.[4]

Location of ASCIs

The predominance of human cervical spinal cord injuries is thought to be secondary to a combination of the increased range of motion, diminished surrounding muscular protection, smaller vertebrae, and the reduced ligamentous strength of the stabilizing structures in the cervical spine.[10] The upright posture, elevated head, and increased range of neck motion may have increased our evolutionary advantage, but the same traits have left us with a much more vulnerable area of the spine. The majority of ASCIs are tetraplegic injuries, resulting from injuries at one of the eight segments that comprise the cervical spine. Of all spine fractures, 55% were of the cervical spine.[11] Approximately 15% of injuries occurred at each of the other regions of the spine (see **Figure 2**). Whereas the national incidence of cervical spine injury is 52%, the actual prevalence is only 40%, reflecting the increased mortality associated specifically with c-spine injuries.[10]

Figure 2. Distribution of spine injuries

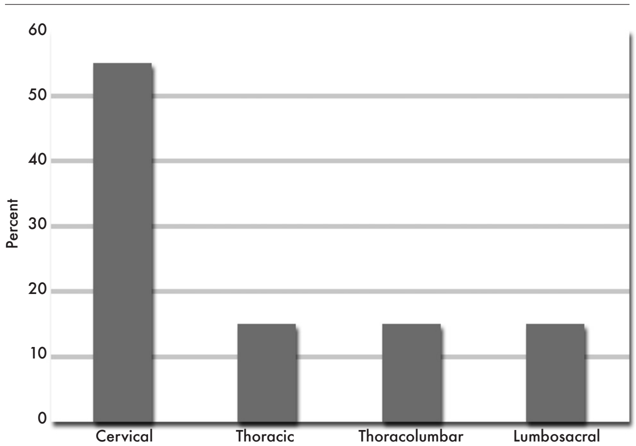
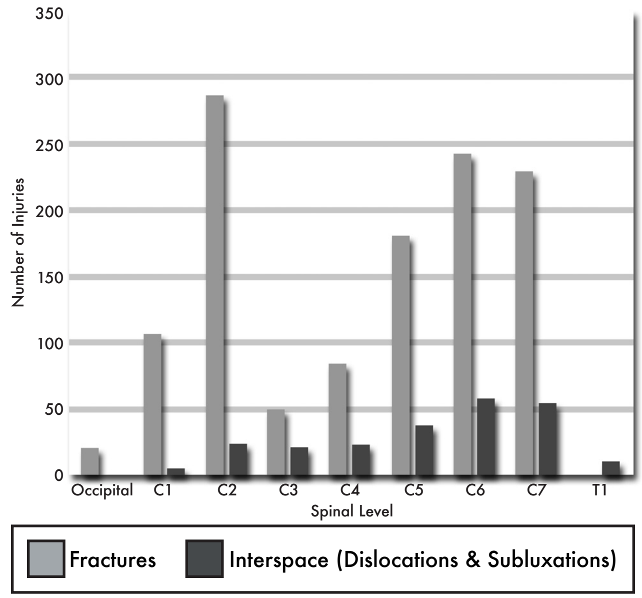


Figure 3. Distribution of injuries in the cervical spine



Goldberg et al reviewed the cervical spine data from the National Emergency X-Radiography Utilization Study. Of 34,069 patients, there were 818 radiographic cervical spine injuries. Fractures of C2 (including odontoid fractures) accounted for 24% of the injuries in this study. C3 was the least-commonly-injured cervical vertebra, accounting for only 4.3% of the injuries in this study. Dislocations occurred most frequently at the C5-C6 and C6-C7 interspaces. The distribution of cervical spine injuries is shown in **Figure 3**.[11]

Spinal cord syndromes

Although many acute spinal cord injuries are complete cord transections, a significant number of patients present with classic neurologic syndromes. Spinal cord syndromes are a result of the paths that the tracts follow in the spinal cord and the layering of the nerves within these tracts. The relevant spinal tracts are shown in **Figure 4**. Injuries involving all tracts of the spinal cord are termed complete spinal cord lesions. Such injuries cause equal bilateral deficits. Injuries that yield unequal deficits bilaterally are termed incomplete spinal cord lesions. These injuries involve a discrete area in the spinal cord, affecting the spinal cord tracts and neuronal layers to different degrees. Individual injuries are unique—causing their own combination of deficits. However, there are three spinal cord injury patterns that most incomplete lesions can be generalized into: the anterior cord, central cord, and the Brown-Sequard syndromes. **Figure 5** shows the nerve functions carried by each of the spinal tracts.

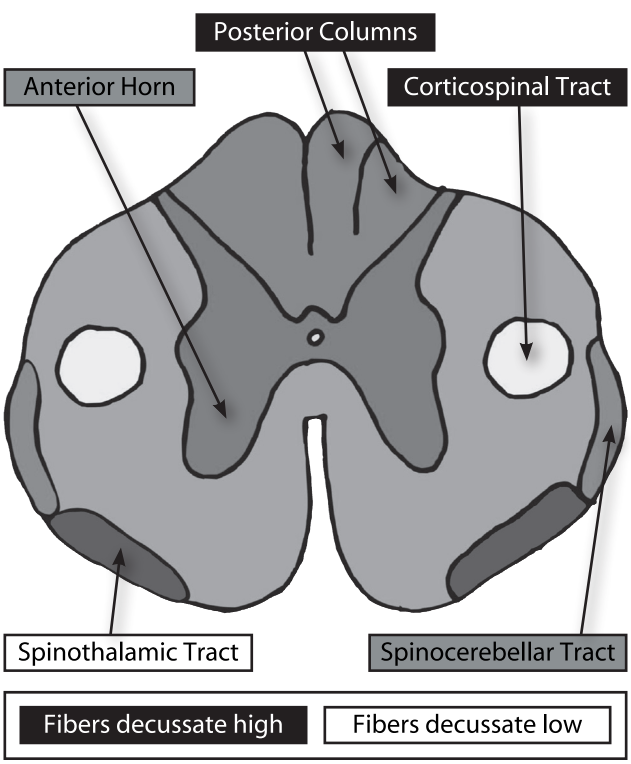
Motor injury

Injuries that affect the motor tracts cause neurological deficits ipsilateral to the area of the injury. Lower motor neurons (LMNs) travel from the motor end plates to the anterior horn where they synapse with the upper motor neurons (UMNs). The upper motor neurons travel up the corticospinal tract ipsilaterally until they leave the spinal cord in the medulla. Injury to the spinal cord will initially result in a global flaccid paralysis below the level of injury. Over several days, the LMNs in the injured anterior horn at the actual level of injury will result in a persistent flaccid paralysis of the muscles these nerves innervate. A spastic motor paralysis results when LMNs are uninjured, but lose their UMN innervation. Thus the lack of UMN innervation below the level of injury will result in an ipsilateral spastic motor paralysis distal to the injury. This spasticity develops over the days following injury.

Sensory injury

Unlike motor injuries, sensory deficits may be ipsilateral or contralateral depending on the tract affected. Neurons responsible for vibration, pressure, light touch, and conscious proprioception travel in the posterior columns. These fibers decussate at a high level in the spinal cord, and as a result, injuries to them cause ipsilateral deficits. Neurons carrying the sensations of pinprick, pain and temperature travel together in the spinothalamic tract, but these fibers decussate close to entry. Therefore, injuries to this tract cause contralateral sensory deficits. Finally, unconscious proprioception travels in the spinocerebellar tract. Interestingly, these fibers cross twice, once near entry and once above the spinal cord. As a result, injuries to the spinocerebellar tract cause ipsilateral deficits.

Figure 4. Tracts of the spinal cord



Neuronal layering

The neuronal layering in the spinal cord also plays a part in the deficits noted in partial injuries. This layering is shown in **Figure 6**. At lowest levels, nerve fibers from the sacrum and lower limbs group together to form the spinal cord and its tracts. As the spinal cord ascends, more fibers are added to each tract, layering in a fashion represented by the stick figures shown in **Figure 6**. The stick figures represent the order of the fibers in the tracts at the upper levels of the spinal cord. For example, a hypothetical injury near the top of the spinal cord affecting solely the lateral portion of the corticospinal tract would affect the upper motor neurons that innervate the ipsilateral lower limbs but leave the upper limb innervation intact. If the hypothetical injury affected the medial side of the corticospinal tract, only the upper limbs would be affected.

Central cord syndrome

The central cord syndrome, shown in **Figure 7**, is an elegant demonstration of how tract position and neuronal layering affect the clinical presentation. It is the most common incomplete spinal cord lesion, and is usually caused by a forced hyperextension injury. It is thought that the ligamentum flavum buckles into the spinal cord causing a concussion or contusion to its central regions. The clinical presentation will vary depending on the size

Figure 5. Spinal cord tract function

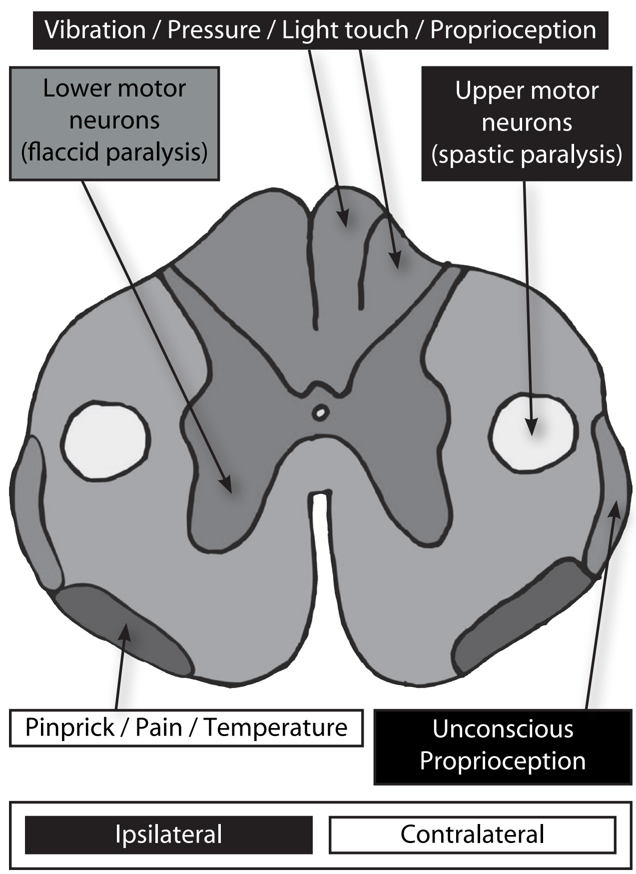
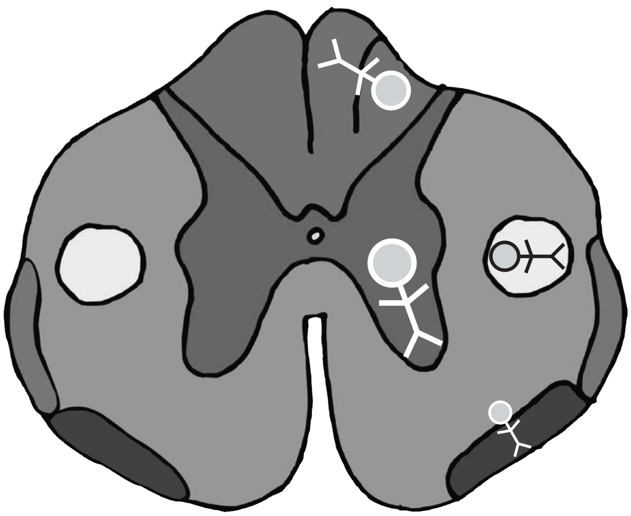


Figure 6. Neuronal layering



of the contusion. If the injury is at the level of the cervical spine, a flaccid paralysis will be seen in the upper limbs as a result of injury to the LMNs in the anterior horn that innervate the arm muscles. If the contusion is large enough, it will affect the UMNs in the corticospinal tracts leading to a lower limb spastic paralysis. Because the majority of sensory neurons lie in the peripheral cord, the sensory findings can be variable and inconsistent. Because of neuronal layering, the sensory dysfunction in the arms is greater than that seen in the legs. Classically, again because of tract position and layering, big toe flexion, voluntary anal tone, peri-anal sensation, and the bulbocavernous reflex are often preserved. The prognosis for this injury is good, and the majority will regain some neurologic function.

Anterior cord syndrome

The anterior cord syndrome (**Figure 8**) can be caused by any process that affects the anterior spinal cord. These are usually mechanical or vascular events. Disc herniation, protrusion of bony fragments, or cord contusion secondary to a cervical hyperflexion injury can all affect the anterior portion of the spinal cord. Compromise of the anterior spinal artery can also result in the same. In anterior cord syndrome, the injury causes distal motor paralysis and distal loss of pinprick, pain, temperature, and unconscious proprioception. Vibration, pressure, light touch, and conscious proprioception are preserved because these sensory tracts lie in the posterior spinal cord.

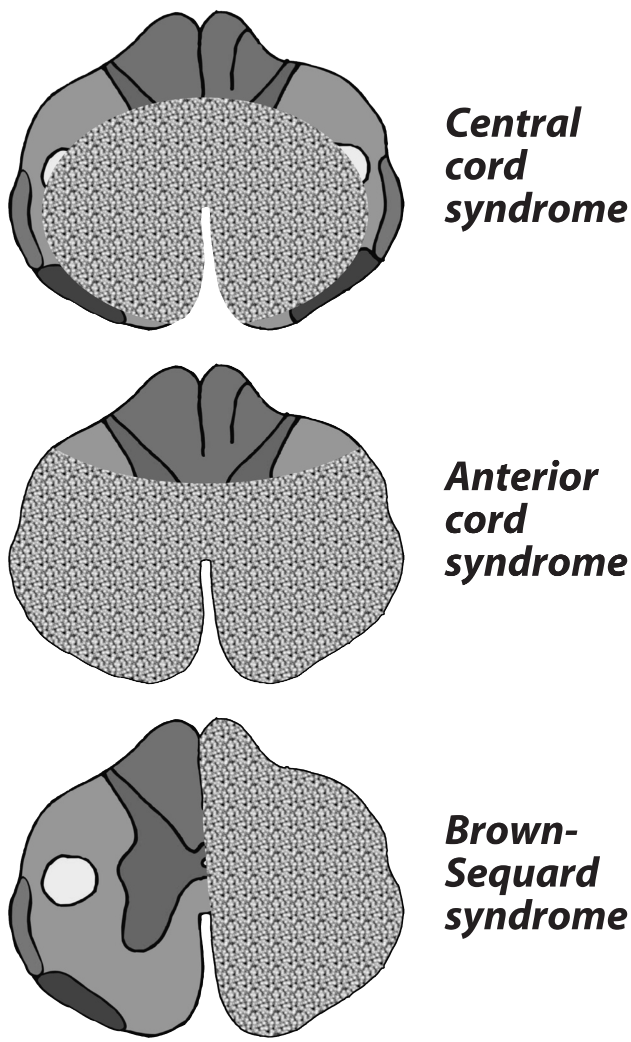
Brown-Sequard syndrome

The Brown-Sequard syndrome, shown in **Figure 9**, is the result of a spinal cord hemi-section. It is usually caused by penetrating injuries, and is rare in blunt trauma. There is complete ipsilateral motor paralysis and loss of vibration, pressure, and all proprioception. Because the neurons in the spinothalamic tract decussate soon after entering the spinal cord, there is contralateral loss of pinprick, pain, and temperature sensations.

Prehospital Care

Modern treatment algorithms for blunt trauma rely on the use of the cervical collar and long board to achieve spinal immobilization. Spinal immobilization is now an integrated part of preadmission care, and is advocated by EMS programs in the US and by the American College of Surgeons in their Adult Trauma Life Support guidelines (ATLS). It is postulated that immobilization prevents movement of the spine and secondary spinal cord injury during the extraction, transport, evaluation, and resuscitation of blunt trauma patients. Since the creation of the emergency medical services (EMS) in 1971, there has been dramatic improvement in the neurological status of spinal cord-injured patients: whereas 55% of patients in the early 1970s arrived at the hospital with complete spinal cord lesions, this had been reduced to 39% by the 1980s.[12] The specific factors for this reduction since the creation of EMS have not been determined.[13-20] There are not any studies that demonstrate immobilization as the key factor responsible for this reduced rate of complete spinal cord lesions. Rather, the current approach of spinal

Figures 7,8,9. Spinal cord syndromes



immobilization has a strong historical rather than scientific precedent, and is based on the concern that a spine-injured patient may deteriorate neurologically without immobilization.

The trials of immobilization techniques that currently exist are based on analyses of spine mobility in cadavers or healthy volunteers without ASCIs. Ethical and practical issues are at odds with a strict study design that can blindly evaluate the effectiveness of immobilization in the US given its widespread use. One interesting study aimed at the evaluation of spinal immobilization in blunt trauma patients was a retrospective chart review carried out by Hauswald and Ong et al in 1998.[21] This study was performed at two university hospitals thought to be similar in regard to clinical practice: The University of Malaya and the University of New Mexico (UNM). All patients with acute blunt traumatic spinal cord injuries transported directly from injury site to hospital were enrolled. None of the 120 patients seen in University of Malaya were immobilized while all 334 patients seen at UNM were. Surprisingly, there were fewer injuries causing significant neurological disability in the non-immobilized patients: 11% at the University of Malaya versus 21% at UNM. The odds ratio for neurologic injury in immobilized patients was calculated to be 2.03 (95%CI 1.03-3.99).

There were certain problems with this study. One can imagine that in the US, the injuries might be more severe because of the prevalence of motor vehicles and the national highway system. Indeed, motor vehicle accidents accounted for 38% of ASCIs in Malaya, versus 74% in the US population. At the time of the study they had no ambulances or EMS in Malaya, and one might argue that the more severely injured patients did not survive long enough to make it to the hospital to have a chart generated. They would not be entered into the study; falsely making it appear that immobilization caused harm. Regardless, the authors postulated that spinal cord damage occurs only at the time of initial trauma where high energy mechanisms are at work.[21] The subsequent movements during transport and evaluation were not thought to be significant enough to cause further neurological damage. It should be clear that this study does not constitute evidence that immobilization is unnecessary or harmful, given the large significant confounding variables in the two groups of patients. Rather, the study serves to illustrate that there are significant gaps in our knowledge about the mechanisms that cause neurologic deterioration.

The lack of evidence that spinal immobilization improves ASCI outcomes is important in light of the significant morbidity associated with the techniques currently used. Certainly, for some patients immobilization is vital to prevent spinal cord injury, yet for a majority, the use of immobilization may be unnecessary and potentially hazardous. It is estimated that over 50% of patients immobilized do not have neck or back pain.[22] In the United States this widespread practice results in approximately five million immobilized patients each year.[6] There are numerous studies that demonstrate the harmful effects of spinal immobilization.[18, 23-28] The potential harmful effects are listed in **Table 1**, the most immediately concerning of which are airway compromise and aspiration. This is particularly alarming as asphyxiation is one of the leading causes of preventable death in trauma patients, and we are potentially increasing the frequency of this.[6] Also of note, it has been suggested that immobilization may cause or worsen the spinal cord injury it was designed to protect.[22] **Figure 10** shows a pressure sore resulting from prolonged spinal immobilization on a hard backboard.[29] There may be a significant amount of harm done to our patients by the arbitrary immobilization of the majority of blunt trauma patients.

Given the sparse evidence to support the use of spinal immobilization and its potential hazards, some have sought means to minimize its use. Domeier et al argued that if clinical criteria effectively cleared patients in the ED, then perhaps they could be applied at the scene of injury by EMS. In a set of rigid studies, Domeier spent the better part of a decade validating a set of prehospital spine clearance criteria and then prospectively evaluating them. In his 1997 study he developed a set of criteria that were

Table 1. Potential harmful effects of immobilization

- Airway compromise
- Aspiration
- Increased intracranial pressure
- Cutaneous pressure ulcers
- Iatrogenic pain
- Increased difficulty of patient handling
- Combativeness in intoxicated patients
- Increased cost

Figure 10. Pressure sore from prolonged spinal immobilization

associated with spine injury[30]. These criteria resembled the NEXUS Low-risk Criteria (NLC) used in EDs to clear patients' cervical spines – **Table 2**. Of note, the NLC were altered to simplify their use by EMS. The NEXUS criterion regarding distracting injuries was narrowed to "suspected extremity fracture." In 2002, Domeier published his observational study demonstrating that the criteria had a sensitivity of about 95% to detect cervical spine fractures as applied by EMS.[31]

In 2005, Domeier completed a prospective randomized evaluation of these criteria. When applied to consecutive trauma patients, the criteria yielded a 39% reduction in the number of patients requiring immobilization.[32] The criteria were found to have a sensitivity of 91% (CI of 88.3-93.8%) and a negative predictive value of 0.993 (CI of 0.990-.0995) for identifying spine fractures. This reported sensitivity does include the patients that were missed because of errors in the application of the criteria by EMS. There were 786 patients (out of 5111) who should have had the criteria applied, but were omitted for various reasons by EMS. Domeier states that although 33 of 415 spine fractures were missed, there were no significant spinal cord injuries that resulted. Although Domeier puts a positive spin on his results, this trial did not demonstrate a high enough sensitivity to reassure EMS protocol designers given the infrequency and consequence of a missed spinal cord injury. We consider the evidence for prehospital spine clearance protocols indeterminate, and further research is needed before recommendations can be made.

There are no prospective randomized controlled trials that have ever evaluated the benefit of spinal immobilization in out-of-hospital trauma victims.[6] Such trials are not likely to be done, given the ethical issues that would be raised by allowing people with spine fractures to ride non-immobilized in the back of a racing ambulance. In the United States, out-of-hospital agency-specific protocols and national guidelines consider spinal immobilization as "the standard of care," but this is largely based on historical precedent and the fear of litigation.[33] Because there are serious potential complications associated with spinal immobilization, routine out-of-hospital spinal immobilization in trauma patients should be questioned. The EMS services have begun to evaluate decision rules in an effort to mitigate negative outcomes associated with routine and unnecessary immobilization practices. However, the current criteria do not have a high enough sensitivity and negative predictive value to be confidently employed at this point.

Our conclusion is to consider spinal immobilization an "option." The class of evidence that exists to support this practice is indeterminate. The Cochrane systematic review of the subject by Kwan et al took a similar stance. It stated that:

> "The effect of pre-hospital spinal immobilization on mortality, neurologic injury, spinal stability, and adverse effects in trauma patients therefore remains uncertain … the possibility that immobilization may increase mortality and morbidity cannot be excluded." [6]

The American Association of Neurological Surgeons also considers pre-hospital spinal immobilization an "option."[34] Under the "option" level of recommendation, they state:

> "All trauma patients with a cervical spinal column injury or with a mechanism of injury having the potential to cause cervical spine injury should be immobilized at the scene and during transport by using one of several available methods." [34]

Although there is currently no ACEP clinical policy regarding spinal immobilization, in an evidence-based review of the topic published in the Annals of Emergency Medicine, Baez et al stated that, because of the potential complications associated with spinal immobilization, the practice of routine out-of-hospital spine immobilization of blunt trauma patients should be questioned.[33]

ABCs

The basic resuscitation of a patient with an ASCI is challenging, especially when there is a high spinal cord injury. The emergency physician must balance the immediate and real dangers of respiratory compromise and hypo-perfusion while preventing further damage to neurologic function. In patients with complete injuries above the level of C3, immediate respiratory paralysis may ensue. Furthermore, victims of blunt trauma frequently have other injuries that can cause respiratory compromise. In this setting, the ATLS guidelines recommend the use of orotracheal intubation to preserve the airway.[35] Although the incidence of neurologic deterioration as a result of orotracheal intubation is low, in patients with potential cervical spine injuries utmost care should still be taken.[36-38] ATLS recommends that an assistant should aid the person intubating by performing in-line spinal stabilization. It is thought that this minimizes axial motion of the head and neck during the intubation process. The evidence in support of in-line spinal stabilization is derived from cadaver studies, and we consider it Class III.[39] There are reports of decreased cervical spine extension when certain types of intubating devices are used, such as the Bullard laryngoscope.[40] However, in other studies, Macintosh laryngoscopes combined with in-line stabilization were

Table 2. Prehospital clinical spine clearance criteria

- Altered mental status
- Evidence of intoxication
- Neurological deficit
- Suspected extremity fracture
- Spine pain / tenderness

found to be equivalent in terms of spine motion and faster.[39, 41] Cricothyrotomy should be considered in patients who have severe maxillofacial injury or who have failed traditional intubation attempts.

Circulatory issues can be challenging as well. In the setting of blunt trauma it is often difficult to distinguish between hypotension caused by blood loss versus pseudo-hypotension caused by the loss of sympathetic tone to the heart and vasculature. Classically, neurogenic shock presents with hypotension and bradycardia, whereas hypovolemic shock presents with tachycardia and either normotension or hypotension depending on the amount of blood already lost. In ASCIs, the loss of vasomotor tone to the peripheral vasculature causes vasodilation and the pooling of blood leading to pseudo-hypotension. Pseudo-hypotension may be preceded by a period of normotension caused by the initial release of catecholamines. The lack of sympathetic tone to the heart prevents the development of tachycardia in the setting of relative hypovolemia. Moderate volume replacement and cautious use of vasopressors will often restore the patient's blood pressure in ASCIs. Massive fluid administration may cause fluid overload and pulmonary edema.[35]

ED Evaluation

Just as there is controversy as to whether someone needs immobilization after blunt trauma in the field, there is controversy about which of these immobilized patients require radiography to rule out a spine fracture. As mentioned previously, the cervical spine is the most delicate part of the spine and the most frequently injured. Due to this and the devastating consequence of ASCIs in the cervical spine, most radiological studies ordered by physicians evaluate this area. In 2000, an estimated 800,000 cervical spine radiographs were ordered in the US, and this number has likely increased since then.[42] Because of the frequency of injuries requiring cervical spine evaluation, large studies that delineate decision rules to lower the number of these x-rays have been reported. Because the thoracic and lumbar spines are better supported and stronger than the cervical spine, the likelihood of injury is much lower. Thus, there is less need and fewer attempts to derive decision rules to decrease radiological studies of these areas.

Cervical spine

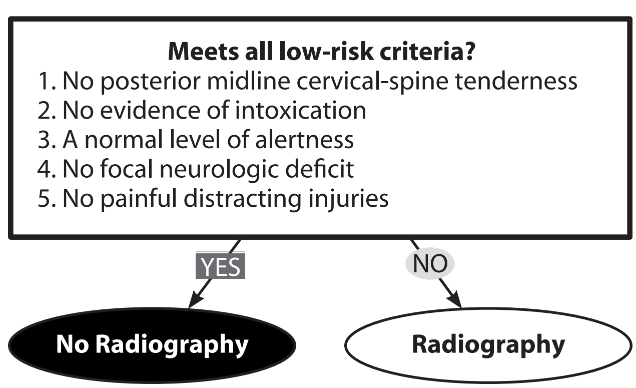
Clinicians tend to order imaging of the cervical spine for most patients with blunt head or neck trauma even if there is only a minute chance of injury. According to the National Hospital Ambulatory Medical Care Survey: Emergency Department Summary, the number of emergency department (ED) visits in the United States for mechanisms potentially causing spine injuries (falls, being struck, striking something, motor vehicle traffic incidents) was approximately 16.5 million in 2003.[43] Only approximately 4% of all cervical spine radiographs reveal a fracture.[44] Despite the low cost of x-rays, the sheer number of radiographs ordered contributes significantly to the financial burden of any health care system. This financial cost is in addition to the potential risks, significant discomfort, radiation exposure, and unnecessary space utilization in crowded emergency rooms caused by continued immobilization. To expedite the care of these patients, clinical decision rules have been developed to safely clear them from the cervical spine immobilization devices without the need for x-rays.

There are three important measures of such rules. To prevent missed cervical spine injuries and their consequences, it is imperative that such clinical decision rules have a high sensitivity as well as a high negative predictive value (NPV). The third important variable, although secondary to sensitivity and NPV, is the specificity of the rule. The higher the specificity of a decision rule, the greater number of unnecessary x-rays it will prevent. Investigators have derived two sets of criteria to evaluate the cervical spine in the last decade: the NEXUS Low-risk Criteria (NLC) and the Canadian C-spine Rule (CCR).

The NEXUS was the first study to address the issue of eliminating x-rays for patients at low risk for injury. Prior to NEXUS, there were numerous small studies that suggested that patients with blunt trauma have a low risk of cervical spine injury if they met low-risk criteria.[45-54] Some of these studies reported a sensitivity of 100%. Because such sensitivities were calculated from studies with few patients, the lower confidence intervals for these sensitivities could be as low as 89%.[48, 55] If this were the "true" sensitivity of the criteria, it would be too low to justify their general deployment to rule out cervical spine injury. In contrast, NEXUS was a much larger multicenter prospective observational study that tested five criteria to get a more accurate estimate of their sensitivity.

In this study, 34,069 patients who underwent radiography of the cervical spine following blunt trauma were evaluated. Of these patients, 818 had radiographically documented injuries. The study assessed the performance of a five-part decision rule to predict which patients would have a spinal injury (illustrated in **Figure 11**). All patients received either a 3-view cervical spine x-ray evaluation or a cervical spine computed

Figure 11. National Emergency X-Radiography Utilization Study (NEXUS) Criteria



tomography (CT) scan to determine if fractures were present. The sensitivity, specificity, and NPV of the NLC were calculated for all spine injuries that were considered to be significant. Insignificant injuries were defined as injuries that, if not identified, would be extremely unlikely to result in any harm to the patient. Of the significant injuries, the sensitivity and specificity of the test were 99.6% and 12.9%, respectively. The NPV was calculated to be 99.9%. Given this sensitivity, the miss rate for significant injuries translates into one missed injury in 17,000 patients. If the average emergency physician orders 50 cervical spine films a year, he/she would miss one significant injury every 340 practice years. Consequently, the NLC rapidly became the trusted rule of choice in emergency departments in the US.

In the United States there is a strong medico-legal incentive not to miss any spinal injuries and few financial disincentives to limit c-spine x-rays on patients with blunt trauma. This led to the widespread adoption of the NLC despite its relatively low specificity. However, the low specificity of the NLC posed problems for healthcare systems outside the US, leading to the development of the CCR.[56] Outside of the US, the NLC were perceived as inefficient, and its application by different attendings varied widely.[56] In Canada, for example, a much higher threshold for ordering c-spine x-rays already existed when the NLC were validated. After the NEXUS, there was concern there that adoption of the NLC might actually increase the number of x-rays ordered in the setting of blunt trauma.[56] Therefore, Stiell et al set a goal to develop a rule with higher specificity that could decrease the number of x-rays ordered in Canada.

The CCR were derived from a set of clinical variables that were either strongly associated with injury or greatly decreased the likelihood of injury.[56] The identified variables were combined into the CCR decision rule shown in **Figure 12**. This tool was prospectively evaluated against the NLC in 2003. The authors evaluated 8283 patients, 162 of whom had clinically important c-spine injuries. For "clinically important" injuries, the primary endpoint of the study, the sensitivity and specificity of the CCR were 99.4%, and 45.1%. In contrast with the sensitivity calculated in NEXUS, the NLC were found to have a sensitivity of only 90.7% on the patients in the CCR study. This translates into NPVs of 100% for the CCR and 99.4% for the NLC. Based on the CCR study results, the authors concluded that their criteria were not only more specific than the NEXUS criteria, but more sensitive as well (See **Table 3**). In a later 2004 study, Stiell et al go as far as to state that "the NEXUS low-risk criteria should be further explicitly and prospectively evaluated for accuracy and reliability before widespread clinical use outside the United States." [57]

Choosing a decision rule

The CCR study finding that the sensitivity of the NLC was only 90.7% contrasts dramatically with the sensitivity found in NEXUS of 99.6%. Certain factors may have been responsible for this.[58] The Canadian team had an important methodological difference from NEXUS in that

Figure 12. Canadian C-spine Rule (CCR)

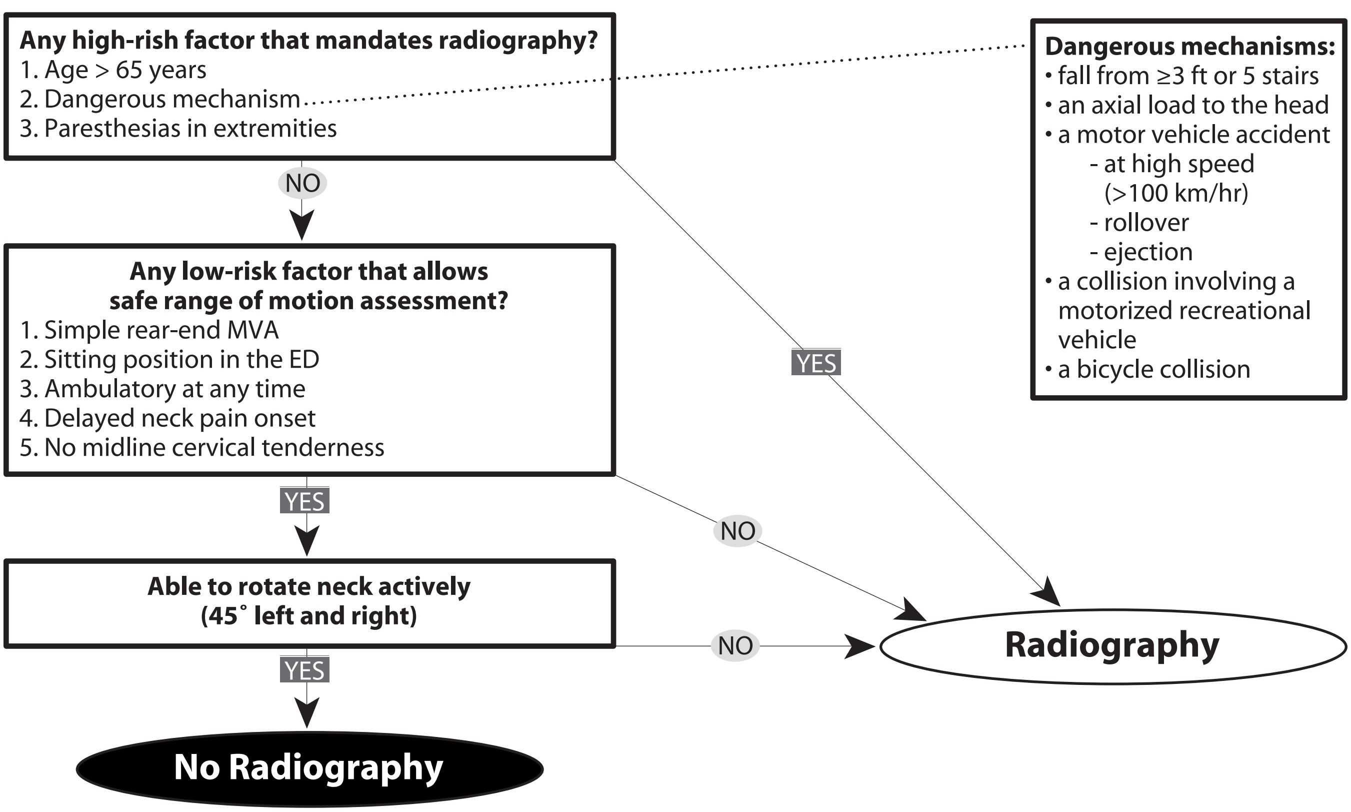


Table 3. Performance of Nexis Low-Risk Criteria (NLC) versus Canadian C-Spine Rule (CCR) for "clinically significant" injuries (with 95% CI)

	NLC	NLC (Pediatrics)	NLC (Geriatrics)	CCR	NLC (CCR Study)
Sensitivity	99.6 (98.6-100) %	100 (87.8-100) %	100 (97.1-100) %	99.4 (96.6-100) %	90.7 (85.3-94.3) %
Specificity	12.9 (12.8-13.0) %	19.9 (18.5-21.3) %	14.7 (14.6-14.7) %	45.1 (44.0-46.2) %	36.8 (35.7-37.9) %
NPV	99.9 (99.8-100) %	100 (99.2-100) %	100 (99.1-100) %	100 (99.8-100) %	99.4 (99.1-99.7) %

the Canadian group used a clinical follow-up protocol to evaluate blunt trauma patients in whom x-rays were deemed unnecessary. This sub-population totaled nearly 30% of all patients in the study. In contrast, the NEXUS investigators excluded these patients, and only examined patients who underwent x-rays. This difference is crucial, because it is very likely that the decision not to perform x-rays was guided (consciously or unconsciously) by the NLC.[59] The NLC were already in widespread use during the CCR study, and the decision to deem patients safe for discharge without x-rays was probably impacted by this familiarity. By the inadvertent pre-selection of the study group, they eliminated some number of true negatives and false negatives upon which the rules were tested. The reduction in the number of false negatives will deceptively elevate the CCR's sensitivity in comparison to the NLC. In addition, by including patients who may have not received x-rays in NEXUS, the CCR significantly increased the percentage of true negative patients. This will elevate both criteria's specificity compared to what their specificities would be if they followed the NEXUS methodology. Indeed, this effect is exemplified in the CCR study by the unexpectedly high NLC specificity of 36.8%, compared to the 12.9% specificity seen in NEXUS. The lower sensitivity and higher specificity for the NLC found in the CCR study is consistent with the effects of these biases.[59]

Another potential flaw of the CCR study was the addition of clarifying definitions to the definitions of "intoxication" and "distracting injuries". The NEXUS investigators deliberately left these definitions broad. In the case of distracting injuries, NEXUS investigators stated that "no precise definition for distracting injury is possible." Consequently the investigators only give examples of such injuries. The CCR study's use of surrogate NLC criteria will inherently cause misclassification errors and alter the performance of the NLC.[44, 60] There were also differing patient eligibility criteria. Whereas NEXUS included patients of 16 years of age and under as well as people with a Glasgow Coma Score (GCS) of 15, the CCR study excluded them. A final important issue to recognize is that the CCR prospective study was performed in the same institutions from which the criteria were derived. Regional familiarity with the CCR rules probably existed and potentiates the possibility of bias. It also brings into question the CCR's applicability to outside institutions.[44]

Traditional x-rays have long been the means for evaluating the spine after blunt trauma. For the cervical spine, the NLC and CCR recommend that x-rays be performed on those that fail their low-risk criteria. Recommended radiographic examination of the cervical spine usually consists of a three-view x-ray: the lateral, anterior-posterior, and open mouth views, although five-view variations exist.[61] A swimmer's view is recommended if the top of T1 is not visualized. If the x-rays are deemed inadequate, a CT scan of the cervical spine is recommended.

In our opinion, the NLC and CCR clinical decision rules are roughly equivalent in their sensitivities. Both the NLC and the CCR were validated in prospective, randomized, multicenter trials, and we consider their validation studies Class I evidence. Our recommendation is that either one of the rules be used, and consider this the standard of care. We do not consider the lower sensitivity of the NLC determined in the CCR study to be an accurate representation of the NLC performance. X-rays should be obtained on patients who fail low-risk criteria.

Thoracolumbar spine

The prevalence of thoracic and lumbar spine injuries is 2-3% in blunt trauma victims. Although more rare, approximately 40-50% of these injuries are associated with a neurologic deficit, likely because of the tremendous forces needed to fracture this area of the spine.[8] **Figure 13** shows a MDCT reconstruction of such an injury, demonstrating a severe T4 on T5 spine fracture-dislocation caused by a high speed motor vehicle accident. In contrast to the numerous studies that have investigated

Figure 13. MDCT of a thoracolumbar spine fracture-dislocation caused by a motor vehicle accident

Table 4. Clinical indicators associated with thoracic or lumbar fractures

- High-force mechanism
- GCS < 15
- Pain or tenderness over spine
- Local signs of injury
- Neurologic deficit
- Previously identified spine injury

clinical guidelines to evaluate the cervical spine, there are relatively few that guide the evaluation of the thoracic and lumbar spines.[62-70] The studies that exist are retrospective reviews and essentially extrapolate the cervical spine data to these regions.[71] Several studies demonstrate variables that are associated with spine fractures (listed in **Table 4**), and identify criteria similar to those used in the NLC or CCR criteria. A decision rule developed by Hsu et al was based on published factors shown to be retrospectively associated with thoracolumbar injury.[65] A modification of his proposed clinical pathway is shown in **Figure 14**. This protocol was evaluated by a retrospective chart review in two groups of 100 patients: patients with confirmed thoracolumbar fractures, and randomly selected multi-trauma patients. Hsu reported a sensitivity of 100%, an NPV of 100%, and specificity of 11.3%. As with NEXUS, this specificity is quite low, and thus may cause implementation issues in regions that have a more restrictive threshold for obtaining radiological studies. The most sensitive of the criteria tested was found to be the combination of either back pain or midline tenderness, with a sensitivity of 62.1%. This association has been confirmed by other studies as well.[70] The most specific criterion, not unexpectedly, was a palpable step-off over the spine, found to have a specificity of 100%.[65] Another factor that should raise one's index of suspicion for a fracture is a previously identified spine fracture (of the cervical spine, for example).[72] This clinical decision rule awaits prospective validation.

Our opinion is that there is very little evidence to support a clinical decision rule for the evaluation of the thoracic and lumbar spines. The level of evidence is Class III. One should maintain a high index of suspicion in high-energy or multi-trauma patients. One spine fracture is often associated with another. A GCS<15 should also increase the level of diligence to rule out fractures of the thoracic and lumbar spine. Until a prospective validation study is performed on a clinical decision rule that assesses these areas of the spine, we recommend looking for the high-risk factors listed in **Table 4** and using appropriate clinical judgment. If there is any likelihood of injury, radiographic studies are recommended.

Special Considerations

Pediatrics

Pediatric spine injuries occur less often than adults and account for only 2-5% of all spine injuries.[8] There is sparse data on injuries to the thoracic and lumbar spine in children, but there are numerous articles that address the cervical spine. As in adults, motor vehicle injuries, including pedestrians struck by vehicles, account for the majority of injuries. However, instead of falls, sports injuries are the second most frequent cause in children.[73] The breakdown of mechanisms causing ASCIs in children is illustrated in **Figure 15**. Spinal injuries are more common in children over 8, where the loss of soft tissue elasticity and anatomic differences make spine injuries more likely.[74] There are currently no prospectively validated clinical decision rules to allow for the safe

Figure 14. Thoracic and lumbar spine evaluation

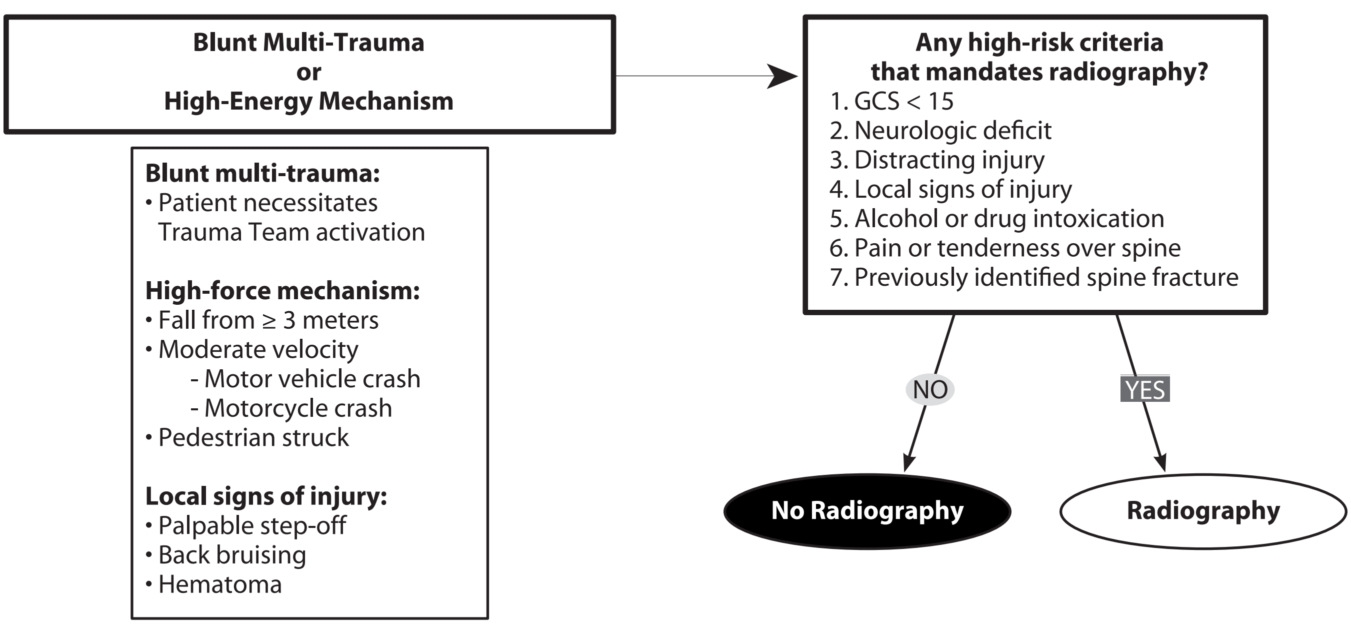
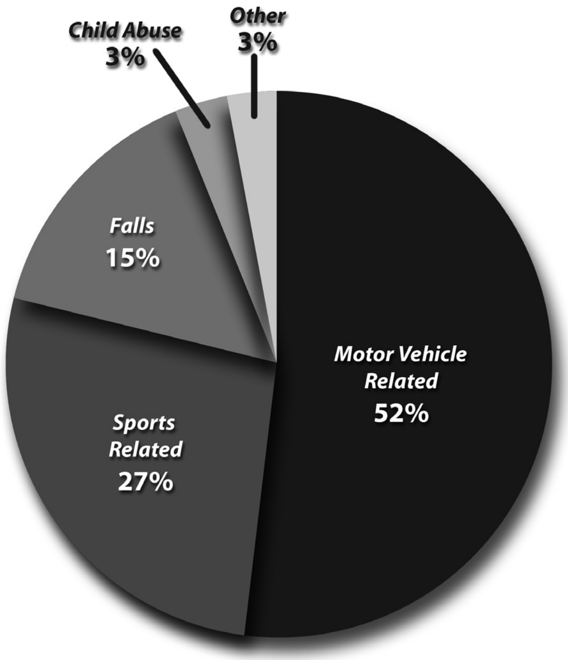


Figure 15. Mechanism of cervical spine injury in children 0-19 years



clearance of the cervical spine in children. However, a sub-study of NEXUS looked at the performance of the NLC in children younger than 18 years old.[75] Of the 34,069 NEXUS patients, 3,065 were younger than 18. In this subset of patients, the NLC identified all 30 of the children with a cervical spine injury. Because this study only examined a small subset of all NEXUS study participants, the 95% confidence intervals of the performance measures are much wider than in the study as a whole. The NLC's sensitivity, NPV, and specificity in this subset of patients were 100% (87.8%-100.0%), 100% (99.2%-100.0%), and 19.9% (18.5%-21.3%), respectively. Although observational, it is the only prospective study regarding pediatric spinal cord injuries that currently exists. However, a potential sensitivity of only 87.8% is not high enough to justify the widespread use of the NLC in children. As there were only 4 children younger than 9 years old with true cervical spine injuries, the sensitivity in this subgroup is potentially even lower.[75]

Of note, pediatric patients are theoretically more at risk for spinal cord injury without radiographic abnormality (SCIWORA). It is a condition commonly affecting those under eight years old and has been estimated to account for approximately 20% of spinal cord injuries in children.[76-78] As its name implies, SCIWORA is a disease that is diagnosed when radiographic imaging is normal yet neurologic compromise is present. Because of their more flexible ligaments and more cartilaginous bones, it is believed that children in blunt trauma may hyper-extend or hyper-flex their cervical spines without resultant fractures. The onset of SCIWORA can be delayed several days, arising only after a persistently compromised spinal cord blood supply affects neurologic function. Prognosis is better in children older than three and for those who have incomplete cord lesions. Usually caused by sporting injuries, SCIWORA is also associated with child abuse.[73] Interestingly, in the 34,069 patients reviewed by NEXUS, no SCIWORA injuries were found in patients less than 18 years of age either clinically or by imaging.[75] Twenty-two such cases were identified in the adults of this study. This suggests that SCIWORA may not be such a predominantly pediatric diagnosis as suggested by older literature.

Generally, there are three camps in terms of clinical clearance recommendations in children that reflect the lack of strong evidence in this area. Each advocate their use based upon the NLC. To date there are no pediatric recommendations based on the CCR, as this study specifically excluded patients younger than 16 years old. The first camp of authors suggests the use of the NLC in children without caveats.[74, 79] Others, such as the authors of the NEXUS pediatric study, state that their data "strongly suggests that children who meet all of the NLC generally do not need to undergo cervical spine imaging." [75] They qualify their use by warning that the NLC should only be applied with caution in infants and toddlers. A third group advocates radiological examinations in all children with blunt trauma.[80, 81]

Our opinion is that there is strongly suggestive evidence to support the use of the NLC for the evaluation of the pediatric cervical spine in blunt trauma. Certainly, in older children (12 years old or above) where the anatomy and cognitive abilities are similar to adults, the NEXUS criteria are useful. In this situation we believe the evidence to be Class II. The level of evidence for younger children is Class III. Therefore we recommend the use of the NLC in children over the age of 12 be viewed as a "guideline." In children younger than this, we agree with Viccellio et al, and believe the NLC should be used only with caution, and consider it an "option." Any child not meeting the NEXUS criteria should get a radiological examination. Further evaluation by MRI is recommended to identify SCIWORA if symptoms persist despite negative radiographic studies.[82]

Geriatrics

In the NEXUS study, geriatric patients, defined as patients over the age of 64, had a relative risk of 2.09 (95% CI 1.77-2.59) for cervical spine injury. This is the highest relative risk of all demographic groups examined in their epidemiology study, exceeding that of being male, 1.72 (95% CI 1.48-2.00).[9] Indeed, in both the NEXUS study and prior studies, cervical spine injuries in the elderly account for a disproportionately large percentage of the total injuries.[9, 83, 84] In the Canadian C-spine Rule derivation article, age greater than 65 was found to have an odds ratio of 3.7 (95% CI 2.4-5.6) in favor of a clinically significant c-spine injury.[56] For this reason, patients 65 years old or above were categorized by the CCR as inherently "high risk," requiring radiography (See **Figure 12**).[85] A disproportionately high number of those injuries in the elderly are caused by cervical spine fractures in women, and it is postulated that this is secondary to the prevalence of osteoporosis in this population.[9] Some authors suggest that the prevalence of all injuries in the elderly is increasing at a rate greater than what can be accounted for by demographic changes.[86] For these reasons, it is important to carefully evaluate these patients as they tend to be at higher risk for injury.

The NEXUS group examined the performance of the NLC in this subgroup of patients. The performance of the rule was similar to the NEXUS as a whole, with slightly higher confidence intervals resulting from the fact that this was a subgroup analysis with a smaller population (See **Table 3**).[87] Trouger et al conclude that NEXUS can be used for geriatric patients, with a caveat. They suspect clinicians generally would be much more conservative in geriatric patients, suggesting that geriatric patients might be more vulnerable to injury than their data shows. More recently, Bud et al have proposed a clinical prediction rule to risk stratify elderly patients who fail the NLC low-risk criteria.[88] Prospective, multicenter evaluation of this risk stratification system needs to occur before widespread adoption.

In our search, we found one case report of a missed injury in the elderly using the NEXUS rules. In this case report, the authors suggest that the CCR may be superior for detecting injuries in the elderly, as they would automatically be classified as high risk.[89] However, on careful review of this case report, the "normal alertness" criterion was misapplied.[89] The elderly, as in the pediatric arena, may be more at risk for SCIWORA as well. It is thought when the elderly fall, their head is frequently hyper-extended leading to a central cord syndrome. Ehara et al suggest further evaluation by MRI if symptoms persist despite negative x-rays and CTs.[82]

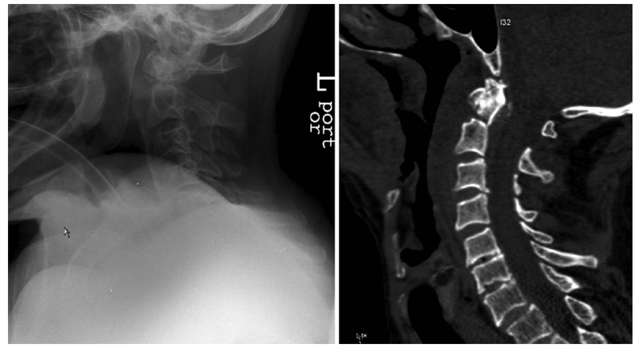
Our opinion is that there is evidence to support clinical decision rules in the elderly. Using the CCR, these patients are automatically classified as high risk and receive radiological studies. In terms of NEXUS, there is strongly suggestive evidence that the criteria apply in the elderly, and no true case reports of missed injuries. However, as this was a post-hoc subgroup analysis, the evidence is not fully conclusive. We consider it Class II, and consider the use of NEXUS in the elderly a "guideline." The "take home message" is that caution should be used in the elderly, and one should be familiar with all aspects of any decision rule one chooses to apply. If neurological symptoms persist after x-rays and CTs are negative, one should consider an MRI in elderly patients.

Radiography

Multidetector computed tomography scans versus traditional x-rays:

With the dissemination of CT scanning, the relatively low sensitivity of plain radiographs has become more apparent. In a study of 50 children, Dietrich et al argued that the lateral c-spine x-ray was up to 98% sensitive on its own.[90] However, others have found lower sensitivities

Figure 16. Comparison of x-ray and MDCT in a patient with a type 2 odontoid fracture



for plain x-rays for the detection of cervical spine injuries, even with multiple views.[45, 91-101] Sensitivities have been reported as low as 39% for cervical spine x-rays and 58% for thoracolumbar x-rays when compared to CT.[100, 102, 103] Generally, it has been accepted that 10-20% of all significant cervical spine injuries are missed by plain films.[61, 92, 95, 96, 104] In addition, patients frequently need to return for further radiographs of poorly visualized areas on plain films. Because of these issues, multi-detector spiral computed tomography scanners will likely change the paradigm for imaging the spine in blunt trauma.

In a retrospective chart review of 1199 patients, Griffen et al looked at the performance of this modality for the detection of cervical spine injuries and found a sensitivity of 100.0% (116/116 patients) compared to 64.5% (95% CI 55.5-77.6%) for plain radiography.[105] As there was no "gold standard" to use to evaluate the MDCT's performance, it is impossible to know the true sensitivity of this test, but it is clear that it performed better than traditional x-rays. Of note, all the cervical spine injuries missed by plain films required some form of treatment, and 13 of these were unstable injuries requiring surgical stabilization.[105] Numerous other studies have confirmed the higher sensitivity of MDCT over x-rays in c-spine fractures.[97, 102, 106-108] When MDCT is used to evaluate blunt trauma patients for thoracolumbar fractures, its sensitivity ranges from 96-99% compared to 58-76% for conventional plain films.[102, 103, 109] The superiority of MDCT over plain films is most apparent when both are compared side by side. **Figure 16** shows such a comparison in a patient with a type 2 odontoid fracture. Not only is the plain film inadequate, but to the untrained eye, it is likely difficult to see the fracture. However, given a basic knowledge of anatomy, the fracture is clearly seen in the reconstructed MDCT images.

Although MDCT has a higher initial fixed cost, it is offset by lower medico-legal and fixed personnel costs.[102] Although the probability of paralysis occurring in a patient as a result of a missed fracture is extremely low, the lifetime medical costs for that person are extreme. In a 1999 cost-effectiveness analysis, it was determined

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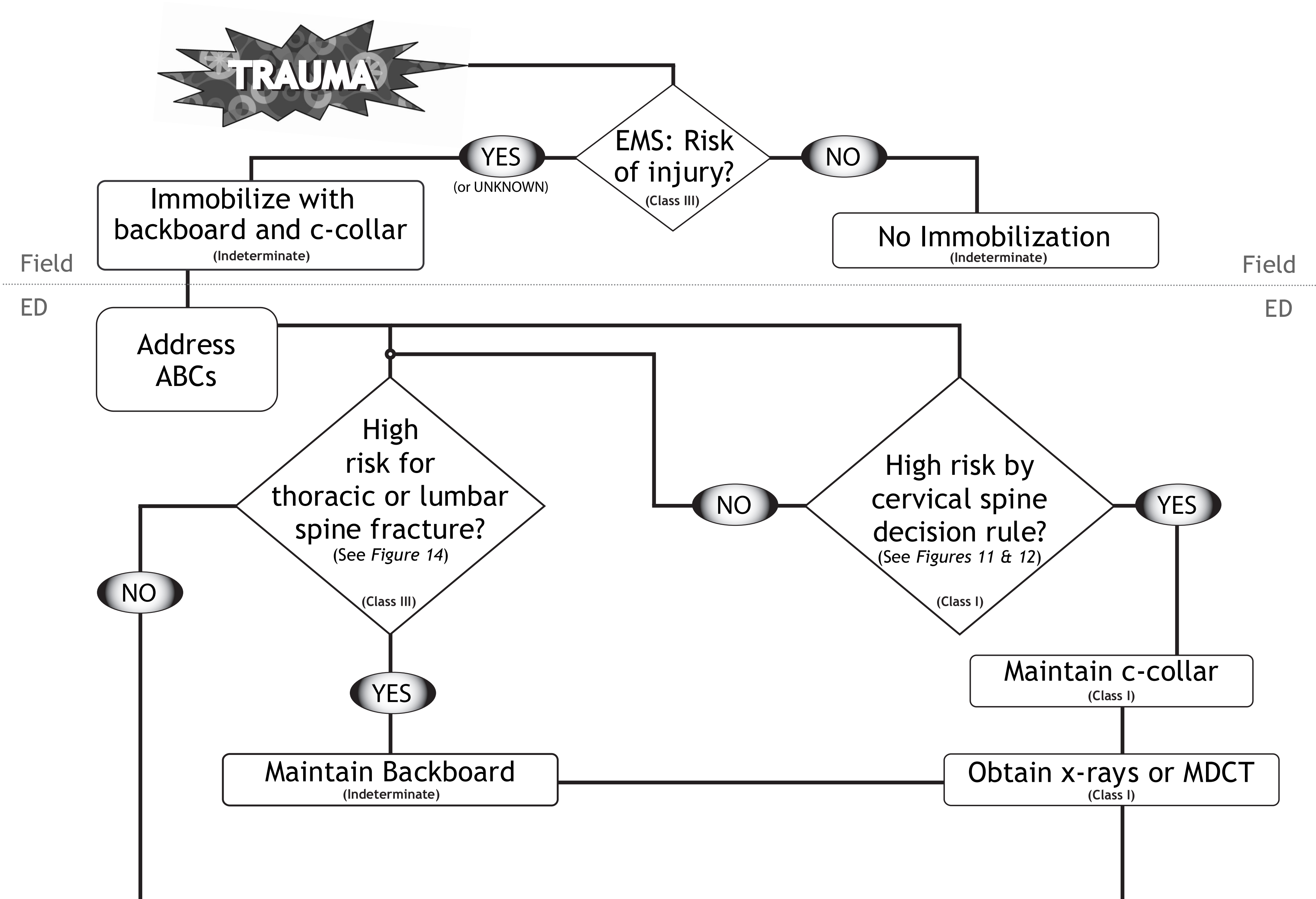
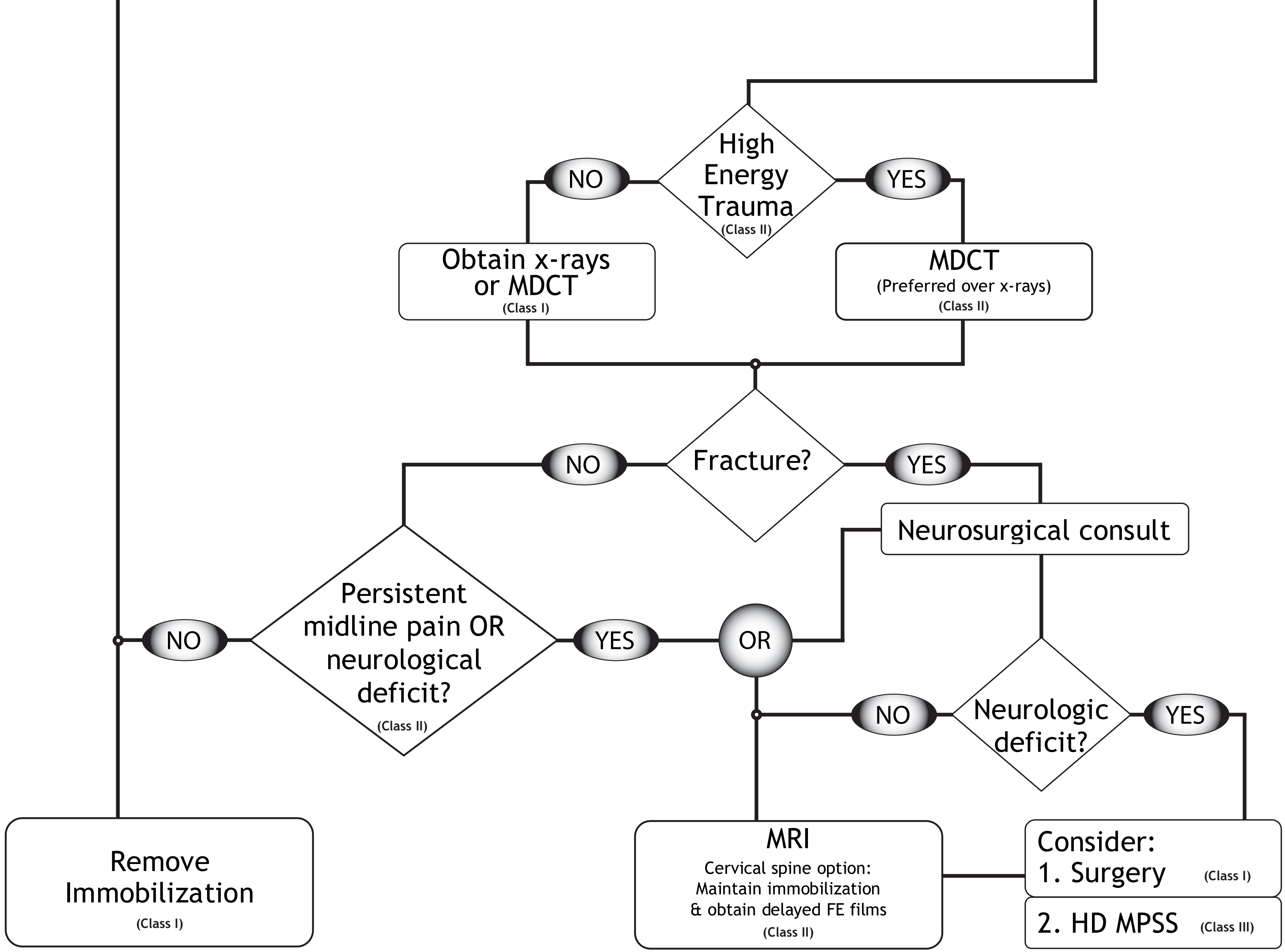
Clinical Pathway: Assessment of an acute spinal cord injury





This clinical pathway is intended to supplement, rather than substitute for, 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.

that in subjects with a high risk of cervical spine fracture (>10%), MDCT would save money and improve societal health through paralysis prevention.[2, 3] There is also a cost savings in that MDCT decreases the number of repeat radiographic examinations needed. Inadequate films squander material resources and waste the efforts of radiologists and radiology technicians.

The one disadvantage of MDCT compared to plain radiography is the higher dose of radiation that it delivers. For cervical spine imaging, there is a 50% increase in mean radiation dose to the spine in pediatric patients.[110] In terms of thyroid exposure, there is a 14-fold increase in dose to the thyroid (26 versus 1.80 mGy) with CT examination of the cervical spine when compared to a five-view radiographic series.[111] This is significant in pediatric patients where the risk of late malignancy caused by pediatric scans is as great as 1 in 5,000.[102]

Multi-detector computed tomography (MDCT) is advocated by many as the test of choice to evaluate spine injuries in blunt trauma patients.[71, 102, 105] In the setting of high-energy blunt trauma, we agree and recommend MDCT over plain films. We consider it a diagnostic "option." In low-energy blunt trauma or in centers where MDCT is unavailable, plain films remain the initial imaging modality, and we consider this the standard of care. The lower sensitivity of plain films when compared to MDCT should not be forgotten, however, and in a patient that continues to have significant midline spine pain in the setting of normal x-rays, an MDCT should be obtained. MDCT scanning is also the standard of care in all blunt trauma patients with significant mechanisms of injury when optimal visualization of the spine is not achieved by plain films alone. In patients with spine pain and low-energy mechanisms of injury, especially in children, plain films should be considered to minimize radiation exposure.

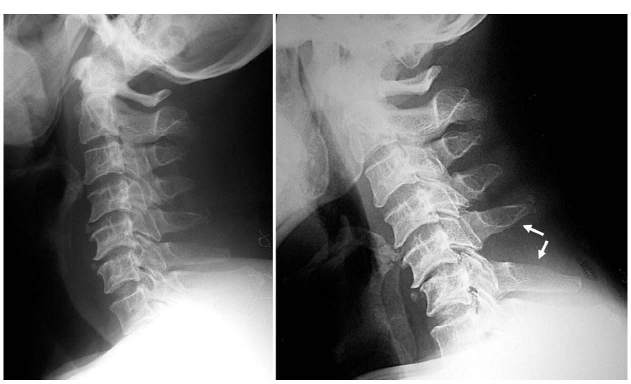
Flexion extension x-rays

Flexion-extension (FE) films have been advocated in the past to identify ligamentous injuries to the spine that are not evident on static plain films or MDCT.[112, 113] Although very sensitive for bony injuries, MDCT has been shown to be an ineffective modality for picking up cervical spine ligamentous injury.[114] **Figure 17** demonstrates a positive FE study. On the left image, the lateral cervical spine x-ray, there is marked soft tissue swelling, suggesting an injury. On the flexion image on the right, the ligamentous instability becomes apparent with "fanning" (widening) of the interspinous space (arrows). The facets at this level have lost their parallel appearance, and there is a slight angular displacement of the C5 vertebra.

Recently, the utility of flexion-extension films to evaluate ligamentous injury has been questioned. Ligamentous injuries without bony fractures of the cervical spine are rare, and FE films only infrequently reveal additional injury.[115, 116] In the NEXUS patient population where there were 818 spine injuries in 34,069 patients, FE films were never the only imaging study to identify cervical spine injury.[116] In the acute setting, other research has shown that up to 30% of FE films may be non-diagnostic.[117] Because FE films necessitate movement of the spine, it has also been argued that they could potentially exacerbate or cause ASCIs in patients with occult ligamentous injury.

In the acute setting, when there is lingering concern about ligamentous instability and the patient's neurologic examination and MDCT scans are normal, MRI is supplanting FE films as the imaging modality of choice. Because of its superior soft tissue resolution, it can demonstrate ligamentous injuries in patients when other studies are negative.[118-128] However, there may still be a small role for FE films at 7-10 days post injury. The low sensitivity of FE films in the acute setting has been hypothesized to occur because muscle pain and spasms limit neck mobility on the day of injury.[117] At this later time, these muscular spasms will have resolved, and ligamentous instability can be better perceived.[61, 71] Very rarely, these delayed films pick up injuries that are missed by MRI.[120, 129, 130] We consider the evidence for delayed FE films Class III, and consider it a diagnostic "option" in patients with persistent pain after negative MDCT.

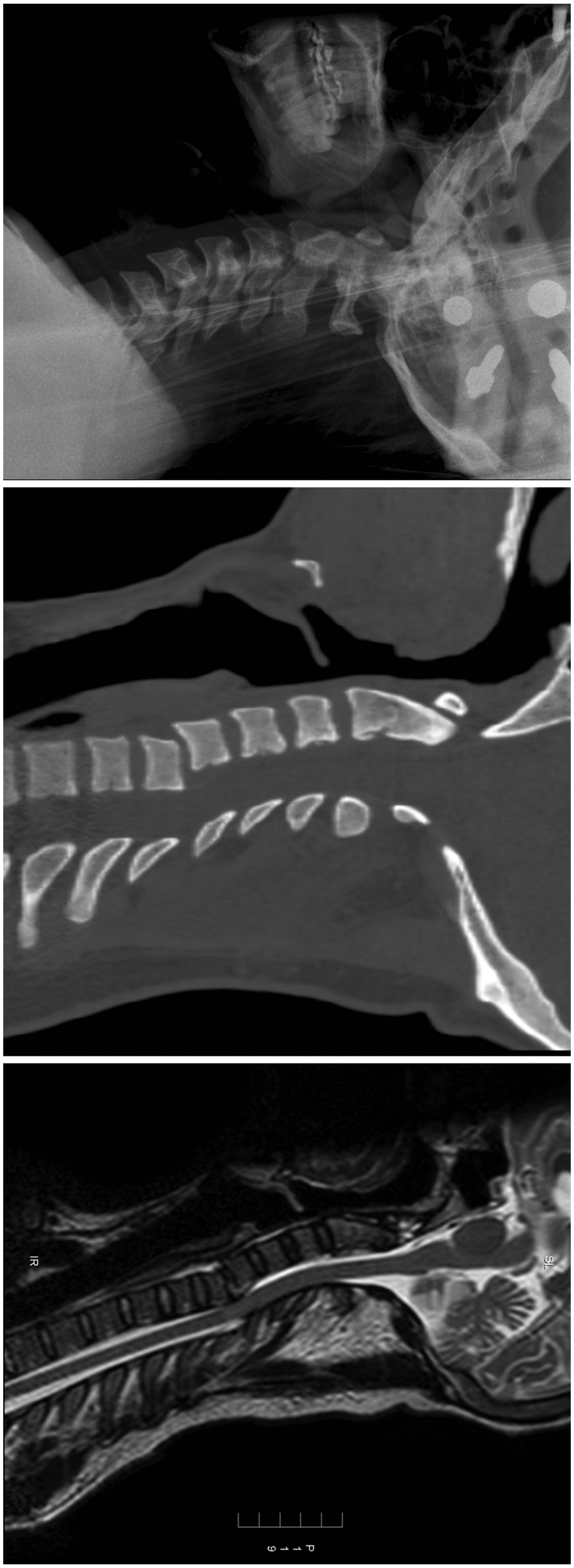
Figure 17. Positive flexion extension study



Magnetic resonance imaging

Despite a paucity of controlled studies to evaluate the accuracy of MRI in the setting of ASCIs, this modality is widely accepted as means to further evaluate such injuries.[131] Although it is less sensitive than other modalities for identifying fractures, MR imaging allows the best evaluation of the biomechanical integrity of the spine's supporting ligaments, intervertebral disks, and vertebral artery patency.[132] It also provides the only evaluation of the spinal cord itself. This is especially important in the diagnosis of ligamentous injuries, as discussed above, and in the detection of SCIWORA.[8, 71, 131] In most institutions, MRI is preferred over CT myelography for evaluation of the spinal cord unless it is contraindicated.[131] Some also propose that MRI be used in the acute setting to assist in differentiating neurologic deficits caused by intrinsic cord injury from

Figure 18. Comparison of the three different imaging modalities in a patient with a C5 on C6 subluxation



extrinsic compression.[133, 134] The relative utility of MRI compared to x-rays and MDCT to evaluate different injury types is shown in **Table 5**.[135] The bottom image in **Figure 18** demonstrates the detailed imaging of the spinal cord and soft tissues that only MRI allows. There is suggestive Class II evidence to support the use of MRI in the acute setting to evaluate the soft tissue structures of the spine. We believe that MRI should be considered a diagnostic "option" in the setting of blunt trauma with neurologic deficits unexplained by MDCT, progressive neurological deficits, myelopathies, or radiculopathies.[8] If an ASCI has occurred, an MRI may also help define the extent of injury to the neuronal tissues.[131, 136]

Figure 18 is a demonstrative comparison of the three different imaging modalities in a patient with a C5 on C6 subluxation. As in **Figure 16**, when compared to the MDCT, the x-ray is inadequate and would require further films. In this case, the anterior dislocation of C5 on C6 is easily visualized, but there would still be uncertainties about the remainder of the cervical vertebrae. In the center image, the MDCT study shows all cervical and the top thoracic vertebrae. Additional injuries were identified by the MDCT that were not visualized on the plain film (Not shown: left locked articular facet with fracture). The MDCT study leaves little doubt about the integrity of the remainder of the cervical spine vertebrae. Still, in this MDCT study, no information is gained about the cervical soft tissues, ligaments, and spinal cord itself. In contrast, the right hand MRI study shows abundant information about these structures. On close inspection of the MRI, a lighter hue is seen over the spinal cord at the fracture site. This likely represents cord compression and edema caused by the vertebrae pushing on the spinal cord.

Treatment of ASCIs – the Steroid Debate

The use of steroids to treat an ASCI remains controversial despite three randomized, double-blind, multi-center trials (National Acute Spinal Cord Injury Study (NASCIS) I, II, and III). Emergency medicine physicians are often the first to manage patients with ASCIs. These injuries are devastating to the patient and difficult to manage for physicians. The medical profession's desire to change the outcome of such terrible injuries has led to the enthusiastic search for and use of medications that promise any minute benefit. Among the current armamentarium for treating such injuries is methylprednisolone sodium succinate. Its use is associated with much controversy and uncertainty. Although prospective and randomized, the NASCIS trials showed no statistical difference between MPSS and placebo in terms of neurological recovery (their primary endpoint) at one year, except in post-hoc analyses of subgroups. A review of the NASCIS trials and major recommendations follows.

NASCIS I

This trial compared 10-day treatment regimens of high dose (11 g in total) MPSS to the standard, ten-fold lower dose for treatment of ASCI. When patients were assessed at 6 weeks, 6 months, and one year, no significant neurological recoveries in motor function, pinprick, and light touch were noted.[137] However, the rate of wound infections had 3.6 times greater frequency in the high dose MPSS group, an important finding that was statistically significant.[138] As this study lacked a placebo group, it can only be viewed as hypothesis-generating study, and did in fact lay the groundwork for the subsequent NASCIS II and III trials.

NASCIS II

In this trial, an even higher dose MPSS regimen (30mg/kg bolus, and then a 5.4mg/kg drip over 23 hours) was compared to naloxone and placebo. As in NASCIS I, there were no differences in neurological recovery among the three groups at all assessments up to one year.[139] However, a post-hoc analysis of patients treated within 8 hours revealed a statistically significant improvement in motor function in the MPSS group which persisted up to the final assessment at one year. Excluding the benefit found in the post-hoc analysis, the mortality and morbidity were the same for all groups at all time points.[140, 141]

NASCIS III

Following up on the NASCIS II trial, NASCIS III attempted to discern whether a treatment benefit existed if MPSS was given within 8 hours. Motor function change and the Functional Independence Measure (FIM)[142] after administration with MPSS for 24 or 48 hours were compared to tirilazad mesylate for 48 hours. Given the suggestion of a clinical benefit of MPSS in NASCIS II, MPSS had become the standard of care in the United States for the treatment of ASCIs. Therefore, a placebo arm was not included in NASCIS III. Although there was a trend towards improved motor recovery in patients who received MPSS for 48 hours, it was not statistically significant. Post-hoc analysis of patients in the 48-hour MPSS group treated within 3 to 8 hours showed statistically significant improvement in motor recovery at 6 weeks and 6 months; this difference was at the limit of statistical significance at one year ($p = 0.053$).[143] It is important to note that the majority of enrolled patients were excluded from this post-hoc analysis, further limiting interpretation of this finding. Finally, the overall FIM score was not significantly changed in this sub-analysis for any time point. Notably, at six weeks in the 48-hour MPSS group, there was an increase in risk of severe pneumonia ($p = 0.02$). There was also a trend towards an increased risk of severe sepsis, although not statistically significant.[144]

Surprisingly, from both the NASCIS II and III trial data, the authors concluded that MPSS has a role in treating ASCIs, and advocated it as the standard of care.

Table 5. Utility of different imaging modalities

Area of Interest	Abnormality	CT & Radiographs	MRI
Spinal cord	Edema		+
	Swelling		+
	Hemorrhage	+	+
	Compression		+
	Dissection		+
Epidural space	Disk herniation	+	+
	Bone Fragment	+	
	Hematoma	+	+
Spinal column	Vertebral body fx	+	
	Posterior element fx	+	
	Dislocation	+	
	Bony edema		+
	Spondylosis	+	
Ligaments	Anterior longitudinal ligament rupture		+
	Posterior longitudinal ligament rupture		+
	Interlaminar ligament (flava) rupture		+
	Supra- or inter-spinous ligament rupture		+
Vascular	Vertebral artery–occlusion/dissection		+

Adapted from Imhof et al, 2002 [135]

In 2003, Bracken, the primary author from the NASCIS trials, wrote the Cochrane Database of Systematic Reviews evaluation of MPSS in ASCIs. He states:

> "High dose methylprednisolone steroid therapy is the only pharmacological therapy shown to have efficacy in a Phase Three randomized trial when it can be administered within eight hours of injury. A recent trial indicated additional benefit by extending the maintenance dose from 24 to 48 hours if start of treatment must be delayed to between three and eight hours after injury." [5]

This conclusion should be regarded with a great deal of skepticism. These conclusions have not been borne out by the NASCIS results, nor by any other independent studies.[145-151] It is central to understand that there were no differences in primary outcome between patients treated with MPSS and those that were not. The results of NASCIS II and III were negative. The only statistically

Ten Pitfalls To Avoid

1. **Failure to prioritize the ABCs over potential ASCIs.**
   a. Respiratory compromise or hypoperfusion will cause death quickly.
   b. If there is a tenuous airway, use in-line cervical immobilization and definitively secure it.

2. **Failure to consider a spine fracture.**
   a. If a patient is obtunded or altered, assume that there is a fracture until proven otherwise.
   b. Do not attribute the back pain to a more benign cause in the setting of a high-energy blunt trauma.
   c. Until proven otherwise, assume the worst. Think "spine fracture" or "ASCI" until proven otherwise.

3. **Attributing the lack of movement over a joint to pain from a fracture.**
   a. As in Pitfall #2, assume the worst.

4. **Failure to expedite the removal of immobilization devices, when possible.**
   a. Immobilization poses its own hazards (see Table 1).
   b. Pressure sores develop within hours in patients placed on backboards.
   c. Expedite surgical fixation if there are unstable fractures.

5. **Using clinical judgment rather than a clinical decision rule to rule out cervical spine injury.**
   a. Clinical judgment is not sufficient anymore.
   b. Use the prospectively validated NLC or CCR to clear patients.
   c. If there is any question, get the study.

6. **Failure to understand the limitations of a clinical decision rule.**
   a. The reliability of the NLC has not been validated in young children.
   b. It should be used with a great deal of caution, if at all, in this patient population.

7. **Failure to appreciate that the elderly are at high risk for spine fractures.**
   a. Elderly people, especially elderly females with osteoporosis, are at high risk for spine fractures and ASCIs.
   b. Seemingly minimal trauma can cause fractures in this patient population.

8. **Failure to visualize the entire cervical spine on the x-ray study.**
   a. The entire cervical spine should be seen on plain films.
   b. If they are inadequate, get a multidetector computed tomography scan (MDCT).

9. **Failure to appreciate that a normal x-ray or MDCT does not rule out ligamentous injuries or SCIWORA.**
   a. Although rare, these injuries do occur.
   b. In the setting of normal x-rays or MDCT where the patient complains of persistent pain or neurologic symptoms, consider further studies.
   c. An MRI or continued cervical spine immobilization with delayed FE films is recommended in patients with persistent pain and a negative MDCT.

10. **Failure to appreciate that administering a high dose of MPSS poses risks.**
    a. Severe pneumonia is more likely in these patients.
    b. The NASCIS studies also showed a trend towards severe sepsis. ▲

significant neurological improvements were found in retrospectively analyzed subgroups of patients. One must be very weary of conclusions drawn from a subgroup analysis in any study.

Although Bracken argues otherwise, the problems with his study design, statistical methodology, and ambiguous data presentation have led to a great deal of doubt regarding the clinical relevance of MPSS.[55, 152, 153] The American Association of Neurological Surgeons/ Congress of Neurological Surgeons Joint Section of Disorder of the Spine and Peripheral Nerves deemed MPSS treatment for 24 or 48 hours only a treatment "option." They qualify their recommendation by stating that evidence of harm may be more consistent with the available evidence than evidence of clinical benefit.[154] The Canadian Association of Emergency Physicians and the American Academy of Emergency Physicians echoed this view and suggested that MPSS should be considered a treatment "option," not a "standard" or "guideline."[155, 156] Similarly, in a 2001 review by Hurlbert, the potential harm of MPSS in treatment of ASCIs leads him to consider this intervention as "investigational" only.[157] Although the Spine Focus Panel suggests that MPSS should be considered in the treatment of ASCIs, it is the minority opinion. Despite its endorsement of MPSS, this panel recognizes the criticisms of the NASCIS II and III trials put forth by others.[158]

In view of the unclear benefit and possible harm imparted by MPSS treatment for ASCIs, we consider MPSS to be a treatment "option." The level of evidence that MPSS benefits recovery from an ASCI is Class III. We recommend that if MPSS is given, it should be done in partnership with the neurosurgery or neurology service that will care for the patient after transfer from the emergency department.

Disposition

Few patients who experience blunt trauma will end up with spinal cord injuries. The majority will experience musculoskeletal neck or back strains. Patients should be made aware that it can take 2-4 weeks for complete healing of these injuries.

As the current medico-legal environment and EMS protocols dictate, patients should be immobilized by the EMS services if a reasonable mechanism of injury is identified. Future studies are needed to identify more sensitive criteria that can be applied by EMS in the field. This will help minimize the harm done by the potential deleterious effects of immobilization.

Patients who have a low-energy mechanism of injury can be safely removed from immobilization and discharged home if they are cleared by either of the clinical decision rules, the NLC or CCR. Patients who

Ten Key Points

- Expedite the removal of immobilization devices when possible as they pose hazards of their own.
- The Nexis Low-Risk Criteria (NLC) and Canadian C-Spine Rule (CCR) are of equal value in clearing the cervical spine.
- The use of either the NLC or CCR clinical decision pathways expedites cervical collar removal and minimizes both radiation exposure and costs.
- Caution is recommended when using the NLC or CCR in the pediatric and geriatric populations as the studies to validate clinical decision rules are not as robust.
- Although more rare than cervical spine injuries, one should consider potential thoracic or lumbar fractures in patients with the high-risk criteria listed in Table 4.
- The elderly, especially elderly women, are at a high risk for spine fractures.
- Manage the ABCs first, using in-line stabilization if intubation is required.
- Obtain an MDCT on any patient in whom traditional x-rays are inadequate or there is a high suspicion of injury.
- Consider an MRI or delayed FE films in any patient in whom there is persistent pain or neurologic deficit despite a normal MDCT.
- Due to the unclear benefit and clear risks, MPSS should be considered a treatment "option" and only given in concert with the neurosurgical service. ▲

fail these clearance criteria and obtunded patients should get radiological studies to evaluate the spine. Clinicians should have a low threshold for imaging patients who: have any high-energy mechanism of injury, are children in whom a thorough exam is not possible, or are elderly.

Any patient in whom a spine fracture or spinal cord injury is identified or strongly suspected requires immediate neurosurgical consultation. Airway protection with attention to in-line stabilization should be initiated in anyone where a high-level cervical spine injury potentially causing respiratory compromise is a concern. Immobilization should be continued, but physicians should be aware of the risks. Definitive stabilization should be expedited. High dose MPSS administration, as discussed, is considered an "option," and should only be given in consultation with the neurosurgical service. These patients should be admitted to the surgical intensive care unit on either a trauma surgery or a neurosurgical service per the extent of the patient's other injuries.

Patients who have had a complete and negative radiological examination, and in whom the spine pain has resolved can be sent home. Those who still have pain, a low-energy mechanism of injury, and no evidence of injury should be given a soft collar for support and symptomatic relief early in the recovery phase. Neurosurgical follow-up is recommended in these patients. If the patient had any significant mechanism of injury, the physician still has doubts about a patient with persistent pain, or there are equivocal radiological findings, a neurosurgical consultation should be obtained. An MRI should be considered if a ligamentous injury or SCIWORA is suspected.

Patients discharged home need appropriate discharge instructions and follow-up. Depending on the institution, follow-up may be arranged with neurosurgery, orthopedics, or neurology. Appropriate pain medications such as NSAIDS with acetaminophen-opioid combinations for breakthrough pain should be prescribed. Patients should be instructed to return immediately if they develop signs of deteriorating spinal injury: weakness, numbness, worsening pain, or bowel or bladder incontinence.

Summary

Developing paraplegia or quadriplegia as a result of a spine injury is a devastating event for any patient. Such injuries place an enormous emotional, social, and financial burden on the individual patient as well as society. This review has emphasized the numerous changes in the approach to ASCIs that have occurred in the last few years. This review also found that there is only meager evidence that MPSS improves ASCI outcomes in any meaningful way. Until better therapies are developed, perhaps through stem cell research, there is currently no ideal treatment for ASCIs. Until future therapies are developed, the best approach is to prevent, identify, and repair existing spine fractures before injury to the spinal cord occurs. Through the use of judicious immobilization, clinical judgment aided by clinical decision instruments, and the use of radiography, the astute emergency physician will identify these spine fractures. This will prevent secondary cord injury, allowing early surgical repair. ▲

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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

65. The most common cause of ASCIs in the United States for all ages is:
a. Falls
b. Motor vehicle accidents
c. Sports injuries
d. Diving injuries

66. According to the NEXUS database, the most frequently and infrequently injured cervical spine vertebrae are (respectively):
a. C2 and C3
b. C5 and C3
c. C5 and C2
d. C2 and C6

67. Central cord syndrome of the cervical spine typically affects:
a. The legs more than the arms because of the vascular supply to the area.
b. The arms more than the legs because of the vascular supply to the area.
c. The arms more than the legs because of the neuronal layering of the spinal cord.
d. Both the arms and legs equally because of the neuronal layering of the spinal cord.

68. SCIWORA is
a. Best evaluated by MRI.
b. Can be associated with child abuse.
c. Cannot be diagnosed in the absence of neurologic injury.
d. All of the above.

69. Which of the following statements is true?
a. Immobilization is a proven, effective, and safe method for the prevention of ASCI deterioration during transport.
b. Immobilization is safe, but there is little evidence to support its use.
c. Immobilization poses hazards, but it has been proven to be an effective means of preventing ASCI deterioration during transport.
d. Immobilization is a tradition that can potentially pose hazards to blunt trauma patients.

70. A patient is brought to the ED by EMS in a cervical collar and on a backboard after crashing his motorcycle into a bus. His GCS is 12, and he is diffusely tender over the entire spine. You should:
a. Image the entire spine because of the tenderness, high-energy mechanism, and GCS of 12.
b. Image the thoracic and lumbar spine because they are at greatest risk.
c. Image the cervical spine only because this is the area most at risk.

d. Administer pain medications and reassess the spine.

71. **The patient from question #7 is found to have a spinous process fracture of C5 on a lateral cervical spine x-ray done in the trauma bay. This should:**
    a. Increase suspicion of another fracture.
    b. Decrease suspicion of another fracture.
    c. Trigger the immediate administration of high dose MPSS.
    d. None of the above.

72. **A four-year-old child is brought in by EMS immobilized after a prolonged extrication from a crashed car. Her father was brought in earlier and found to have a spinous process fracture and multiple pelvic fractures. She is cooperative, and you use the NLC to evaluate her cervical spine. The child does not appear to have any spine tenderness. You:**
    a. Remember the Class I evidence for the use of the NLC in children and remove her cervical collar.
    b. Remember that one should use the CCR rather than the NLC to clear the cervical spine in children.
    c. Remember there is no Class I evidence for the use of the NLC in young children, and given the significant mechanism of injury, decide to get imaging of her cervical spine.
    d. Get an MDCT of her entire spine because this is safe and the only way to reliably rule out fractures in children.

73. **An 87-year-old woman is brought in by EMS immobilized. The patient has a GCS of 15 and states she tripped and fell at home. She is not complaining of any pain. You remove the backboard after finding no neurologic deficit, spine tenderness, or deformity on a log roll. You examine her cervical spine and find no tenderness. You should:**
    a. Clear her cervical spine by using the NLC.
    b. Clear her cervical spine by using the CCR.
    c. Obtain cervical spine imaging because she is elderly and at high risk according to the CCR.
    d. A or C.
    e. A, B, or C.

74. **Which statement(s) are true?**
    a. The elderly are at equal risk for spine fractures as the rest of the population.
    b. The elderly are more frequently involved in MVAs and this is responsible for their increased spine fracture rate.
    c. Osteoporosis puts the elderly (especially females) at increased risk for spine fractures from minor trauma.
    d. B and C.

75. **The most sensitive test for spine fractures is:**
    a. 3-view x-rays.
    b. MDCT.
    c. MRI.
    d. Flexion-Extension films.

76. **MRI:**
    a. Is of no value in the evaluation of ASCIs.
    b. Differentiates between intrinsic and extrinsic spinal cord injuries.
    c. Is necessary for spine clearance.
    d. Is useful for the evaluation of ligamentous injuries.
    e. B and D.

77. **With regard to high dose MPSS:**
    a. There is high quality prospective evidence of its efficacy in the treatment of ASCIs.
    b. There are few risks of administering high dose MPSS.
    c. The majority of guidelines relevant to ASCIs recommend their use.
    d. None of the above.

78. **A patient is brought in by EMS after being found in his crashed car. He is clearly inebriated but is awake and cooperative with the history and exam. Which statement is true?**
    a. An intoxicated patient cannot be cleared by the CCR.
    b. An intoxicated patient cannot be cleared by the NLC.
    c. An intoxicated patient cannot be cleared by either clinical decision rule.
    d. An intoxicated patient can be cleared by either rule.

79. **Thoracic and lumbar spine fractures are:**
    a. As common as cervical spine fractures.
    b. More common than cervical spine fractures.
    c. More commonly associated with ASCIs.
    d. Less commonly associated with ASCIs.

80. **Neurogenic shock:**
    a. Presents with hypotension and bradycardia.
    b. Is seen in all ASCIs.
    c. Is caused by loss of vasomotor tone to the peripheral vasculature and loss of sympathetic tone to the heart.
    d. A and C.

The x-rays used in this review were generously provided by:

1. Paul Solodnik, MD of the Mt. Sinai School of Medicine – Elmhurst Hospital Center Department of Neuroradiology and Diagnostic Radiology, Elmhurst, NY 11373.
2. David T. Schwartz, MD of the New York University – NYU / Bellevue Department of Emergency Medicine, New York, NY 10018.

Physician CME Answers

65. **B**	69. **D**	73. **D**	77. **D**
66. **A**	70. **A**	74. **C**	78. **B**
67. **C**	71. **A**	75. **B**	79. **C**
68. **D**	72. **C**	76. **E**	80. **B**

Errata: Volume 8, Number 3

Please note that there was an error in Table 8 on page 11. The table listed screening frequency for 5.0-5.5cm as 1.0 months. However, screening frequency for 5.0-5.5cm should be every 3.0 months. We regret any confusion this may have caused.

Class Of Evidence 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

Levels of Recommendation

Standard - primarily supported by Class I evidence

Guideline - primarily supported by Class II evidence

Option - primarily supported by Class III evidence or concensus

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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