C.1. Diagnosis and Management of Spinal Cord Injury

a. The emergency room diagnosis and interpretation of radiologic studies in spinal trauma

i. Diagnosis:

aa. Presentation:

There are approximately 11,000 new spinal cord injuries per year.

Mechanism of Injury:

- Motor vehicle crashes: 45%
- Falls: 22%
- Sports: 14%
- Violence: 14%
- Other: 5%

Most patients (75%) are males. Sixty percent are between the ages of 16 and 30. Slightly more than half of all patients with cervical spine trauma will present with signs of neurologic injury. Up to 10% of patients with cervical spine trauma will develop signs of neurologic injury after presentation.

bb. Association with other injuries

Five to ten percent of unconscious patients who have been involved in a fall or motor vehicle accident will have a cervical spine injury. Conversely, 60% of patients with a cervical spine fracture will have at least one major associated injury. Five to fifteen percent of patients with a cervical spine fracture will have a second vertebral column fracture.

cc. History and physical examination clues to the presence of spinal injury

Pain

-local pain, due to bone/soft tissue injury

-radicular pain, due to nerve root compression

Vitals

-bradycardia indicating loss of sympathetic input to the heart from cervical or high thoracic lesion

-hypotension due to loss of sympathetic input tosystemic vasculature ("spinal shock")

External

-tenderness, bruising, or swelling due to local soft tissue damage

-palpable step-off due to malalignment

-paraspinous muscle spasm

-torticollis due to muscle spasm or unreducedvertebral dislocation

Weakness

-partial vs. complete

-level: motor level is defined as the most caudal level with grade III (antigravity) strength, assuming that more cranial levels have grade IV strength

Sensation

-decreased vs. absent vs. hyperesthesia

-level : sensory level is defined as the most caudal dermatome with normal sensation

-saddle region needs to be tested - may be the only region of preserved sensation ("sacral sparing")
Reflexes
-normal vs. absent vs. increased
-absent may indicate the presence of spinal shock
-increased may indicate the presence of an older complete or incomplete injury
Sphincter
-decreased or absent tone
-loss of voluntary contraction
-loss of bulbocavernosis reflex

dd. In the comatose or intoxicated patient

The comatose or intoxicated may be unable to transmit information regarding pain or cooperate with strength or sensory testing. Intracranial injury may co-exist with spinal injury. Therefore one must assume that all comatose or intoxicated trauma patients have a spinal injury until proven otherwise.
Clues to the presence of a spinal injury in such a patient include:
-flaccid areflexia
-diaphragmatic breathing
-loss of grimace to painful stimuli below specific level
-loss of withdrawal response below a specific level
-loss of spontaneous movement below a specific level
-loss of sphincter tone
-priapism
Frankel grading system

Frankel Grade	Designation	Definition
	Complete neurological injury	
A		No motor or sensory function detected below level of lesion
	Preserved sensation only	
B		No motor function detected below level of lesion, some sensory function below level of lesion preserved
	Preserved motor, nonfunctional	
C		Some voluntary motor function preserved below level of lesion but too weak to serve any useful purpose, sensation may or may not be preserved
	Preserved motor, functional	
D		Functionally useful voluntary motor function below level of injury is preserved
	Normal motor function	
E		Normal motor and sensory function below level of lesion, abnormal reflexes may persist

ii.

iii. Radiologic studies

aa. Plain x-rays

Static:
-Need to see down to the C7-T1 disc space on the lateral plain x-rayof the cervical spine

-Anterior-Posterior and Lateral (Cervical/Thoracic/Lumbar)
Evaluate for the presence of:
-Prevertebral soft tissue swelling
-Malalignment
-Vertebral body fractures or loss of vertebral body height
-Posterior element fractures (spinous process, transverse process, lamina, facet)
-Widening of interpedicular distance
-Fracture of dens
-Open Mouth Odontoid (Cervical)
-Evaluate for the presence of:
-Fracture of dens
-Widening of lateral masses of C1
Dynamic (Flexion/Extension):
-Performed only if static x-ray are normal but there is a high suspicion of ligamentous injury not be visible on static x-rays
-Can only be performed in the conscious cooperative patient
-Evaluate for the presence of:
-Vertebral subluxation
-Widening of distance between dens and arch of C1
-Abnormal kyphosis or opening up of posterior elements in flexion

bb. Computed axial tomography

-Has largely replaced conventional polytomography
-Most useful for assessing bone detail; poor visualization of neural elements
-Usually performed whenever the plain x-rays are abnormal in order to:
-More completely characterize a known fracture
-Rule out spinal canal compromise due to indriven bone fragments with a known fracture
-Rule out occult fracture in the presence of known ligamentous injury
-Occasionally used to image the lower cervical spine when this cannot be done using plain x-rays
-May be combined with intrathecal contrast (myelography) in order to visualize neural elements when MRI is contraindicated or not available

cc. Magnetic resonance imaging (MRI)

-Most useful for visualizing soft tissue structures
-Resolution of bone inferior to computed axial tomography
-May be performed when plain x-rays are abnormal in order to rule out:
-Spinal cord injury/hematomyelia
-Traumatic intervertebral disc herniation
-Hematoma
-Ligamentous injury

b. Initiate acute management of spinal cord injury including immobilization, steroids and systemic measures

i. Immobilization

aa. Cervical

Traumatic cervical spine injury should be presumed to be present until it is ruled out by physical examination and appropriate radiographic studies. In order to prevent new or additional neurologic injury, immobilization of the cervical spine should be instituted as soon as possible. Patients with a known or suspected cervical spine injury, or those who are comatose or intoxicated at the scene of injury, should ideally be placed in a cervical orthosis at the scene. Alternatively, if an appropriate cervical orthosis is not available, the head and neck may be immobilized by placing sandbags or towel rolls on either side of the head.

If a cervical spine injury is found radiographically, it is usually imperative that cervical spine immobilization be continued until definitive management is complete. In some patients this may consist of continued treatment in a cervical orthosis, combined with bed rest.

In other patients, especially those with neurologic injury, cervical spinal instability, or unreduced cervical spinal dislocation, in-line cervical traction may be used. Cervical traction is frequently applied using Gardner-Wells tongs secured to the skull. Five pounds of weight are initially applied. More weight is occasionally added in an attempt to reduce a spinal dislocation. While the patient is in cervical traction, neurologic examinations should be performed frequently. Radiographic examinations should be performed after the initial application of weight and after any subsequent change to assess for changes in spinal alignment and the presence of overdistraction (pulling apart of the spine). Weight should be immediately reduced if a decline in the neurologic examination or overdistraction occurs. Cervical traction is contraindicated in certain highly unstable cervical injuries, as well as in occipital-cervical dislocation.

Finally, some patients may initially be placed in a halo vest. In addition to effective immobilization of the upper and middle cervical spine, placement in a halo vest may constitute definitive therapy for a variety of lesions.

bb. Thoracolumbar

As with the cervical spine, thoracolumbar spine fracture should be presumed to be present until it is ruled out by physical examination and appropriate radiographic studies. Present extrication and transport techniques emphasize maintenance of a neutral position during the prehospital phase. Most commonly, patients are transported to the hospital on a backboard. They should not be allowed to sit or stand prior to evaluation. During the physical examination, patients should be carefully logrolled by multiple personnel for examination of the back. Unless the patient has a highly unstable lesion, the backboard may be removed while the patient is flat in bed. Whenever the patient is moved, for example to the CT or MRI scanner, the patient should be carefully placed back onto the backboard.

ii. Steroids

aa. Spinal cord injury

Results of the NASCIS II study showed that patients with spinal cord injury who were treated with methylprednisolone within eight hours of injury had significantly greater improvement in their neurologic function (motor, pinprick sensation, and

touch sensation) than those given a placebo. The dose administered in the study was 30mg/kg given as a bolus over 15 minutes, followed by an infusion of 5.4 mg/kg/hr for 23 hours, begun 45 minutes after completion of the bolus.

Results of a follow-up study, NASCIS III, concluded that patients with acute spinal cord injury who receive methylprednisolone within 3 hours of injury should be maintained on the treatment regimen for 24 hours. When methylprednisolone is initiated 3 to 8 hours after injury, patients should be maintained on steroid therapy for 48 hours.

bb. Cauda equina injury

No data from randomized, controlled studies.

cc. Gunshot wounds to the spinal cord

No data from randomized, controlled studies. However, a recent retrospective study of 254 patients reported no neurological benefit from intravenously administered steroids after a gunshot wound to the spine (C1-L1). Both infectious and noninfectious complications were more frequent in the group receiving steroids. It was recommended that patients with spinal cord injury secondary to a gunshot wound to the spine not be treated with steroids.

iii. Systemic measures

aa. Respiratory

Maintenance of an adequate airway and breathing remains the first priority in the trauma patient. Spinal cord injured patients may suffer from inadequate respiratory function due to paralysis of the intercostal muscles or diaphragm. Concomitant injuries may also compromise respiratory function. Maintenance of spinal alignment is critical during intubation. If endotracheal intubation is needed, it is best performed in conjunction with in-line cervical traction, nasotracheally (if there is no evidence of basilar skull fracture) or fiberoptically.

bb. Cardiac

After airway and breathing abnormalities are treated, adequate perfusion must be assured. Hypotension in the patient with a spinal injury may be due to intravascular volume loss due to bleeding or spinal cord injury. These two processes may co-exist. Identification and control of bleeding is the first priority. Hypotension, due to loss of sympathetic vascular tone, and bradycardia, due to loss of sympathetic innervation of the heart, are the most important elements of spinal shock due to spinal cord injury. Initial treatment of spinal shock consists of intravascular volume expansion. In patients refractory to this therapy, sympathomimetic drugs may be needed

cc. Genitourinary

Placement of an indwelling urinary catheter is mandatory in the severely injured patient for monitoring of urine output volume. In the patient with a spinal injury, urinary catheterization during the period between identification of the injury and definitive treatment facilitates nursing care and avoids unnecessary patient movement. In the neurologically injured patient, the bladder may not function normally. Continuous urinary drainage prevents the complication of bladder rupture due to overdistension.

c. Understand the definition and subsequent management principles of the unstable spine

i. Unstable spine: Definition

Spinal instability has been defined as "the loss of the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve roots and , in addition, there is no development of incapacitating deformity or pain due to structural changes." Notice that this is a clinical definition.

Numerous sets of radiographic criteria have been developed in an attempt to predict which patients are or will become unstable after a spinal injury. The most commonly used is the three-column model of Denis. In this model, the spine is divided into a posterior, middle, and anterior column. The posterior column includes all of the posterior bony and ligamentous elements while the middle column includes the posterior longitudinal ligament and all of the elements comprising the posterior one third of the vertebral body and intervertebral disc. The anterior column is comprised of the remaining portions of the vertebral body and intervertebral disc, as well as the anterior longitudinal ligament. Injuries with incompetence of two or three columns are inferred to be unstable. The three-column theory applies to the thoracolumbar spine only.

ii. Management principles

As described above, initial management of the unstable spine consists of immobilization of the injured vertebral segment while the patient is being stabilized and other injuries are being ruled out. After this initial phase, management decisions are generally based on three factors:

aa. Need for decompression of neural elements.

General indications for neural decompression will be discussed in the next section. It is important to consider that, in some cases, decompressive procedures may further destabilize the unstable spine or render the stable spine potentially unstable.

bb. Need to mobilize the patient as soon as possible.

Some unstable spinal injuries may be potentially treatable with prolonged bed rest. However, by avoiding prolonged periods of bed rest, early surgical stabilization of the unstable spine may help to prevent atelectasis, pneumonia, deep venous thrombosis, and decubiti. In addition, early stabilization allows the patient to begin rehabilitation earlier, potentially reducing the complications of joint contracture and deconditioning, as well as potentially reducing time off work.

cc. Need to stabilize the spine that is not likely to heal without surgical intervention.

In general, injuries that are not likely to heal include those with widely displaced fractures, unreduced or unreducible dislocations, severe deformity, or severe ligamentous injury. Also include in this group are injuries which have been treated with prolonged bed rest or bracing which have not healed correctly.

Surgical stabilization has two components. The first component is arthrodesis, or fusion. The goal of fusion is to induce adjacent vertebrae above and below the injury to heal together into a solid block of bone, eliminating any potential movement between them. This usually involves placement of bone graft between

the vertebrae. Bone graft may be placed anteriorly, between adjacent vertebral bodies, or posteriorly, between adjacent laminae, facets, or transverse processes.

The second component of surgical stabilization involves internal fixation (instrumentation). This provides immediate strength and maintains anatomic alignment during the time it takes for fusion to occur. Internal fixation usually involves the implantation of some combination of wire, hooks, screws, and/or rods. Internal fixation is not a substitute for fusion. A general principle is that all internal fixators will eventually fail if fusion does not occur.

d. Understand management principles in spinal cord injury including indications for decompressive surgery and treatment of the medical complication associated with cord injury (skin, bladder, bowel movement, respiratory)

i. Indications for surgery

The most compelling indication for decompressive surgery in spinal cord injury is the presence of an incomplete neurologic injury with persistent neural compression at the site of injury. Compression may be due to indriven bone fragments, traumatic disc herniation, epidural hematoma, or persistent vertebral malalignment. While there is currently debate regarding the most appropriate timing of decompression in the presence of a stable neurologic examination, most clinicians agree that it should be done emergently in the presence of a rapidly declining neurologic examination.

The goal of decompressive surgery is restoration of a normal spinal canal without additional injury to the neural elements. This, in theory, will facilitate neurologic recovery. A review of the most common causes of neural compression reveals that most are ventral processes. Therefore, technically demanding ventral decompressive procedures are frequently necessary. As has been previously stated, these procedures may further destabilize the unstable spine or render the stable spine potentially unstable.

ii. Treatment of medical complications associated with cord injury

aa. Skin:

Patients with spinal cord injury are at particular risk for skin breakdown due to inability to sense pain and prolonged periods of bed rest. This may be further aggravated by incontinence and the necessity of wearing an orthosis. All insensate regions should be surveyed regularly. While in bed, spinal cord injured patients should be turned every two hours. Bony prominences (sacrum, heels) should be protected. Shearing forces, which frequently occur during transfers, should be avoided. Bowel and bladder dysfunction should be treated accordingly as described below. All orthoses and wheel chairs should be fitted appropriately and adjusted to accommodate weight loss or gain.

bb. Bladder:

Patients with spinal cord injury frequently suffer from some form of urinary bladder dysfunction. This may manifest as a lower motor neuron bladder with overflow incontinence and urinary retention. Alternatively, an upper motor neuron bladder may be present with incontinence and reduced bladder capacity. In either instance, the goals of treatment are to maintain a functional lower urinary tract free

of infection and to preserve renal function. As has been described above, the initial treatment of urinary bladder dysfunction is usually placement of an indwelling urinary catheter. After the acute period, sterile, intermittent catheterization is preferable to the long-term use of an indwelling urinary catheter. Intermittent catheterization should initially be performed every 4 hours and urinary volumes should not be permitted to exceed 450cc. If possible, patients may be taught to perform self-catheterization. Renal function should be closely monitored long-term.

cc. Bowel movement:

Patients with spinal cord injury also frequently suffer from some form of bowel dysfunction. The goals of management are for the patient to be free of incontinence and to develop a predictable bowel routine without fecal impaction. Patients with lower motor neuron bowels frequently require manual removal of feces. Those with upper motor neuron bowels may require daily digital rectal stimulation or suppositories. Adequate daily fluids and fiber intake facilitate development of a bowel routine. Diarrhea may be due either to excessive laxative intake or fecal impaction.

dd. Respiratory:

All trauma patients are susceptible to atelectasis and pneumonia during the acute phase. This is especially true in the patient with concomitant traumatic brain injury. Incentive spirometry should be instituted early in treatment. If the patient is not able to participate, consideration should be given to the use of intermittent positive pressure breathing (IPPB).

Additional problems arise in the spinal cord injured patient. The phrenic nerve is supplied by the C3, C4, and C5 roots. Patients with a C4 or higher level of injury most often require placement of a tracheostomy and the assistance of a ventilator. Patients with a C6 or higher level of injury will require some assistance with cough and clearing of secretions. Patients with a low cervical or thoracic level of injury remain at higher risk for atelectasis, pneumonia, and respiratory failure, despite normal phrenic nerve function, due to dysfunction of the intercostal musculature. All should be started on incentive spirometry, as well as exercise programs to increase strength in the remaining muscles of inspiration. Prophylactic clearing of secretions should be encouraged.