Approach to Spinal Cord Injury

Habib Emil Rafka, Dr. Paul Shu, and Dr. Fraser Henderson Jr.

Background:

The best outcomes from management of traumatic spinal cord injury are achieved with expedient and appropriate management. These patients, predominantly young and male, present after traumatic events such as motor vehicle collisions and falls. A spinal column injury might be one aspect of poly-trauma and its management must be prioritized as soon as cardiopulmonary stability is achieved.

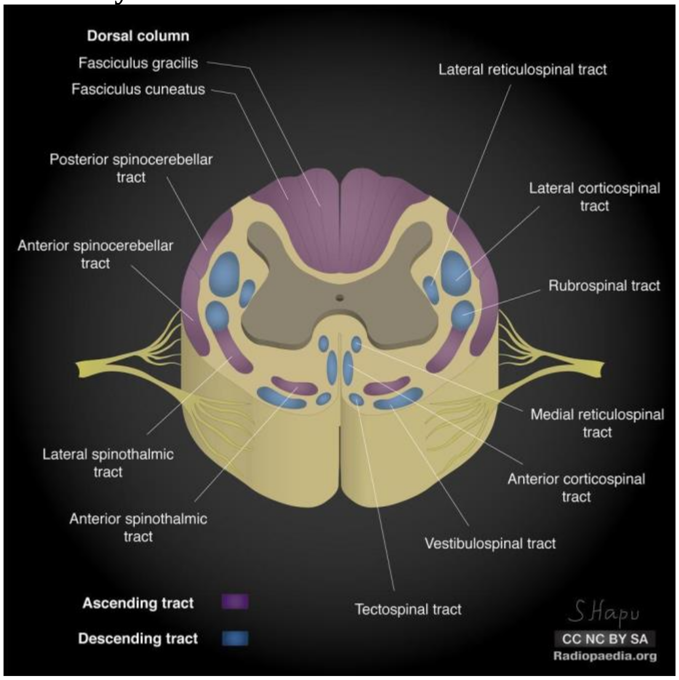
Current understanding of spinal cord injury recognizes both the primary injury (the trauma itself) and the secondary injury (damage occurring after the trauma itself). Primary spinal cord injury is the initial damage done to the spinal cord, most commonly due to physical, traumatic stress. Secondary spinal cord injury is understood to occur from the delayed and harmful inflammatory response that can itself cause further neurological damage. Decades of research have sought to block this cascade, though sadly no definitive treatment has been found. High-dose steroid protocols have helped in occasional situations, though clinical trials have largely remained disappointing. Steroid use is no longer standard for spinal cord injuries in most management guidelines.

Primary spinal cord injuries might result from impact, laceration, hyper-flexion or -extension, or ongoing compression. An efficient but thoughtful neurological exam remains critical for the managing surgeon because the clinical presentation will result from the specific level and the specific part of the spinal cord that is involved. There are several syndromes of paraplegia, hemiplegia, quadriplegia, sensory deficits, loss of bowel control, sexual dysfunction, and others that will be recognized by an astute surgeon and can localize to the level of injury. Imaging can then confirm the diagnosis.

Because international guidelines generally assume a high-resource setting, we must often modify our approach in lower resource settings. In this chapter we will aim to address:

- Inconsistent availability of advanced imaging
- Shortage of material resources such as cervical neck braces, ventilators, halo reduction vests, Wells-Gardner tongs, etc.
- Delayed presentation
- Patients without funds
- Theater and nursing staff limitations, team fatigue and burnout

Anatomy:



A cross-sectional image of the spinal cord, highlighting important anatomical structures. Source: [*https://doi.org/10.53347/rID-53264*](https://doi.org/10.53347/rID-53264)

A *stable* spine is one that can protect the neural elements (cord and nerve roots) within the physiologic range of normal human motion. An *unstable* spine, therefore, has lost the ability to protect and encase the neural elements in their journeys from the skull to the vertebral foramina at each level.

33 vertebrae occur in the human spine: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and about 4 coccygeal. The Greek root for *vertebra* is *"spondylo"* which explains why we often refer to *spondylosis* or *spondylo-listhesis* (vertebral slip). The vertebral bodies anteriorly stack upon one another, held in place by interlocking portions called *facets*. Facets articulate to permit some movement; the cervical spine is relatively mobile in flexion and rotation, the thoracic spine is limited mostly to rotation, and the lumbar spine is limited mostly to flexion. The *pars* is the portion of bone connecting superior facets to inferior facets. Transverse processes extend posterolaterally, forming joints with the rib cage in the thoracic spine. *Pedicles* separate the anterior bodies from the posterior bony

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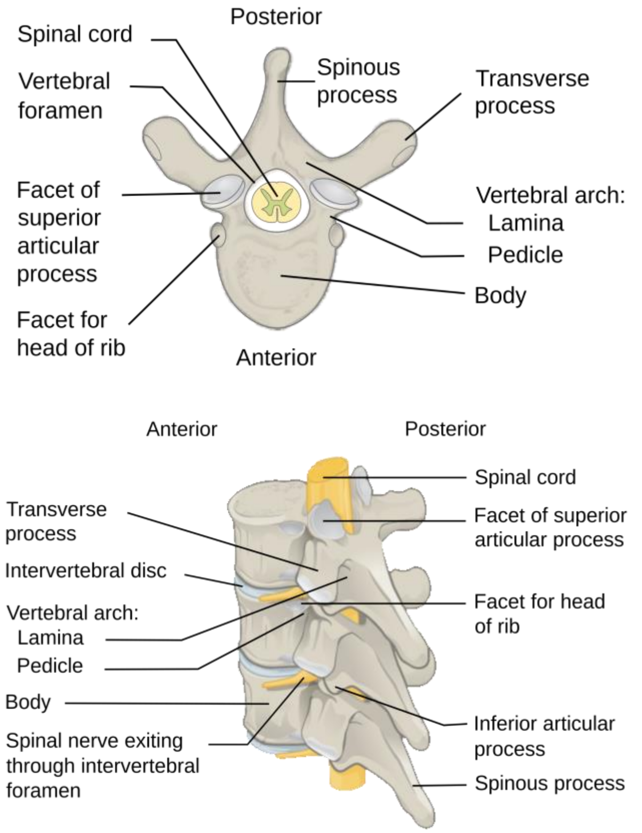
surfaces called *laminae*, and thereby forming the spinal canal, a hollow channel in which the tube-like *dura* runs. Posteriorly a spinous process protrudes at the midline, forming the part we can palpate as when performing lumbar punctures or massage. Over these spinous processes runs the supraspinous ligament which contributes to stability. Damage to any part of this anatomy that permits non-physiologic extension, stretch, compression, etc. will lead to a neurologic deficit in the affected territory.



Superior (Top) and posterolateral (Bottom) views of the components of the vertebrae. Source: Jmarchn, CC BY-SA 3.0 via Wikimedia Commons [*https://commons.wikimedia.org/w/index.php?curid=45613313*](https://commons.wikimedia.org/w/index.php?curid=45613313)

The vertebral column has a natural lordosis in the cervical and lumbar region and a natural kyphosis in the thoracic region. Between each vertebra is a cartilaginous, poorly vascularized intervertebral disk that acts as a natural cushion to distribute forces evenly.

The Human Spine, aka, Vertebral Column. Note the natural cervical and lumbar lordosis and thoracic kyphosis. When intact, the many articulating joints allow the complex mobility of the spinal column.

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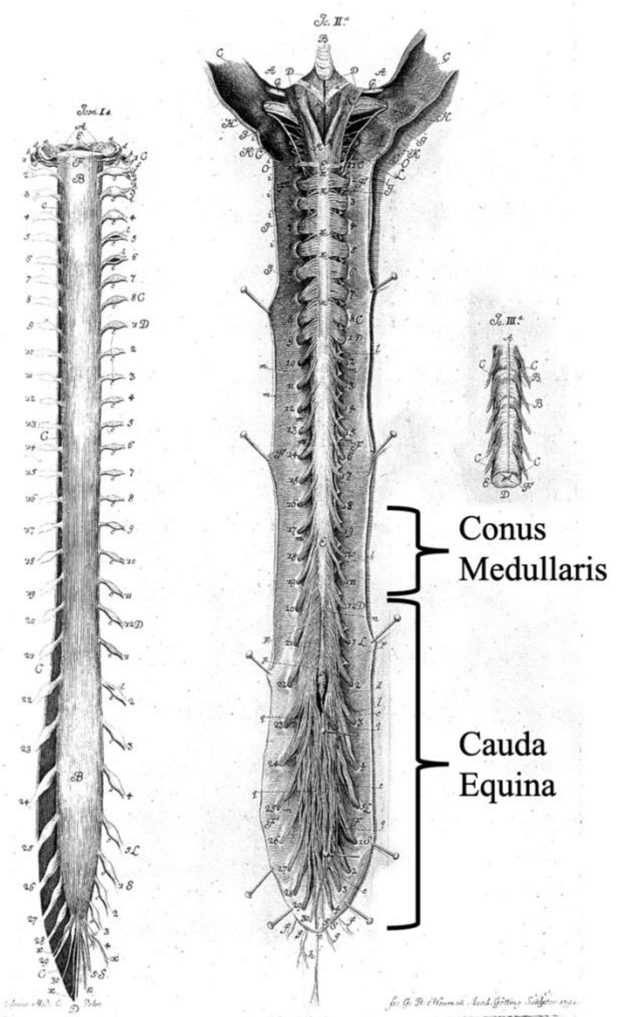


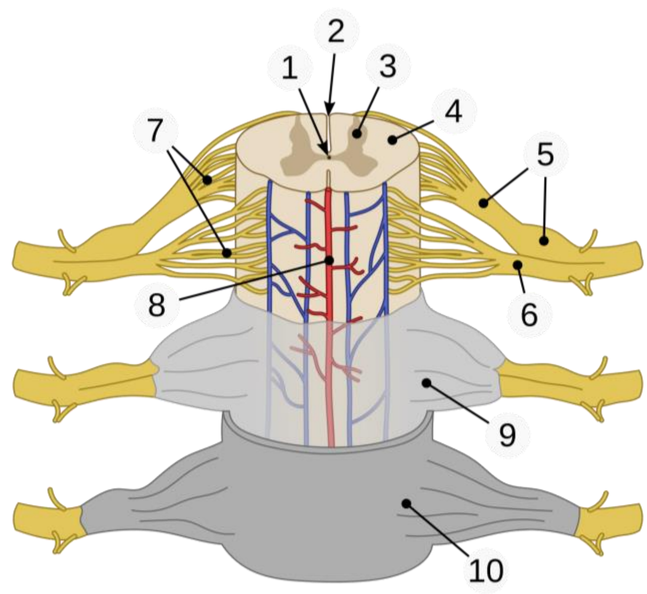
Left: Image of the extradural spinal cord with nerve roots. Right: intradural view of the spinal cord with associated nerve roots piercing the dura. The cauda equina, a collection of nerves described below, is seen below the conus medullaris, the inferior most extent of the spinal cord. Source:CC BY 4.0 https://creativecommons.org/licenses/by/4.0 via Wikimedia Commons

The spinal cord emerges from the brainstem and continues down through the cervical and thoracic vertebrae to ultimately end at the L1/L2 vertebrae where it is called the *conus medullaris*. Below the level of L1/L2, a collection of nerve roots called the *cauda equina* (because the many nerve roots resemble the fibers of a horse's tail) float in cerebrospinal fluid within the *thecal sac* (aka, *dura*).

Each spinal level has its own paired spinal nerves exiting below the pedicle of that respective level (L2 spinal nerve exits below the L2 pedicle), except for the cervical level, where the spinal nerves exit above the respective vertebrae. Note: although there is no C8 vertebra, the C8 *nerve* exits between the C7 and T1 vertebra.

The spinal cord is surrounded by three meningeal layers: *dura*, *arachnoid*, and *pia*. Blood, pus, or external penetrating foreign bodies typically cause meningeal inflammation which can be quite painful. Infection within these layers can travel up from the spine to the brain; meningitis should be considered after penetrating trauma with a dural leak if prompt infectious precautions have not been taken. The spinal cord is a complex organ with a plethora of functions at each level – hence the various presentations of spinal cord injury. Given the structure of the anatomy and the tight space in which the spinal cord resides, a spinal cord with ongoing compression and some preserved neurologic function should be surgically decompressed emergently. If there are spinal injuries, a specialist should make an assessment of "stable" versus "unstable." Stabilization of the unstable spine with internal or external bracing is essential to maximize the opportunity for a good outcome.

Although spinal cord and column anatomy can be complex and overwhelmingly intricate, there are simple fundamentals that every surgeon can remember.



A cross section view of the spinal cord within the vertebral canal, ventral is anterior in this picture. 1. the central canal, 2. posterior median sulcus, 3. gray matter, 4. white matter, 5. Left dorsal root and dorsal root ganglion 6. Left ventral root 7. Right fascicles 8. Anterior spinal artery 9. Arachnoid mater 10. Dura mater. Source: Tomáš Kebert & umimeto.org, https://creativecommons.org/licenses/by-sa/4.0

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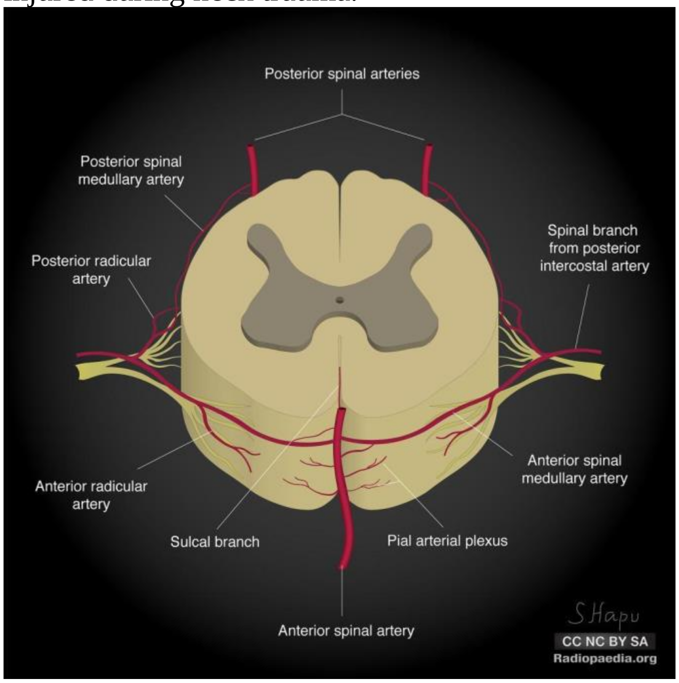
The anterior spinal artery runs midline from the junction of vertebral arteries at the foramen magnum and travels down the entirety of the spinal cord before ending at the conus medullaris. The vertebral arteries pass through the transverse processes of the cervical spine at C6 - C2 and can be injured during neck trauma.



An illustration showing the relationship of important vasculature of the spinal cord, ventral is anterior in this picture. Injury to any of these arteries can cause a stroke at the respective spinal level. Anastomoses in the mid- and lower-thoracic spine make it vulnerable to ischemia from hypotension or aortic dissection. Source: Hapugoda S, Spinal cord (illustrations). Case study, Radiopaedia.org [*https://doi.org/10.53347/rID-54777*](https://doi.org/10.53347/rID-54777)

Principles:

Begin your evaluation of the injured patient with a primary survey. The goal of this is to identify rapidly life-threatening injuries to ensure cardiopulmonary stabilization. Like the brain, the spinal cord can suffer irreversible damage with prolonged hypoxia.

A. **Airway and Cervical spine immobilization**: Confirm airway patency. Assign a quick Glasgow Coma Score (GCS) and alert the team to intubate the patient with GCS of 8 and below. Immobilize the cervical spine in all patients in whom you cannot clearly rule out a cervical spine injury. Though airway management can be the primary concern, do not exacerbate a concurrent cervical spine injury by careless manipulation.
B. **Breathing**: Ensure adequate ventilation and air entry in the chest to rule out hemothorax, pneumothorax, tamponade, and other immediately life-threatening thoracic injuries.
C. **Circulation**: Obtain hemodynamic stability. Note that hypotension may not always be associated with bleeding. Spinal cord injury could present with neurogenic shock which presents as hypotension from loss of sympathetic tone. Recognizing hypotension caused by spinal cord injury is discussed further below.
D. **Disability**: To test for disability, you must complete a neurologic exam as discussed below.
E. **Exposure/Environment:** Evaluate other potential injuries, taking note of the environment from which the patient came, and taking note of any other hazardous exposures.

After the primary survey, move on to the secondary survey. The mnemonic for secondary survey is AMPLE: **A**llergies, **M**edications, **P**ast illness, **L**ast meal, and **E**vents. This history is usually taken from the patient's caretaker if the patient is unconscious.

Neurologic examination consists of checking strength, assessing sensation at each limb and if necessary, discerning the particular level where sensation is lost, and examining reflexes. Motor strength is graded by muscle group from 0 (no strength) to 5 (full strength); a grade of 3 indicates only anti-gravity strength, 4 means there is some resistance. Unilateral motor deficits affecting both arm and leg on one side should point towards a *brain* injury. Note that *hemiplegia* refers to complete weakness 0/5 whilst *hemiparesis* implies some strength is preserved. Conversely, bilateral leg weakness (*paraplegia* or *paraparesis*) as well as the combination of bilateral arm and leg weakness (*quadriplegia* or *quadriparesis*) are more likely to be associated with spinal cord injury.

Spinal shock is loss of all or most of motor and sensory function immediately following a severe spinal cord injury. Flaccid paralysis, anesthesia, and loss of reflexes all occur, including loss of the bulbocavernosus reflex. The management is usually nonoperative. *Neurogenic shock* occurs in the same

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population but refers to the vascular phenomenon of peripheral vasodilation resulting from the loss of sympathetic tone (such as lesions above T6) and unopposed parasympathetic activity. Neurogenic shock is characterized by hypotension, bradyarrhythmia, and temperature dysregulation. This life-threatening condition requires intensive care for volume support and often pressors. Because phenylephrine may incite reflex bradycardia, norepinephrine is the preferred agent to maintain the mean arterial pressure of patients with neurogenic shock at 85-90mmHg for at least the first seven days.

Syndrome: Complete Cord Transection

Causes:	Clinical Findings:
• Trauma • Infection • Transverse Myelitis • Abscess • Tumor	• Complete loss of sensation below level • Complete paralysis below level

Syndrome: Cord Hemisection

Causes:	Clinical Findings:
• Trauma • Multiple Sclerosis • Tumor • Abscess	• Ipsilateral loss of motor, proprioception • Contralateral loss of pain, temperature

Syndrome: Central Cord Syndrome

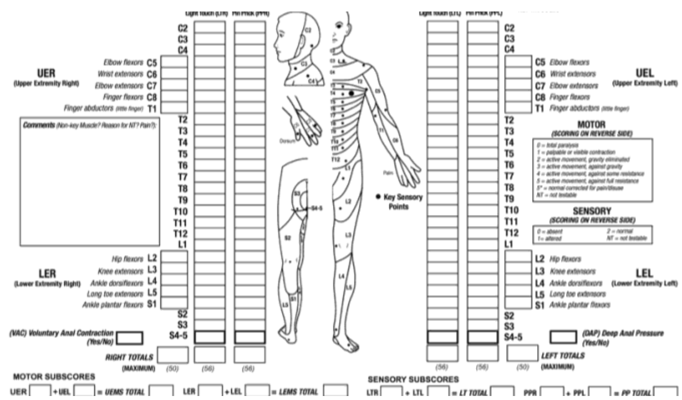
Causes:	Clinical Findings:
• Neck hyperextension • Spinal Stenosis • Osteoarthritis • Syringomyelia • Tumor	• Motor impairment > sensory impairment • Upper extremities > lower extremities • Distal > Proximal • Bladder dysfunction • "Cape-like" distribution of pain and sensory loss

Syndrome: Anterior Cord Syndrome

Causes:	Clinical Findings:
• Hyperflexion • Disc protrusion • Anterior spinal artery occlusion • Abdominal aortic aneurysm	• Motor function loss • Pain and temperature loss • Proprioception spared

Cauda Equina Syndrome

Causes:	Clinical Findings:
• Disc prolapse • Tumor • Infection	• Bladder and bowel dysfunction • Saddle anesthesia • Sexual dysfunction



Spinal cord injury diagnosis can be made from clinical examination and confirmed on imaging. The most thorough tool is called the ASIA Impairment Scale. The ASIA "level" refers to the lowest spinal cord segment with *preserved/normal* *function. A full-size copy of this worksheet is provided at the end of this chapter. Source:* *https://asia-spinalinjury.org/wp-content/uploads/2019/04/ASIA-ISCOS-IntlWorksheet_2019.pdf*

Sensation travels to the thalamus of the brain through several types of nerves bundled into different parts of the spinal cord. Therefore, examination should include testing for both *light touch/vibration* (posterior columns) and also *pain/temperature* as with a safety pin or sharp object (anterior and lateral spinothalamic tracts). Presence or absence of sensation, whether temperature, fine touch, or position and vibration sense can help you determine the type of incomplete spinal cord syndrome as shown above. Sensation from the sacral area is the most likely to be preserved because it travels in the most *lateral* part of the sensory tract

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(“sacral sparing”) and is therefore most resistant to traumatic stretch injury which affects central fibers foremost.

Reflexes must be examined. Levels below a spinal cord injury will exhibit increased reflexes, whereas reflexes will be decreased if the respective nerve root is injured. This is because in a normal patient the brain is constantly sending inhibitory signals to reflex synapses; if the brain signal is interrupted along its path down the spinal cord, the reflex synapse is no longer tonically inhibited, and the reflex becomes more brisk or even clonic. However, a peripheral nerve root injury will decrease the reflex because the reflex arc is directly injured. Recall that a patient in spinal shock will have loss of all reflexes: this condition may persist hours to days and rarely for weeks.

Cervical spine injuries are more associated with mortality especially if the C3-C5 cervical vertebrae are involved; this is where the phrenic nerve arises, supplying the diaphragm.

Some basic landmarks for sensory loss are:

- Loss of sensation below the umbilicus indicates a lesion at the T10 level.
- Loss of sensation below the nipple in men, or the inframammary fold in women, indicates a lesion at the T4 level.

In the absence of “spinal shock,” if complete loss of sensation and motor function is found, recovery is unlikely, and therefore emergent surgery may be a waste of resources as recovery of function is unlikely even after surgery; long term external bracing may be a better use of resources depending on the context.

Cauda equina syndrome refers to an injury pattern. Consider it with patients who present with some of the following components, especially if the symptoms are progressing:

- Bilateral leg weakness
- Urinary incontinence
- Loss of sphincter control
- Sensory loss around the perineum and anus

Refer these patients promptly for imaging to assess for severe compression of the lumbar nerve roots and the need for emergent decompression.

The pre-hospital management of these patients is universal- it begins with immobilization of the neck and primary and secondary surveys as described above. The neck should be immobilized with a hard collar at the scene and the patient should be maintained supine. Transportation to the hospital should be done with a hard board unto which the patient is logrolled.

Ideally, a cervical collar is applied at the scene before the patient is moved, and the patient is transported on a backboard. Source: Baedr-9439, CC0, via Wikimedia Commons

If a neck collar is not available at the scene but a hard board is, the patient’s head can be secured to the board using tape to prevent movement of the head, hence immobilizing the spine.

Imaging is an important adjunct to the diagnosis of spinal cord injury. This is especially true for unconscious patients. These include plain x-rays, CT scan and/or MRI. Contrast is usually unnecessary for trauma situations. The National Emergency X-Radiography Utilization Study (NEXUS) criteria and the Canadian C-Spine Rules are important concepts to keep in mind when contemplating imaging for spinal cord injury.

According to the NEXUS criteria, cervical spine injury should be considered if there is:

- **N**eurological deficit
- **S**pinal tenderness
- **A**lternated mental status
- **I**ntoxication
- **D**istracting injury.

This can be remembered with the mnemonic “**NSAID**.” Traumatic patients that would not need spine imaging require ***all*** of the following:

- Alert and stable

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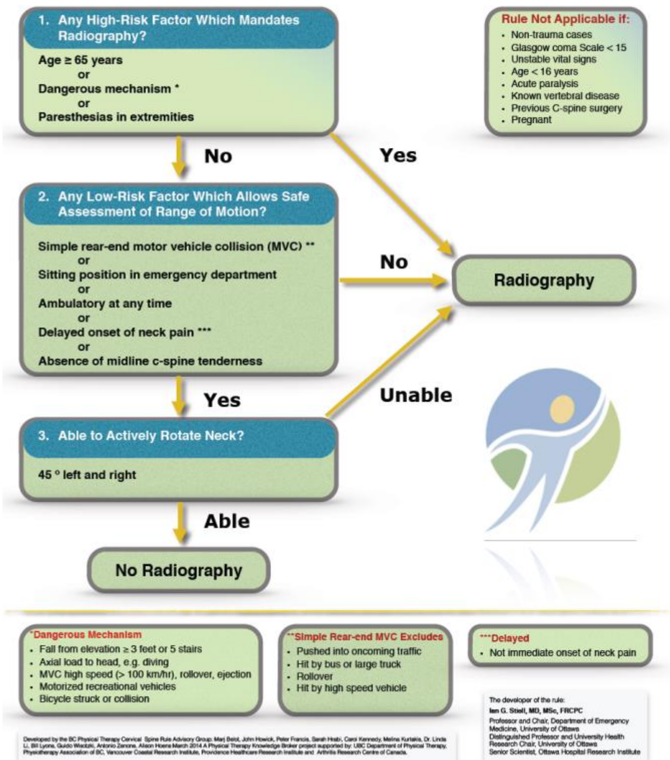
- No focal neurological deficit
- No altered level of consciousness
- No intoxication
- No midline spinal tenderness
- No distracting injury

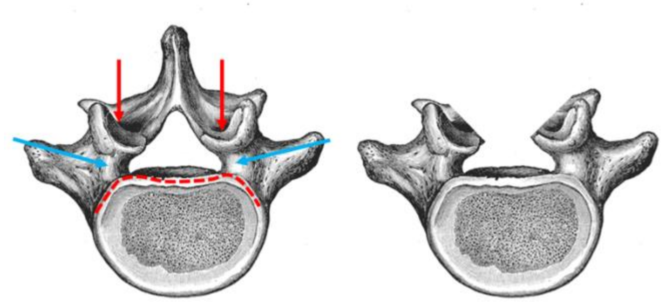
The Canadian C-Spine Rule, shown below, also offers an intuitive algorithm to think through whether imaging is required.



A flow-chart highlighting the Canadian C-spine rule Source: [*https://www.physio-pedia.com/Canadian_C-Spine_Rule*](https://www.physio-pedia.com/Canadian_C-Spine_Rule)

Any unconscious or intoxicated patient with a mechanism of injury suggestive of neck injury should get imaging studies. In resource-rich settings, a CT scan of both the head and the cervical spine without contrast is usually performed. For conscious patients, a midline tenderness, focal neurological deficit, and any distracting injury is an indication for imaging. In areas where there is no CT scan, an Xray series should be ordered even though it is more likely to miss non-bony injuries compared to a CT scan.

In-hospital management includes medical and sometimes surgical management. Triage patients and diagnose neurogenic shock versus hemorrhagic shock. Hemorrhagic shock is usually associated with tachycardia and hypotension, unlike neurogenic shock which has just hypotension and sometimes bradycardia. Support the cardiovascular system with fluid resuscitation and then pressors for neurogenic shock as necessary to adequately maintain mean arterial pressure 85-90. Guidelines no longer support high dose steroids for acute spinal cord injury because of the adverse side effects, even though it may improve recovery in younger patients with some motor preservation. Immobilize the neck if ligamentous or bony injury (not requiring surgery) is suspected. Halo traction, when available, may prevent the need for open internal fixation of the spine in some cases. Surgery may apply an anterior or posterior approach depending on the pathology and the instrumentation available. Chronic spinal cord compression can be relieved by simple laminectomy provided that the neck retains a natural lordosis and not a kyphosis, in which case instrumented fusion would be warranted.



Laminectomy decompresses the spinal canal by removing its "roof," the lamina and spinous process. Essential structures such as the intervertebral facet joints (Red arrows) are preserved. Diskectomy can also be performed if disc rupture and herniation passes beyond the dotted Red line and compresses the spinal canal or the nerve roots passing through the neural foramina (Blue arrow.)

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Approach to Spinal Cord Injury

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A halo vest provides complete immobilization of the neck during the healing period. Source: BruceBlaus, CC BY-SA 4.0 via Wikimedia Commons

In-hospital management also involves the prevention of complications associated with spinal cord injuries. Complete spinal cord injuries of the cervical spine ultimately lead to death because of the many complications that can occur including respiratory failure, pneumonia, urosepsis, pulmonary embolism, and pressure sores. Intensive nursing measures like turning the patient, clean intermittent catheterization, aggressive respiratory toilet, and prevention of deep venous thrombosis can be taught to family/caregivers.

Rehabilitation including the above measures will be a patient's best chance to regain function. Exercises can be started in-hospital and physiotherapy should be involved with spinal cord injury from the first day of hospitalization.

Decision Making:

The decision making of these patients starts with first contact. After ruling out or addressing all life-threatening conditions and the pattern of injury determined, referral is a key decision in the management of these patients. Patients with incomplete spinal cord injuries with no other life-threatening condition, those with worsening spinal cord injury on repeated exams or those with cauda equina syndrome should be referred to a spine specialized center immediately since early surgery is associated with better recovery compared to those with complete injury. Cervical spine injuries are more delicate to handle. Patients with cervical fractures especially C1 and/or C2 fractures with greater than 7mm displacement should be referred for operative management. Others may benefit from halo traction or rigid neck collar. A decision to operate or not depends on the availability of a competent surgeon and the patient's overall status.

Complication Avoidance and Considerations Specific to Low Resource Settings

Surgeons in low resource settings must occasionally develop and apply unique solutions for spinal cord injury patients. The authors recognize the absurdity of applying the same standard of care across all global settings. In the authors' experience, however, the spine injury patient population in low-resource settings are otherwise young and previously healthy, meaning that remarkable recoveries can be observed. This is particularly true when injuries are addressed promptly and when complications are avoided. For example, tuberculosis infection of the spine remains rampant and presents late in the disease, but it can often be treated successfully with a combination of medications and surgical decompression and fusion or bracing.

In settings without available instrumentation, plaster casting of the cervical spine or thoracolumbar junction can brace fractures while they heal or while a patient is transported to a facility for definitive treatment: https://www.neurosurgeryglobal.com/cases-videos/cervical-spine-injuries

Centers without the equipment for spinal instrumentation should search for international partners to help expand the scope of their services. Institutional competition or a surgeon's pride should never prevent a physician from seeking external advice in patient management, or from transferring a patient who would be better served at another institution.

When surgery is undertaken, complications must be fastidiously avoided because in low-resource settings, patients can rarely afford the first surgery, much less a second surgery for resolving a

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complication. Appropriate infection control measures must include complete sterile technique, double-gloving, and copious intraoperative irrigation. For example, the authors utilize a diluted solution of povidone to irrigate wounds before closure in every case, and vancomycin powder can be sprinkled in wounds.

Fusion surgeries require three properties for bones to fuse properly: osteoinduction, osteogenesis, and osteoconduction. If you do not have bone allograft options for osteoconduction, fusion cases must rely on autograft from separate incisions for harvesting of rib or iliac crest bone. Bone marrow aspiration through a sterile Jamshidi needle from the iliac crest can enhance osteogenesis and osteoinduction. Gentle decortication should be performed using a drill on adjacent surfaces of bone where a fusion is desired. Antibiotics must be given at the time of anesthesia induction and re-dosed accordingly during the surgery. Placement of a sub-fascial surgical drain at the end of surgery can decrease postoperative fluid accumulation, thereby relieving pressure on the healing wound and providing further insurance against a post operative infection. The drain is tunneled to exit at least 5 cm from the surgical incision and removed promptly when the drainage decreases. Data from high income countries remains mixed on the use of routine drains for spinal surgery. However, in our experience the lack of robust hemostatic agents, occasional lapses in sterility, and higher ratio of patients to nurses inhibiting administration of pain medication favor routine use of a subfascial drain. Of course, this must be weighed against the expense and availability of surgical suction drains at a particular institution. And drains should never be put to suction when the dura has been compromised or a cerebrospinal fluid fistula will develop. Compressive stockings can be obtained cheaply and may be a cost-effective method for deep venous thrombosis prevention in high-risk patients, especially where pharmacological prophylaxis is unavailable.

The importance of close follow-up must be explained to patients so that postoperative complications can be recognized and addressed quickly. For conservatively managed injuries, close clinical and radiological follow-up can also recognize when an unstable kyphosis starts to progress or when a neurologic deficit is worsening.

Finally, all surgeons of the spine must keep excellent records of their cases and outcomes to facilitate their internal reviews and as a source of future research. By sharing experiences and outcomes in journals and at conferences, surgeons will find that many of their challenges have been similar to those of their colleagues, and the data will indicate the superior treatment algorithms.

<u>Resource-Rich Settings</u>

Spinal cord stimulation (SCS) involves implantation of a pulse-generating battery pack connected to epidural electrodes overlying the dorsal horns of the spinal cord. The Gate Control Theory of pain presumes that stimulation of the dorsal sensory columns inhibits perception of pain in the brain.

Neural Stem Cell transplantation is an unproven but exciting area of research that might harness a patient's own neural stem cells and inject them into sites of injury to promote healing, reduce scarring, and decrease painful inflammation.

Habib Emil Rafka
Medical University of South Carolina
USA

Paul Shu MD
Mbingo Baptist Hospital
Cameroon

Fraser Henderson Jr MD
Tenwek Hospital
Kenya

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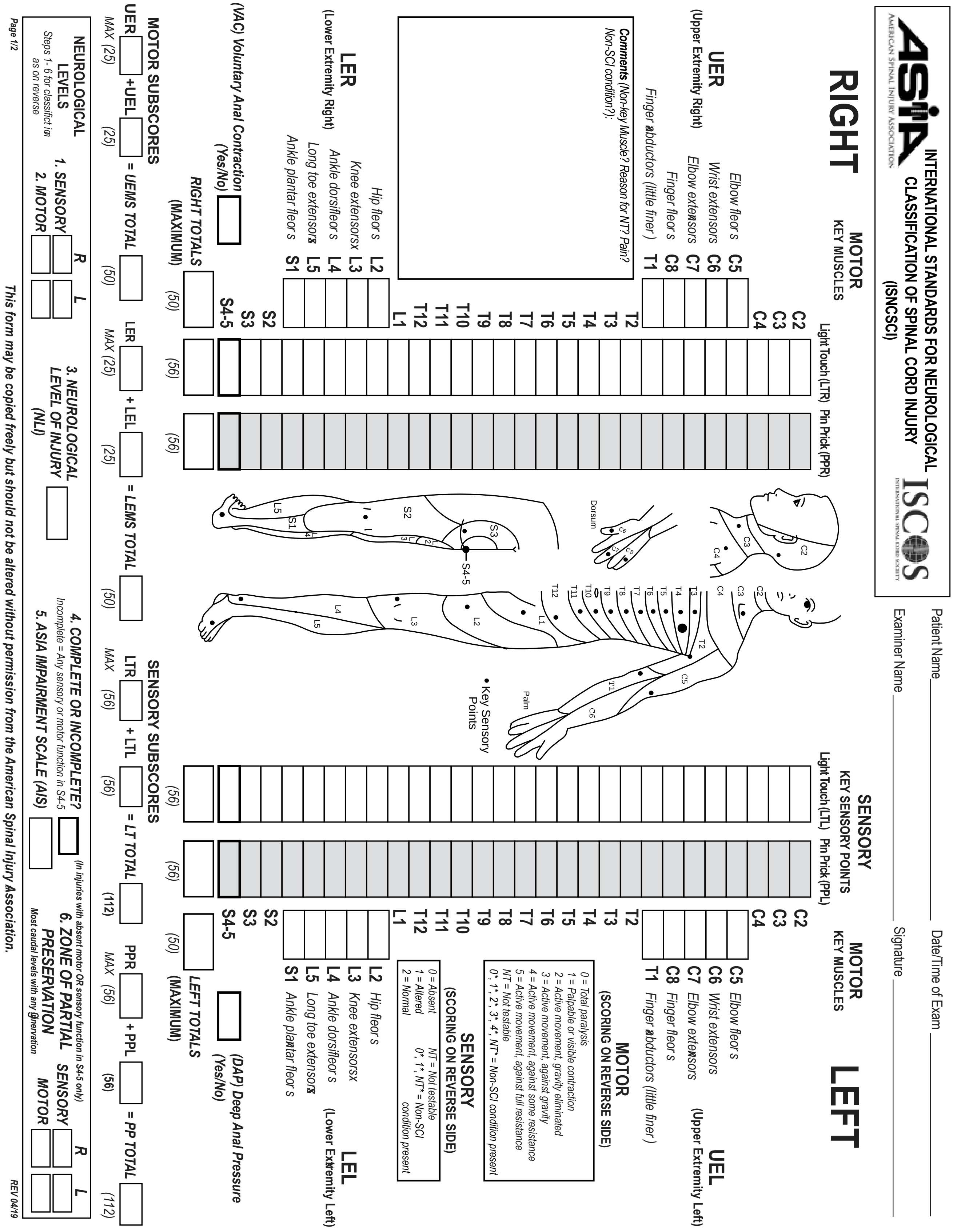

AMERICAN SPINAL INJURY ASSOCIATION

INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)

ISCOS INTERNATIONAL SPINAL CORD SOCIETY

Patient Name ______ Date/Time of Exam ______

Examiner Name ______ Signature ______

RIGHT

MOTOR KEY MUSCLES

SENSORY KEY SENSORY POINTS

Light Touch (LTR) Pin Prick (PPR)

C2
C3
C4

UER (Upper Extremity Right)

Elbow flexors C5
Wrist extensors C6
Elbow extensors C7
Finger flexors C8
Finger abductors (little finger) T1

T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 L1

Comments (Non-key Muscle? Reason for NT? Pain? Non-SCI condition?):

LER (Lower Extremity Right)

Hip flexors L2
Knee extensors L3
Ankle dorsiflexors L4
Long toe extensors L5
Ankle plantar flexors S1

S2 S3 S4-5

(VAC) Voluntary Anal Contraction (Yes/No)

RIGHT TOTALS (MAXIMUM) (50) (56) (56)

LEFT

SENSORY KEY SENSORY POINTS

Light Touch (LTL) Pin Prick (PPL)

MOTOR KEY MUSCLES

C2
C3
C4

C5 Elbow flexors
C6 Wrist extensors
C7 Elbow extensors
C8 Finger flexors
T1 Finger abductors (little finger)

UEL (Upper Extremity Left)

T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 L1

MOTOR (SCORING ON REVERSE SIDE)

0 = Total paralysis
1 = Palpable or visible contraction
2 = Active movement, gravity eliminated
3 = Active movement, against gravity
4 = Active movement, against some resistance
5 = Active movement, against full resistance
NT = Not testable
0*, 1*, 2*, 3*, 4*, NT* = Non-SCI condition present

SENSORY (SCORING ON REVERSE SIDE)

0 = Absent NT = Not testable
1 = Altered 0*, 1*, NT* = Non-SCI condition present
2 = Normal

L2 Hip flexors
L3 Knee extensors
L4 Ankle dorsiflexors
L5 Long toe extensors
S1 Ankle plantar flexors

LEL (Lower Extremity Left)

S2 S3 S4-5

(DAP) Deep Anal Pressure (Yes/No)

LEFT TOTALS (MAXIMUM) (56) (56) (50)

MOTOR SUBSCORES

UER ___ + UEL ___ = UEMS TOTAL ___ LER ___ + LEL ___ = LEMS TOTAL ___

MAX (25) (25) (50) MAX (25) (25) (50)

SENSORY SUBSCORES

LTR ___ + LTL ___ = LT TOTAL ___ PPR ___ + PPL ___ = PP TOTAL ___

MAX (56) (56) (112) MAX (56) (56) (112)

NEUROLOGICAL LEVELS
Steps 1-6 for classification as on reverse

R L
1. SENSORY
2. MOTOR

3. NEUROLOGICAL LEVEL OF INJURY (NLI)

4. COMPLETE OR INCOMPLETE?
Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS)

(In injuries with absent motor OR sensory function in S4-5 only)

6. ZONE OF PARTIAL PRESERVATION
Most caudal levels with any innervation

R L
SENSORY
MOTOR

Page 1/2

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Muscle Function Grading

0 = Total paralysis
1 = Palpable or visible contraction
2 = Active movement, full range of motion (ROM) with gravity eliminated
3 = Active movement, full ROM against gravity
4 = Active movement, full ROM against gravity and moderate resistance in a muscle specific position
5 = (Normal) active movement, full ROM against gravity and full resistance in a functional muscle position expected from an otherwise unimpaired person
NT = Not testable (i.e. due to immobilization, severe pain such that the patient cannot be graded, amputation of limb, or contracture of > 50% of the normal ROM)
0*, 1*, 2*, 3*, 4*, NT* = Non-SCI condition present [a]

Sensory Grading

0 = Absent **1** = Altered, either decreased/impaired sensation or hypersensitivity
2 = Normal **NT** = Not testable
0*, 1*, NT* = Non-SCI condition present [a]

[a] Note: Abnormal motor and sensory scores should be tagged with a '*' to indicate an impairment due to a non-SCI condition. The non-SCI condition should be explained in the comments box together with information about how the score is rated for classification purposes (at least normal / not normal for classification).

When to Test Non-Key Muscles:

In a patient with an apparent AIS B classification, non-key muscle functions more than 3 levels below the motor level on each side should be tested to most accurately classify the injury (differentiate between AIS B and C).

Movement	Root level
Shoulder: Flexion, extension, adbuction, adduction, internal and external rotation **Elbow:** Supination	C5
Elbow: Pronation **Wrist:** Flexion	C6
Finger: Flexion at proximal joint, extension **Thumb:** Flexion, extension and abduction in plane of thumb	C7
Finger: Flexion at MCP joint **Thumb:** Opposition, adduction and abduction perpendicular to palm	C8
Finger: Abduction of the index finger	T1
Hip: Adduction	L2
Hip: External rotation	L3
Hip: Extension, abduction, internal rotation **Knee:** Flexion **Ankle:** Inversion and eversion **Toe:** MP and IP extension	L4
Hallux and Toe: DIP and PIP flexion and abduction	L5
Hallux: Adduction	S1

ASIA Impairment Scale (AIS)

A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.

B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.

C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments S4-5 by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body.
(This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3.

D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.

E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.

Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

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Page 2/2

Steps in Classification

The following order is recommended for determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
The sensory level is the most caudal, intact dermatome for both pin prick and light touch sensation.

2. Determine motor levels for right and left sides.
Defined by the lowest key muscle function that has a grade of at least 3 (on supine testing), providing the key muscle functions represented by segments above that level are judged to be intact (graded as a 5).
Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level, if testable motor function above that level is also normal.

3. Determine the neurological level of injury (NLI).
This refers to the most caudal segment of the cord with intact sensation and antigravity (3 or more) muscle function strength, provided that there is normal (intact) sensory and motor function rostrally respectively.
The NLI is the most cephalad of the sensory and motor levels determined in steps 1 and 2.

4. Determine whether the injury is Complete or Incomplete.
(i.e. absence or presence of sacral sparing)
*If voluntary anal contraction = **No** AND all S4-5 sensory scores = **0** AND deep anal pressure = **No**, then injury is **Complete.***
*Otherwise, injury is **Incomplete**.*

5. Determine ASIA Impairment Scale (AIS) Grade.
Is injury Complete? If YES, AIS=A

NO ↓

Is injury Motor Complete? If YES, AIS=B

NO ↓ (No=voluntary anal contraction OR motor function more than three levels below the motor level on a given side, if the patient has sensory incomplete classification)

Are at least half (half or more) of the key muscles below the neurological level of injury graded 3 or better?

NO ↓ **AIS=C** **YES** ↓ **AIS=D**

If sensation and motor function is normal in all segments, AIS=E
Note: AIS E is used in follow-up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact and the ASIA Impairment Scale does not apply.

6. Determine the zone of partial preservation (ZPP).
The ZPP is used only in injuries with absent motor (no VAC) OR sensory function (no DAP, no LT and no PP sensation) in the lowest sacral segments S4-5, and refers to those dermatomes and myotomes caudal to the sensory and motor levels that remain partially innervated. With sacral sparing of sensory function, the sensory ZPP is not applicable and therefore "NA" is recorded in the block of the worksheet. Accordingly, if VAC is present, the motor ZPP is not applicable and is noted as "NA".

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