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Subject: SPINE TRAUMA AND ACUTE SPINAL CORD INJURY PROTOCOL	
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Purpose: To standardize the management of patients with acute spinal column and spinal cord injuries at NYC Health + Hospitals/Elmhurst (EHC) according to the current literature and guidelines.

Objectives:
1. Establish parameters for the initial management of spine trauma.
2. Establish parameters for the critical care management of spine trauma.
3. Prompt diagnosis of acute spinal column and spinal cord injuries.
4. Prevention of secondary insults to the injured spinal cord.
5. Optimization of spinal cord perfusion following spinal cord injury.
6. Guidelines for definitive decompression and stabilization as necessary.

CONTENT OF DOCUMENT

Patients with acute spinal column trauma or acute spinal cord injury (SCI) sustain the primary insult at the time of the accident. Injuries may be to the osseous or ligamentous portions (or both) of the spinal column and may result in spinal column instability. Spinal cord injury may be associated with or without spinal column injury. Spinal column instability may put the spinal cord, conus medullaris, or cauda equina at risk for initial or secondary insults and injury. Secondary insults and injury to the spinal cord can also result from an inability to maintain adequate spinal cord perfusion and oxygenation sufficient for spinal cord metabolism in the setting of an acute spinal cord injury with edema/swelling.

This protocol has been developed based on evidence-based guidelines and protocols endorsed by the American College of Surgeons (ACS), American Association of Neurological Surgeons (AANS), AOSpine North America (AOSNA), Congress of Neurological Surgeons (CNS), Eastern Association for the Surgery of Trauma (EAST), and the Neurocritical Care Society (NCS), among others. These include:

- ACS Advanced Trauma Life Support (ATLS), 10th Edition

- AOSpine North America (AOSNA) and the Cervical Spine Research Society (CSRS) Clinical Practice Guidelines for the Management of Degenerative Cervical Myelopathy and Traumatic Spinal Cord Injury (2017)
- CNS/AANS Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries (2013)
- CNS/AANS Guidelines on the Evaluation and Treatment of Patients with Thoracolumbar Spine Trauma (2018)
- EAST Guidelines on Cervical Spine Collar Clearance in the Obtunded Adult Blunt Trauma Patient (2015)
- NCS Emergency Neurological Life Support (ENLS) 3rd Edition Spinal Cord Compression Protocol (2016)

Additionally, content and evidence from several book chapters and peer-reviewed articles were included in the formation of this protocol. These are listed in the "References" section of the protocol.

PREAMBLE

Clinical judgment is required during the application of this protocol. As with any protocol, every clinical scenario cannot be foreseen and appropriate treatment of an individual patient may require deviation from the established protocol should the specific circumstances require. The clinical expertise of the treating Neurosurgery, Trauma, Intensivist, and/or Emergency Department (ED) attending(s) necessarily supersedes the protocol in such instances. However, sound clinical justification for protocol deviations are expected.

I. Prehospital Management

A. Patients with suspected acute spinal column or spinal cord injuries should be managed in the prehospital setting according to existing New York City Fire Department (FDNY) and NYC EMS protocols.

B. Specifically, prehospital management should ensure the following until the patient arrives at an appropriate level trauma center for definitive care:

1. Establishment of an appropriate airway, as needed. If placement of an advanced airway is indicated, care should be taken not to hyperextend the neck during placement to avoid secondary spinal cord insult and injury.
2. Maintenance of appropriate breathing or ventilation to ensure adequate spinal cord oxygenation. **Target is $SpO_2 \geq 95\%$**
3. Maintenance of adequate spinal cord perfusion. **Target is SBP $\geq$ 90 mmHg** until arrival at definitive care (with **MAP $\geq$ 85 mmHg** for acute spinal cord injury once accurate mean arterial pressure measurements are established).

4. Restriction of spinal motion per FDNY-EMS protocols, including in-line immobilization with a rigid cervical collar, long spinal board, and spine precautions. If a rigid backboard is used, it should be carefully removed while maintaining in-line restricted spine motion upon arrival at the EHC ED to prevent the formation of pressure ulcers.

II. Emergency Department (ED) Management

A. The initial in-hospital Emergency Department management of a patient with a suspected spinal column or SCI is an extension of the prehospital management with a focus on:

1. **Maintenance of appropriate in-line restrictions** of spinal motion until suspected spinal column or spinal cord injuries are ruled-out.
2. In conjunction with the Trauma Surgery team, resuscitation of the trauma patient, **establishment and maintenance of adequate airway, ventilation, oxygenation, and perfusion** to avoid secondary spinal cord insults and injury.
3. **Prompt neurological assessment** and Neurosurgical consultation for any patient with spinal column trauma or suspected spinal cord injury.
4. **Prompt establishment of a definitive diagnosis**, including cervical spine clearance and radiological evaluation, if needed. These should be done in consultation with the Trauma Surgery and Neurosurgery teams as necessary.
5. **Assessment for additional traumatic injuries** (e.g. polytrauma), including traumatic brain injury, chest and abdominal injuries, extremity injuries, etc. according to existing EHC Trauma protocols.
6. **Initiation of acute medical interventions** as necessary until the patient can be transferred to the ICU, stepdown unit, floor/ward, or operating room, as appropriate.
7. **Disposition of the patient** with a spinal column or spinal cord injury to an appropriate service and setting for definitive care, including transfer of stable pediatric patients to the nearest Level 1 Pediatric Trauma Center (Children's Cohen Hospital-LIJ), if necessary, and approved by the Trauma Medical Director.

B. Restrictions of spinal motion ("Spinal precautions").

1. Patients with a suspected or known spinal column injury or SCI should be kept in a supine position on a firm surface (e.g. hospital stretcher) without undue rotation or bending of the spinal column. **A properly sized and placed rigid cervical collar (e.g. Miami J collar) should be maintained until the cervical spine is cleared.**
2. Rigid cervical collars placed in the pre-hospital setting should be changed to a Miami J cervical collar by the Neurosurgery service when deemed safe and appropriate, as these collars provide superior support and padding.
3. If a patient arrives on a rigid backboard, it should be carefully removed while maintaining in-line restricted spine motion (i.e. "log-rolling") upon arrival at the EHC

ED to prevent the formation of pressure ulcers. Pressure ulcers can begin to develop after even brief periods (< 30 min) of immobilization on a rigid backboard.

4. Patients with suspected spinal column injuries or SCI should be transported and transferred carefully, using standard spinal precautions. If the patient needs to be turned, this should be done while maintaining in-line restricted spine motion (i.e. "log-rolling").
5. For patients requiring head elevation (e.g. concomitant traumatic brain injury, nausea/vomiting, etc.), in-line restricted spine motion should be maintained and the patient placed in a reverse Trendelenburg position until the thoracolumbar spine can be cleared.
6. Special attention should be paid to pediatric patients who have a large head in relation to their body. A flat surface might result in inadvertent flexion of the cervical spine. Pediatric patients need a slight elevation of their trunk (e.g. by placing folded sheets under the body) in order to allow the occiput to lay in a recess and prevent undue cervical flexion.
7. Older (e.g. age >65 years) patients might have a pre-existing kyphotic deformity at the cervicothoracic junction. A supine position on a flat surface may inadvertently leave the head unsupported, resulting in extension and posterior translation of the cervical spine. These patients should have additional support placed under their head (e.g. folded blankets) to maintain their baseline anatomical cervical spine alignment.
8. Closed reduction of a traumatic spine deformity (e.g. children with torticollis) should only be attempted by the Neurosurgery attending. Patients with a traumatic spine deformity should be left in a position of comfort with movement of the spine restricted.
9. If the spinal column is cleared clinically or radiologically (see section on Radiological Evaluation/Spine Clearance) then restrictions on spine motion can be lifted.

C. Resuscitation (ABCs) of the acute spinal cord injury (SCI) patient.

1. <u>Airway/Breathing</u>
   a. **<u>All patients with a complete cervical SCI C1-4 should be considered for early intubation and mechanical ventilation</u>** given the risk of respiratory distress from reduced diaphragmatic and intercostal innervation.
   b. Patients with incomplete or lower spinal cord injuries (C5 and below) have a variable ability to maintain adequate oxygenation and ventilation.
      i. If there is concern for respiratory distress, the patient should be promptly intubated, given the high likelihood of respiratory muscle fatigue and worsening respiratory distress.
      ii. If the decision is made not to intubate, but to observe, then this should be done in a monitored setting with continuous SpO_2 monitoring. If available, non-invasive end-tidal CO_2 monitoring should be used to alert for hypercapnia and impending respiratory collapse.

iii. Cervical SCI patients should ideally be intubated by an experienced provider using a method that minimizes cervical extension and manipulation while maintaining in-line restriction of spinal column motion. These include awake fiberoptic or GlideScope intubation (allows for immediate reassessment of neurological exam after intubation) or asleep/sedated fiberoptic intubation when an awake intubation cannot be performed. Note that some patients may have discomfort, coughing, gagging with awake fiberoptic intubation that may cause them to move their neck involuntarily. As such, GlideScope or sedated intubation may be preferred in some patients.

iv. The rigid cervical collar should remain in place and in-line restriction of spinal column motion maintained during intubation.

v. Administer supplemental O_2 to keep $SpO_2 \geq 95\%$ as needed to ensure adequate spinal cord oxygenation.

2. Circulation

a. **Maintain SBP ≥ 90 mmHg** during initial resuscitation to maintain spinal cord perfusion in patients with a suspected or proven spinal cord injury. Once accurate mean arterial pressure (MAP) readings are available, **MAP should be maintained at ≥ 85 mm Hg for 7 days post-injury** in patients with SCI unless there are absolute/relative contraindications (e.g. active cardiac ischemia, peripheral ischemia, volume overload) in accordance with CNS/AANS guidelines for the management of acute cervical and thoracolumbar spinal cord injury.

i. An arterial line should be placed as soon as feasible for accurate and continuous blood pressure monitoring during the acute phase following SCI.

ii. Intravenous fluids and vasopressors should be used as necessary to maintain MAP targets.

iii. The concept of permissive hypotension in patients with hemorrhage is likely to be detrimental to patients with acute spinal cord injuries as it can compromise perfusion of the spinal cord. Irreversible injury to the nervous tissue can ensue even after a brief transient period (i.e. 10-15 minutes) of decreased perfusion.

b. Neurogenic Shock

i. SCI above a T6 level can cause neurogenic shock via impaired sympathetic outflow to the heart and peripheral vasculature.

ii. Neurogenic shock presents with:
- Hypotension
- Bradycardia or inability to induce an appropriate tachycardia response to hypovolemia
- Warm, dry skin (due to unopposed peripheral vasodilation)

iii. Neurogenic shock can present immediately or even several hours following the SCI (due to progressive spinal cord edema).

- Rule out other causes for hypotension (e.g. hypovolemia, cardiogenic shock, sepsis, etc.) before making the diagnosis of neurogenic shock.
- An arterial line should be placed for accurate and continuous blood pressure monitoring if not done so already.
- **<u>First-line treatment:</u> administer isotonic intravenous fluids to reach a euvolemic status**. Note that hypotonic fluids should be avoided in patients with acute spinal cord or brain injuries given the likelihood to worsen CNS edema.
- **<u>Second-line treatment:</u> Administer vasopressors and/or inotropes as necessary to achieve a MAP ≥ 85 mm Hg and normal cardiac output.**
    a. *Norepinephrine (alpha/beta-agonist):* **preferred agent** as it improves both blood pressure and bradycardia.
    b. *Phenylephrine (pure alpha agonist):* **second-line agent** if norepinephrine is not available or if there is no significant bradycardia. Note phenylephrine may cause or worsen existing bradycardia through reflexive mechanisms.
    c. *Dopamine:* high doses needed for alpha agonism, but has significant beta agonism at lower doses. However, may lead to diuresis worsening hypovolemia.
    d. *Epinephrine (alpha/beta agonist):* high doses needed which may risk mucosal ischemia.
    e. *Dobutamine (beta agonist/inotrope):* can be useful as adjunct, but may cause hypotension in patients not adequately fluid resuscitated.

iv. Maneuvers that stimulate the vagal nerve (e.g. oral or endotracheal suctioning) can cause reflex bradycardia due to unopposed parasympathetic function. Prevent or treat this with intravenous atropine (0.3 mg IVP).

v. For pediatric patients with SCI patients the target SBP is above the 5th percentile for age (SBP ≥ 70 mmHg + [age in years x 2]).

3. <u>Neurological Assessment</u>
    a. A focused neurological exam should be performed prior to intubation, if possible, due to the confounding effects of sedation, paralytics, and induction agents.
    b. If a focused neurological exam is unable to be performed prior to intubation, it should be performed as soon as possible after completion of resuscitation. **Note that hypotension and hypoxia prior to resuscitation may confound the neurological exam.**
    c. The focused neurological exam should focus on:
        i. Assessment of the patient's mental status (including GCS score), particularly in the setting of concomitant traumatic brain injury.
        ii. Pupillary size and reactivity.
        iii. Assessment of midline spine pain or tenderness.

iv. Assessment of motor strength in the main muscle groups of each extremity, with attention to tetraparesis/plegia or paraparesis/plegia, suggesting a severe cervical or thoracolumbar SCI, respectively.
v. Assessment of sensation in the trunk/abdomen and each extremity.
vi. Assessment of perineal sensation (S3-S4 dermatomes).
vii. Assessment via digital rectal exam (DRE) of deep anal pressure (DAP) and voluntary motor contraction (VMC) of external anal sphincter (or presence of bulbocavernosus reflex if sedated/intubated).
viii. Note that it is the clinical assessment of perineal sensation (S3-S4 dermatomes) and presence/absence of DAP and VMC that determines whether a given spinal cord injury is complete (ASIA grade A) or incomplete (ASIA grades B-E).

d. The formal Neurosurgical exam should include documentation of the ASIA SCI grade and neurological level of injury (NLI) in accordance with the American Spinal Injury Association (ASIA) and International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI).

D. Radiological evaluation and clearance of the spine.

1. <u>Craniovertebral Junction and Cervical Spine</u>
   a. Most trauma patients arrive to the EHC ED with a rigid cervical collar or blocks in place. If a spinal column trauma or SCI is suspected, but the patient arrives without a rigid cervical or blocks, these should be instituted (along with in-line restriction of spinal motion as described in Section III.B) until the cervical spine is cleared.

   b. ***ADULT (18 years and older) Cervical Spine Clearance:*** Cervical spine clearance in adults will be according to the existing "EHC/NYS In-Hospital Cervical Spine Clearance Guidelines in Blunt Trauma". Clinical screening decision tools such as the National Emergency X-Radiography Utilization Study (NEXUS) and Canadian C-Spine Rule (CCR) should be used to initially determine which adult patients require radiologic imaging.

      i. <u>Canadian C-Spine Rule (CCR)</u>
         - High-risk factors: age >= 65 years, dangerous mechanism (fall from elevation >3 feet or 5 stairs, axial load to head, high-speed MVA >60 mph or rollover/ejection, motorized recreational vehicles, bicycle collision), parasthesias in extremities
         - Low-risk factors: simple rear-end MVA (excludes high-speed MVA, large vehicle, rollover), sitting position in ED, ambulatory at any time since injury, delayed onset of neck pain, absence of midline C-spine tenderness.

- If any High-risk factor is present, then cervical spine imaging is indicated.
- If no High-risk factor is present, but the patient does not meet criteria of Low-risk injury, then cervical spine imaging is indicated.
- If the patient meets criteria for Low-risk injury, then attempt at clinical clearance may be attempted (rotate neck 45° in each direction without significant pain or neurological symptoms). If patient unable to be clinically cleared, then cervical spine imaging is indicated.

ii. NEXUS suggests that radiological imaging may not be necessary in the absence of all the following criteria:
- N - Neurological deficit
- E - EtOH (alcohol, or other) intoxication
- X - eXtreme distracting injury
- U - Unable to provide history (altered level of consciousness)
- S – Spinal tenderness (midline)

iii. **If imaging is not indicated and the patient is awake, alert, has no significant midline spinal tenderness**, and can actively demonstrate neck movements (rotation of 45° to either side) without eliciting parasthesias or other referable neurological symptoms, the patient may have their cervical spine cleared clinically.

iv. **If imaging is indicated**, CT without contrast from the occiput to T1 with sagittal and coronal reconstructions is the first choice of imaging modality to diagnosis cervical spine injury. If CT is not available for technical reasons or mass casualty scenarios, plain films (XR) from the occiput to T1, including lateral, anteroposterior (AP), and open-mouth odontoid views should be obtained.

v. **Adult patients who are awake and alert and have a normal high-resolution cervical CT scan** can have their cervical spine cleared and rigid hard collar removed. A normal CT scan is one without a fracture (even if a "stable" fracture, as these are associated with a higher incidence of ligamentous injury), subluxation, evidence of disc disruption, cervical canal compromise, facet splaying, or abnormal interspinous widening. Care should be taken in patients with significant neck pain before clearing based on the CT alone. In these cases, consider Neurosurgical consultation and possible dynamic imaging (upright flexion/extension XR) or MRI C-spine within 48 hours of injury. Alternatively, the cervical collar may be continued until the patient is asymptomatic or completes delayed dynamic imaging.

vi. **Adult patients who are obtunded/comatose and have a normal high-resolution cervical CT scan** may have their cervical spine cleared and hard

collar removed. This is based on several studies that have demonstrated that the incidence of significant cervical spine injuries (osseous or ligamentous) with a negative high-resolution CT scan and careful review of all sequences approaches zero. However, care should be taken with this approach in patients with chronic cervical spondylosis/stenosis and a neurological deficit referable to the cervical spine, as they may have traumatic central cord syndrome (a subtype of SCI) without either osseous or ligamentous injury. In such cases, Neurosurgical consultation and an emergent MRI is warranted to rule out a central cord-type SCI.

vii. **Adult patients with a positive cervical CT scan or those with a neurological deficit** referable to the cervical spine should have an emergent/urgent Neurosurgical consultation and remain in the rigid cervical collar.

- Patients with a suspected cervical spinal cord injury or suspicion of highly unstable injury should have an emergent non-contrast cervical spine MRI with fat suppressed (STIR) images obtained unless the patient is too medically unstable to allow for safe imaging, additional imaging would unnecessarily delay emergent surgery/treatment, or in the opinion of the attend Neurosurgeon, additional imaging would be unlikely to alter management or pose an unnecessary risk to the patient (e.g. some ankylosed spine fracture patients).
- If cervical spine MRI with fat-suppressed (STIR) images to assess for spinal cord injury and/or ligamentous injury is indicated, it is best obtained within 48 hours of injury; following this, there is an increase in false negative results for ligamentous injury due to resolution of soft tissue edema. An exception is in the awake and alert patient with an otherwise presumed “stable” spine fracture (e.g. isolated transverse process fracture) that can participate in dynamic imaging (e.g. upright flexion/extension films). These may be obtained in the ED or in a delayed fashion once the patient’s neck pain has subsided to allow for adequate participation.
- Patients with a positive CT C-spine, but without negative dynamic imaging or MRI within 48 hours of injury that excludes associated ligamentous injury, should remain in the rigid cervical collar until ligamentous healing or definitive stabilization.

c. ***PEDIATRIC (less than 18 years old) Cervical Spine Clearance:***

i. Pediatric patients are at increased risk of occult ligamentous and spinal cord injury compared to adults due to biomechanical differences in the immature cervical spine.

ii. While NEXUS and the CCR are not specifically validated for use in pediatric patients, use of NEXUS is acceptable to reduce need for imaging

as its successful use in screening patients less than 18 years of age has been demonstrated.

iii. Additionally, the 2013 CNS/AANS Guidelines may be used to assess the need for cervical spine imaging in pediatric trauma patients:
- Cervical spine imaging is not recommended in children who are 3 years of age or older following trauma and who:
  a. Are alert;
  b. Have no neurological deficit;
  c. Have no midline cervical tenderness;
  d. Have no painful distracting injury;
  e. Do not have unexplained hypotension;
  f. Are not intoxicated.
- Cervical spine imaging is not recommended in children who are less than 3 year of age following trauma and who:
  a. Have a GCS > 13;
  b. Have no neurological deficit;
  c. Have no midline cervical tenderness;
  d. Have no painful distracting injury;
  e. Are not intoxicated;
  f. Were not involved in a motor vehicle collision;
  g. Do not have unexplained hypotension;
  h. Did not have a fall from a height > 10 feet;
  i. Did not have non-accidental trauma as a known or suspected mechanism of injury

iv. Cervical spine radiographs or high-resolution CT is recommended for children who have experienced trauma and who do not meet either set of the above criteria.

v. **If imaging is indicated, pediatric patients <u>should not</u> have their cervical spine cleared based on negative <u>static C-spine imaging</u> alone**. Ligamentous injury is more common than osseous injury in the pediatric population and they have an increased risk of occult instability and SCIWORA (spinal cord injury without radiographic abnormality) in the setting of a negative static CT or XR.

vi. **Pediatric patients who are awake and alert with negative C-spine imaging** should also be evaluated clinically to assess for appropriate range of motion without significant pain and/or eliciting neurological symptoms. If the patient has significant neck pain, dynamic flexion-extension XR should be considered to rule-out a ligamentous injury with hard collar immobilization until adequate imaging or pain subsides to permit clinical clearance.

vii. **Pediatric patients who are obtunded should have a high-resolution CT C-spine obtained. If the CT is negative, an MRI C-spine should still be**

obtained within 48 hours to rule out SCIWORA and/or ligamentous injury. If this cannot be done, the patient should remain in a rigid cervical collar until they regain sufficient mental status to be clinically cleared or dynamic imaging can be obtained. In exceptional circumstances, dynamic imaging can be performed on obtunded patients under fluoroscopy with the Neurosurgery attending present.

viii. **Pediatric patients are at increased risk for atlanto-occipital dissociation (AOD).** Patients who are apneic at the scene should have AOD suspected and careful attention paid to the O-C1 articulating facet joints on high-resolution CT. In these cases, rigid cervical collar placement may inadvertently accentuate the AOD. An O-C1 separation of >4 mm in either coronal or sagittal views on either side is suggestive of AOD.

ix. **C1-2 stability should be assessed by measurement of the atlantodental interval (ADI)**, although additional measurements are acceptable. The ADI should normally be less than 5 mm in children < 8 years old and less than 3 mm in those 8 years or older and in adults.

x. **Pediatric patients with a neurological deficit** referable to the cervical spine should be evaluated with emergent non-contrast cervical spine MRI with fat suppression (STIR sequences) to rule out spinal cord and ligamentous injury.

2. <u>Thoracolumbar and Sacral Spine</u>
   a. The principles for radiological imaging of the thoracolumbar and sacral spine are similar to that of the cervical spine. Imaging is warranted in patients with a neurological deficit referable to the thoracolumbar or sacral spine, significant back pain, palpable deformity, have suffered a significant mechanism of injury, or have altered mental status in the setting of a traumatic injury.
   b. High-resolution CT imaging is preferred, though patients who are neurologically intact with minimal pain may be first evaluated with XR imaging. This is particularly true of awake, alert, and neurologically intact children to minimize unnecessary radiation exposure.
   c. CT chest/abdomen/pelvis studies (including reformatted coronal and sagittal views) can be used in lieu of dedicated spine imaging if there is a low clinical suspicion for an unstable spinal column injury or SCI. This is particularly true in Pediatric patients to minimize radiation exposure. If a spinal column injury is detected, then a dedicated spine CT scan should be considered for increased delineation of the injury at the discretion of the treating physician(s).
   d. Emergent non-contrast thoracolumbar spine MRI is warranted in any patient with a referable acute neurological deficit, high suspicion of SCI, significant spinal canal compromise, or concern for significant instability at the discretion of the treating attending Neurosurgeon, Trauma surgeon, or ED physician.

e. Non-contrast thoracolumbar spine MRI with fat suppressed (STIR) sequences should be obtained within 48 hours of injury to rule out associated ligamentous injury in patients with CT findings suggestive of posterior ligamentous complex (PLC) involvement. Disruption of the PLC is considered when determining if a thoracolumbar spine injury is stable or unstable and is often necessary for surgical decision making. MRI has been shown to influence the management of up to 25% of patients with thoracolumbar spine fractures.
f. Patients who are awake and alert with otherwise stable-appearing minor lumbar spine fractures (e.g. simple anterior-wedge compression fracture, isolated transverse process fracture) may have dynamic (upright flexion-extension) XR in lieu of MRI at the discretion of the treating attending Neurosurgeon.

3. <u>CT Angiogram</u>
   a. Patients with the following cervical spine injuries should have a CTA of the head/neck to assess for blunt cerebrovascular injury (BCVI) or the vertebral arteries based on the Denver criteria:
      i. Cervical spine fracture that involve C1-3
      ii. Transverse foramen fractures
      iii. Cervical spine subluxation
   b. Patients with thoracolumbar or sacral spine dislocations or significantly displaced fractures should have a CTA of the respective anatomical region to assess for aorta or iliac artery injury. This is particularly true in patients with hyperextension (AOSpine Classification B3) thoracolumbar injuries.
   c. Patients with BCVI should be treated according to established guidelines. This usually involves initiation of antithrombotic agents (unfractionated heparin or ASA) once medically feasible. UFH is often preferred in the acute setting as it is reversible. Consultation with the Mount Sinai Hospital Cerebrovascular Service should be highly considered for all BCVI to determine the need for surgical or endovascular repair. Some cases of vertebral artery occlusion from subluxation may be ameliorated with reduction of the fracture.

4. <u>Spine Trauma Classification</u>
   a. **AOSpine Classification:** Documentation of subaxial cervical, thoracolumbar, and sacral spine injury morphology by the Neurosurgery Service in accordance with the AOSpine Classification System should be considered.
   b. **Spinal Cord Injury Classification:** The ASIA SCI grade and neurological level of injury (NLI) should be documented for patients with SCI in accordance with the American Spinal Injury Association (ASIA) and International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) (see Appendix).
   c. **Subaxial Cervical Spine Injury Classification (SLIC) and Thoracolumbar Injury Classification (TLICS) Systems:** These classification systems should be considered for use by the Neurosurgery Service, when appropriate, to aid in

determining the need for non-operative versus operative management of patients with spine trauma.

E. Disposition.

1. Admitting Service
   a. Patients with spine trauma or SCI requiring admission will be in accordance with the existing EHC Trauma Admissions Criteria:
      i. Red Trauma activations and patients admitted to the Surgical-Trauma Intensive Care Unit (STICU) will be initially admitted to the Trauma Service (for at least 24 hours or until hemodynamically stable). After this period, if the patient has isolated spine (or spine and head) trauma the patient may be transferred to the Neurosurgery Service following documentation of a negative tertiary trauma survey.
      ii. Traumas other than Red Traumas (Yellow/Green Trauma, Non-activated Traumas) with isolated spine (or spine and head) trauma that are not admitted to the STICU will be admitted to the Neurosurgery Service.
      iii. Patients with polytrauma (excluding concomitant head trauma) are admitted to the Trauma Service.
      iv. Trauma patients should not be admitted to Medicine unless they are at significant risk of serious cardiac dysrhythmia or cardiac ischemia as determined by the ED attending.

2. Admitting Unit
   a. **Patients WITH acute SCI** should be initially admitted to the STICU in order to:
      i. Continuously monitor the patient's vital signs.
      ii. Monitor the patient's neurological function on an hourly (or more frequent) basis.
      iii. Ensure adequate ventilation/oxygenation and circulation/perfusion (MAP ≥ 85 mmHg) to prevent secondary insults/injury.
      iv. Patients who demonstrate a stable neurological exam over 12-24 hours and do not require vasopressors or inotropic agents to maintain target MAPs may be transferred to the Neurosurgical or Trauma SDU as appropriate if agreed upon by the STICU and treating/accepting teams.
   b. **Patients with UNSTABLE (or suspected unstable) spinal column injuries WITHOUT acute SCI** should be admitted to the STICU or SDU as appropriate.
      i. Admission to the regular ward (e.g. A2) should be avoided in these patients (particularly cervical/thoracic injuries) given the need for close neurological monitoring (q2 hours or more frequent) and potential for acute neurological decline.

c. **Patients with STABLE spinal column injuries WITHOUT acute SCI** may be admitted to the regular ward (e.g. A2), SDU, or STICU, as appropriate based on their other injuries or need for cardiopulmonary or neurological monitoring.

3. Pediatric Patients
   a. Pediatric trauma patients are those under age 15 years as defined by the ACS and EHC Trauma protocols. All trauma patients 15 or over requiring admission should be admitted to EHC.
   b. Pediatric trauma patients, including those with spinal column injuries or SCI, will be managed and transferred according to the current EHC Pediatric Trauma Transfer Policy. This specifies that such patients should be transferred to the nearest Level 1 Pediatric Trauma Center (LIJ-Northwell Cohen's Children's Medical Center) once they are stable for transfer.
   c. Transfer should occur expeditiously if in the judgment of the on-call Trauma Attending it is safe to transfer the patient prior to intervention. Such intervention might include surgery. For pediatric patients with spinal column/cord injuries, the Trauma Attending should consult with the on-call Neurosurgery Attending prior to deciding to transfer the patient. The Neurosurgery Attending is responsible for determining whether it is safe to transfer the patient prior to intervention from the perspective of the spinal column and spinal cord injury.
   d. Select pediatric patients with stable spinal column injuries without spinal cord injury (e.g. lumbar transverse process fracture, spinous process fracture) that do not require ICU admission may be admitted to the EHC Pediatric Service with Neurosurgery as a Consulting Service if the Trauma Attending and Pediatric services agree.

III. Interventions

A. Closed reduction.

1. The Neurosurgeon Attending may opt to attempt immediate closed reduction of a cervical spine dislocation by applying manual or weighted cervical traction through Gardner-Wells tongs. Closed reduction may allow for more rapid decompression of the cervical spinal cord in some cases.
2. Closed reduction should only be attempted by the Neurosurgery Attending. Closed reduction should only be attempted in awake and alert patients with a reliable neurological exam unless concomitant neuromonitoring and fluoroscopy are used (e.g. in the OR under general anesthesia).
3. Extreme caution should be used when there is intervertebral disc disruption as closed reduction may result in disc herniation and additional cord compression.
4. Closed reduction can be performed in the ED, STICU, or the OR. The OR offers significant advantages, including access to increased sedation/anesthesia, availability

of fluoroscopy, neuromonitoring, and the ability to rapidly convert to open surgery should there be a neurological decline or reduction in neuromonitoring potentials.

B. Surgical intervention.

1. The need for surgical intervention and specific surgery required will be determined by the Neurosurgery Attending based on their clinical judgement.

2. Goals of Surgical Intervention
   a. Preservation of neurological function via decompression of the affected neural elements (e.g. spinal cord, conus medullaris, cauda equina, nerve roots).
   b. Definitive stabilization of the spinal column, as necessary.
   c. Prevention of delayed deformity and pain.

3. Surgical Timing
   a. The AOSpine Foundation 2017 Clinical Practice Guidelines suggest that early (within 24 hours post-injury) decompressive surgery be offered as an option for adult acute SCI patients **regardless of ASIA grade/level.**
   b. Recent evidence suggests that **earlier decompression in acute SCI may result in improved outcomes**, even for patients with complete injuries. However, the effect of early (less than 24 hours post-injury) versus late (more than 24 hours) decompressive surgery on outcomes is inconsistent in the literature.
   c. Patients with an acute neurological deficit (SCI, conus medullaris syndrome, or cauda equina syndrome) with neural element compression should undergo decompression as soon as feasible and medically stable to tolerate the surgery. Decompression **within the first 24 hours post-injury (or earlier)** should be considered though this is may not be possible in some cases.
   d. If a patient has an unstable spinal column injury requiring surgical intervention, with or without SCI, then it may be advantageous to expedite surgery once the patient is medically optimized. Delays in definitive stabilization of the spine continue to expose the patient to the risk of neurological deterioration from secondary insults/injuries.
   e. An exception to the above are patients with chronic cervical spondylosis/stenosis who present with traumatic central cord syndrome without an unstable cervical spine injury and without malalignment or subluxation.
      i. These patients are often older with more comorbid medical conditions.
      ii. Meta-analyses suggest that these patients have equivalent long-term neurological outcomes with early versus late decompression/stabilization. However, early decompression may afford a quicker neurological recovery.
      iii. The decision to pursue early surgical intervention should be considered and weighed against the medical comorbidities of the patient and the need for

further medical optimization prior to a potentially long surgery with risk of surgical and/or post-operative medical complications.

4. Medical Optimization
   Several important factors should be considered in determining the medical stability of a patient to undergo emergent or urgent spine surgery, including:
   a. Intraoperative positioning of the patient. The majority of spine surgeries are performed in the prone position, which impacts ventilation/oxygenation and access to the thoracic/abdominal cavity should the need arise (e.g. chest tube placement for hemothorax). Additionally, the prone position places significant stress on the sternum (which may exert additional stress on the heart if the patient has sternum/anterior rib fractures, cardiac contusion, etc.) and the anterior pelvis (which may result in pelvic fracture displacement).
   b. Spine surgeries often have a long operative time.
   c. Spine surgeries may be associated with significant intraoperative blood loss.
   d. Spine surgeries are often difficult to abort once initiated, as the initial surgical step is often decompression of the neural elements, which often further destabilizes the spinal column. If the procedure needs to be aborted at this point, the patient will still be at risk of secondary insult/injury, and will require definitive stabilization at a later date.

C. Steroids.

1. **The use of steroids in acute spinal cord injury remains controversial.** Guidelines have alternatively recommended their use, recommending against their use, or considered steroids as a treatment option, despite largely being based on the same main studies (NASCIS II/III).

2. **The AOSpine Foundation 2017 Clinical Practice Guidelines reintroduced the administration of intravenous steroids as a treatment option in acute SCI.** Specifically, these guidelines suggest a 24 hour intravenous infusion of high-dose methylprednisolone sodium succinate (MPSS) be considered in adult patients within 8 hours of acute SCI as a treatment option. This option has been determined to be safe to administer with no significant risk of complications and may be associated with a small incremental improvement in neurological outcome. If steroids are used, the duration of administration should be kept to 24 hours or less, as an increased risk of complications, particularly infection (e.g. pneumonia, sepsis), has been seen in 48-hour infusions of MPSS.

3. The current consensus of the attending Neurosurgeons at EHC is to consider administration of intravenous steroids in select patients with acute SCI presenting within 8 hours of injury according to the below criteria:

a. Steroids will be considered for acute SCI more frequently in patients with less risk for steroid-induced complications (younger, healthier patients without pre-existing diabetes).
b. Either high-dose **methylprednisolone** (30 mg/kg bolus over 15 min, followed 45 minutes later by 5.4 mg/kg/hr infusion for 23 hours) or **dexamethasone** (Decadron) 10-20 mg IV bolus may be given in the acute setting, followed by a short (up to 24 hours) tapering dose to off (if desired) based on Neurosurgery attending discretion.
c. **Steroids should be discontinued as soon as possible post-decompression, and generally administered for no longer than 24 hours duration, to prevent steroid-induced complications.** Exceptions include patients with traumatic central cord syndrome (see below) or rebound spinal cord edema where a more prolonged steroid taper may be warranted.
d. The decision of whether to use steroids or not as a treatment option in a given patient will remain in the purview of the treating Neurosurgery attending, unless there are absolute contraindications to its use (e.g. active infection, acute severe TBI).
e. A special case exists for the use of steroids (i.e. dexamethasone in the usual neurosurgical doses tapered over several days) is older patients that present with traumatic central cord syndrome in the absence of a spinal column fracture or dislocation.

IV. Critical Care

A. Clinical parameters.

The optimal clinical parameters for the critical care management of SCI patients are similar to those for TBI, given that the goal in both cases is to prevent secondary insults and injury to neuronal tissue. **As such, the following parameters are considered optimal for acute SCI patients:**

Pulse Oximetry ≥ 95%	Temperature 36-38°C
PaO_2 ≥ 100 mmHg	Glucose 80-180 mg/dL
$PaCO_2$ 35-45 mmHg	Serum sodium 135-145
MAP ≥ 85 mmHg*	INR ≤ 1.4
PH 7.35-7.45	Platelets ≥ 75 x 10^3 / mm^3**
Hemoglobin ≥ 7 g/dl	

*MAP ≥ 85 mmHg should be maintained for 7 days post-SCI in CNS/AANS guidelines for the management of acute cervical and thoracolumbar spinal cord injury.

**Platelets ≥ 100 x 10^3 / mm^3 prior to, and for at least 24 hours after, any invasive spine procedure

B. Pulmonary.

1. **Maintain $SpO_2 \geq 95\%$ and $PaO_2 \geq 100$ mmHg**, if possible, to prevent spinal cord hypoxia and ischemia.
2. Patients with **complete cervical SCI C1-4 should be considered for early intubation and mechanical ventilation** given the risk of respiratory distress from reduced diaphragmatic and intercostal innervation.
3. **Patients with cervical SCI (particularly C1-4) may require higher tidal volumes (10-15 cc/kg ideal body weight)**, compared to routine lung-protective strategies, to prevent atelectasis due to reduced diaphragmatic and/or intercostal innervation.
4. For patients with C1-5 SCI consider placement of diaphragm pacer, if necessary.
5. Lack of sympathetic innervation following SCI above T6 causes bronchoconstriction and increased airway secretions. These patients should be started on bronchodilator nebulizer treatments.
6. For patients without intercostal muscle function, a flat position (i.e. no HOB elevation) facilitates diaphragmatic breathing. If there is a need to elevate the head (e.g. concomitant TBI), consider using reverse Trendelenburg positioning.
7. Intubated patients with cervicothoracic SCI should have frequent chest PT.
8. **If prolonged intubation is anticipated, consider early tracheostomy (particularly for cervical SCI).** Percutaneous tracheostomy is contraindicated in patients with unstable cervical spines and may be difficult in those who cannot safely or easily have their neck sufficiently extended (e.g. post-cervical fusion). In these cases, open tracheostomy may be preferred.

C. Cardiovascular.

1. **MAP should be maintained at ≥ 85 mm Hg for the first 7 days** following acute cervical or thoracolumbar SCI to ensure adequate spinal cord perfusion.
2. The effect of MAP-directed therapy on neurological outcome after SCI is delayed, therefore even in the setting of a stable neurological exam, this parameter should be maintained unless there is a cardiopulmonary contraindication (e.g. volume overload, cardiac ischemia).
3. **An arterial line should be placed and maintained for accurate and continuous blood pressure monitoring during the acute phase following SCI, if feasible.** Once the patient demonstrates a stable and reliable non-invasive MAP recording, the arterial line may be discontinued and MAP followed via non-invasive blood pressure (NIBP) monitoring.
4. **Isotonic intravenous fluids should be administered to maintain euvolemia.** This is particularly important for patients at risk of neurogenic shock (T6 SCI and above).

Hypotonic solutions should be avoided in SCI and other patients with neurological pathologies to avoid potentiation of edema and/or hyponatremia.

5. **Vasopressors should be used as necessary to maintain MAP targets, if necessary.**
   a. *Norepinephrine (alpha/beta-agonist):* **preferred agent** as it improves both blood pressure and bradycardia.
   b. *Phenylephrine (pure alpha agonist):* **second-line agent** if norepinephrine is not available and if there is no significant bradycardia. Note phenylephrine may cause or worsen existing bradycardia through reflexive mechanisms.
6. In patient able to take PO medications (orally or via NGT/PEG), consider midodrine 5 mg PO TID to wean off vasopressors.
7. Development of early cardiac (e.g. ischemia/myocardial infarction) or pulmonary (e.g. volume overload) complications may preclude continued safe MAP-augmentation. In such patients, MAP-augmentation may need to be discontinued and a lower goal of MAP $\geq$ 65 mmHg instituted at the discretion of the attending Intensivist(s), Neurosurgeon, and/or Trauma surgeon.

D. Neurological.

1. Patients admitted to the STICU should initially have hourly neurological assessments by the nursing staff and followed closely by the Neurosurgical and ICU team per STICU protocol during the acute phase of SCI.
2. **Development of a new or worsening neurological deficit constitutes an emergency and should be relayed immediately to the Neurosurgical and STICU teams, including responsible attending physicians.**
   a. Consider repeat spine imaging (CT or MRI) or emergent surgical intervention, if needed, in the setting of a new or worsening neurological deficit.
3. Autonomic dysreflexia can develop with SCI above T6.
   a. Presents with hypertension, pallor below the SCI dermatome, flushing/sweating above the SCI dermatome.
   b. Causes include bowel or bladder distention, pain from fractures or pressure ulcers, UTI.
   c. Best treatment is prevention or remove the causative agent/source. Consider additionally treating with intravenous opioid medications. Consider treating hypertension with nifedipine.
4. Once patients are deemed by the Neurosurgery, Trauma, and Intensivists teams to be at less risk for neurological decompensation, the frequency of neurological assessments may be reduced as appropriate to afford patients longer periods of rest and sleep to aid in recovery and prevent delirium and agitation.

E. Sedation/Analgesia.

1. Avoid sedation with long-acting sedatives (e.g. midazolam) during the acute phase post-injury given the need for frequent neurological exams. Use of benzodiazepines may be necessary, however, if sedation with other agents (e.g. propofol or dexmedetomidine) is not feasible due to induction of hypotension or other injuries (e.g. severe TBI with need for increased sedation/analgesia).
2. Acetaminophen (PO or IV) and opioids (e.g. fentanyl gtt) are first line analgesics.
3. Discuss with Neurosurgery prior to use of NSAIDS, including ketorolac (Tramadol), given the potential for increased bleeding associated with these medications (due to inhibition of platelet aggregation). However, they may be safe to use 24 or more hours after surgery or trauma. Do not recommend use if concomitant acute TBI (bleeding risk and lowers seizure threshold). Additionally, NSAIDs (particularly ketorolac) have been reported to reduce fusion rates after spine surgery.
4. Muscle relaxants (e.g. diazepam 2-5 mg PO/IV q6-8h, methocarbamol 500-1500 mg PO 4 times per day, cyclobenzaprine 5-10 mg PO three times per day) are often useful adjuncts in the acute phase post-injury or post-surgery for treatment of pain related to muscle spasm. Use caution to avoid over sedation when used in conjunction with opioids or gabapentin.
5. For neuropathic pain, consider gabapentin (start 100-300 mg PO TID, max 3600 mg/day, taper dose over >7 days to discontinue) or amitriptyline 25-50 mg PO QHS (start 25 mg PO QHS).

F. Endocrine.

1. **A serum glucose of 80-180 mg/dL should be targeted during the acute phase (first 7 days post-injury)** to avoid excessive hyperglycemia and also hypoglycemia (which is detrimental after CNS injury). Consider insulin infusion if sliding scale insulin does not allow sufficient control. Tighter glucose control may be instituted following the acute phase post-injury, if desired.
2. **Adrenal insufficiency might complicate neurogenic shock. In the presence of neurogenic shock following SCI above T6**, consider assessment by testing blood cortisol levels. Administration of stress dose steroids may help maintain blood pressure and lower the vasopressor requirements.

G. Gastrointestinal.

1. **Administer GI prophylaxis with a proton pump inhibitor (PPI) or H2-blocker for patients with cervical and upper thoracic SCI.** These patients are at high risk for gastric ulcers due to unopposed parasympathetic activity.
2. **Nutritional support is critical in all patients with neurological injury.**
   a. Enteral nutrition is recommended over the use of parenteral nutrition; however, paralytic ileus is common after SCI (see below).

   b. Post-pyloric feeding methods are preferred as they are associated with a lower rate of pneumonia.
   c. Full nutritional supplementation should be achieved within 7 days of injury.
3. **Paralytic ileus is very common after SCI. Consider the following to prevent complications from paralytic ileus:**
   a. Keep the patient NPO for 24-48 hours following acute SCI;
   b. Administer metoclopramide 10 mg IV prior to initiating enteral feeding;
   c. Aggressive bowel regimen, including Senna 1-2 tabs PO daily;
   d. Place a nasojejunal tube, if necessary.
   e. The goal is that the bowel should be evacuated every day; this might require digital stimulation/manual evacuation in some cases.

H. Genitourinary.

1. **Trauma patients require strict I/O's which should be monitored and recorded frequently. Additionally, SCI patients are at risk for neurogenic bladder and urinary retention.**
2. Insert and maintain an indwelling Foley catheter, as needed, for strict I/Os and bladder decompression. Assess continuing need daily.
3. Consider removing indwelling Foley catheters when patients are no longer on IVF, total input is no more than 2 L/day, and no diuretics are being used.
4. A condom catheter is not recommended for during the acute phase after SCI given need for strict I/O and potential for neurogenic bladder/urinary retention.
5. **Begin routine bladder straight catheterization q4-6 hours following Foley catheter removal, if needed.**
   a. the goal is to obtain **no more than 400 mL** of urine per straight catheterization;
   b. if > 400 mL per catheterization, increase frequency to q4 hours;
   c. if < 400 mL per catheterization; decrease frequency to q6 hours;
   d. obtain a bladder scan if there is any spontaneous void between routine straight catheterization; repeat straight catheterization if the residual urine volume is > 250 mL

I. Musculoskeletal.

1. Joint contractures can rapidly develop. Prevent them with:
   a. early initiation of physical therapy;
   b. consider bracing to prevent contractures

J. Skin.

1. Patients with spinal column trauma or SCI are at high risk for pressure ulcers. Prevention is paramount with:

a. frequent turns (q2 hours) to prevent pressure ulcers;
b. prompt removal of rigid backboards upon arrival in the ED;
c. removal of rigid cervical collars as soon as feasible;
d. use a foam wedge to maintain patients in the lateral position;
e. adequate nutritional support

2. Patients with pressure ulcers should be graded, inspected daily, and treated according to hospital and nursing protocols.
3. General surgery should be consulted for patients with deep pressure ulcers for possible debridement and VAC placement.

K. Psychosocial.

1. All patients will be screened for early Palliative Care according to the "EHC Palliative Trauma Care Clinical Practice Guideline".
2. Additional psychosocial considerations:
   a. child life if patient is under 18 years old or for siblings;
   b. consider patient's religious needs;
   c. social worker consultation;
   d. education of patient and his family about the prognosis and the lifestyle changes due to the injury

L. Venous Thromboembolic (VTE) Prophylaxis.

1. Prophylaxis of VTE in patients with Spine Trauma will be according to the existing "EHC Trauma VTE Prophylaxis Clinical Practice Guidelines."

V. <u>Subacute Care and Rehabilitation</u>

A. Early PM&R input and initiation of frequent Physical Therapy (PT) following spine stabilization and cessation of spine precautions is recommended.

B. Spasticity is a frequent sequela of SCI. Severe spasticity is painful, makes effective PT difficult, and can lead to contractures and hyperostosis of chronically spastic joints if untreated. Advanced hyperostosis may need to be treated surgically.
   1. Consider baclofen 20-80 mg/day PO (or via NGT/PEG) divided TID or QID for patients with significant spasticity from SCI (or concomitant TBI). Do not stop high-dose baclofen without slow taper given risk of acute withdrawal.
   2. Frequent PT.
   3. If the above measures fail, consider dantrolene 100 mg PO TID-QID in consultation with PM&R (start 25mg PO QD x7 days, then in 25 mg PO TID x7 days, then 50 mg PO TID x7 days, then 100 mg PO TID; max dose 100 mg PO QID; use lowest effective dose; d/c if no response after 45 days).

4. If the patient continues to have significant chronic spasticity, consider intrathecal baclofen trial and implanted baclofen pump placement by a qualified Neurosurgeon.

C. Placement in an acute SCI Rehabilitation Facility is recommended to maximize potential neurological and functional recovery.

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