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Evaluation and Initial Workup Guide of Spine Trauma Patients for Orthopaedic Surgery Residents

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Introduction

Trauma to the spine is common. For the consult resident challenges in diagnosis exist and managing critical patients can be a daunting task. Determination of stability requires understanding of relevant anatomy, imaging literacy, and a working knowledge of injury classifications to avoid catastrophic consequences. The consult resident must develop a systematic approach to evaluate and manage spine trauma patients. We hope the following guide will help to address critical aspects of the initial workup, examination, and diagnosis of different injuries in spine trauma patients.

Physical exam

The physical exam is one of the most important components of a spine exam. It involves inspecting the spine for alignment, assessing for any prior surgical scars or skin defects, as well as noting any muscular atrophy. Be sure to palpate for any tenderness or step-offs along the spine as well. Flexion, extension, rotation can also be assessed. Care must be taken with mobilization of a patient with concern for higher energy injury or injury to the spinal cord and in these instances strict spinal precautions should be employed with use of careful log roll with one person stabilizing the head and neck and two others carefully supporting the thoracolumbar region (Figure 1).

Sensation can be assessed in dermatomal distribution. This includes pain, light touch, vibration, and 2-point discrimination. The ASIA sensory grading system is as follows: 0= absent, 1= impaired, 2= normal, NT= not testable

Motor function can be assessed using the ASIA grading system. 0= no movement. 1= visible or palpation contraction. 2= full range of motion with gravity eliminated. 3= full range of motion against gravity. 4= full range of motion against gravity and moderate resistance. 5= full strength and gravity and resistance.

Figure 2 and 3 show tabled that demonstrates motor testing as well as the affected muscle and associated neural structure for the upper extremity and lower extremity respectively.

Spine reflexes should also be tested by the consult resident. The following spinal nerve levels are associated with the corresponding reflex. C5= biceps brachii reflex. C6= brachioradialis reflex. C7= triceps brachii reflex. L1/2= cremasteric reflex L4= patellar tendon reflex. S1= Achilles tendon reflex.

Figure 1. Example of a logroll of a patient to maintain spinal precautions. One person stabilizes the head and neck and two others carefully support the thoracolumbar region.

Motor Testing of Upper Extremity Muscles			
Primary Motion	**Primary Muscle**	**Innervation**	**Nerve Root**
Scapular stabilization	Serratus	Long thoracic n.	C4
Shoulder abduction	Deltoid	Axillary n.	C5
Shoulder internal rotation	Subscapularis	Subscapular n.	C5
Shoulder external rotation	Infraspinatous	Suprascapular n.	C5
Elbow flexion (palm up)	Biceps & Brachialis	Musculocutaneous n.	C5
Elbow flexion (thumb up)	Brachioradialis	Radial n.	C6
Wrist extension	ECRL	Radial n.	C6
Wrist supination	Supinator	PIN	C6
Elbow extension	Triceps	Radial n.	C7
Wrist flexion	FCR & PL	Median n.	C7
Wrist pronation	PT & PQ	Median n.	C7
MCP & PIP finger flexion	FDS	Median N.	C8
DIP finger flexion	FDP	Ulnar n. & AIN	C8
Thumb extension	EPL	PIN	C8
Finger abduction	Interossei	Ulnar n.	T1

Figure 2. Upper extremity musculature action and innervation.

Nerve root	*Primary Motion*	*Primary muscles*
L1		
L2	Hip flexion and adduction	Iliopsoas (lumbar plexus, femoral n.) Hip adductors (obturator n.)
L3	Knee extension (also L4)	Quadriceps (femoral n.)
L4	Ankle dorsiflexion (also L5)	Tibialis anterior (deep peroneal n.)
L5	Foot inversion Toe dorsiflexion Hip Extension Hip abduction	Tibialis posterior (tibial n.) EHL (DPN), EDL (DPN) Hamstrings (tibial) & gluteus max (inf. gluteal n.) Gluteus medius (sup. gluteal n.)
S1	Foot plantar flexion Foot eversion	Gastroc-soleus (tibial n.) Peroneals (SPN)
S2	Toe plantarflexion	FHL (tibial n.), FDL (tibial)
S3 & S4	Bowel & bladder function	Bladder

Figure 3. Lower extremity musculature action and innervation.

Provocative tests

The spurling test which assesses for cervical radiculopathy. This is performed by rotating the head to the affected side, extending the neck, and applying an axial load to the head. The test is positive if pain radiates down the ipsilateral affected arm.

Hoffman's Test assessed for cervical myelopathy. It is performed by stabilizing the long finger and flicking the distal phalanx into extension. A positive test causes involuntary contraction of the thumb interphalangeal joint.

Lhermitte's sign tests for cervical spinal cord compression and myelopathy. A positive test occurs when cervical flexion or extension produces a shocking sensation down the spine or into the appendages.

The straight leg raise can be used to assess compression of the lower lumbar nerve roots. This test is positive if

radicular symptoms are produced when the leg is raised beyond 30 degrees at the hip joint maintaining the knee in full extension.

The Babinski test assesses for upper motor neuron lesions. It is positive when stroking along the plantar aspect of the foot produces an extensor plantar response.

The following sections will illustrate different fracture types and pathologies based on anatomic location.

Cervical Spine Fractures

1. Upper Cervical Fractures

b. Atlas (C1) Fractures

Often caused by axial loading and hyperextension mechanism injury. Neural deficits are often rare due to the large space available for canal. High suspicion for transverse ligament rupture if lateral mass displacement $\geq$ 6.9 mm on open-mouth odontoid views (Figure 4).

- Review the Landell classification of C1 fractures.

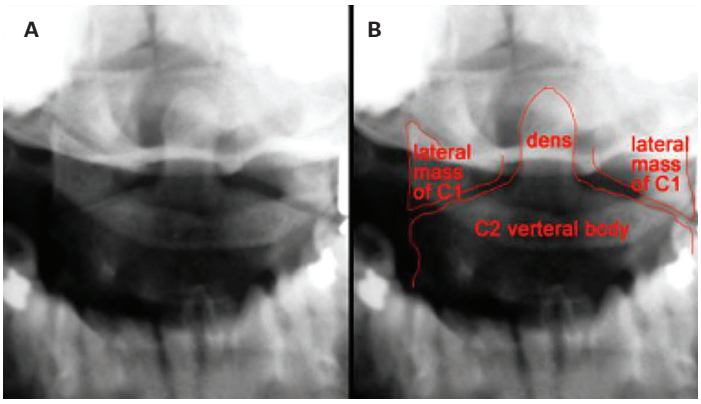

Figure 4. Open-mouth odontoid view x-ray showing dens, C2 vertebral body, and lateral masses of C1. **(A)** Unlabeled; **(B)** Labeled.

Treatment

i. Fractures of the posterior arch or lateral mass fractures can be treated nonoperatively with hard collar or halo application.
ii. Jefferson burst fracture is treated with fusion.

b. C1-C2 Subluxation (Ruptured Transverse Ligament)

An injury Transverse Atlantoaxial Ligament (TAL) is inferred by an increase in the Atlanto-Dens interval (ADI) which is seen on the lateral radiograph. ADI > 3-5 mm is indicated of injury to the transverse ligament, while all ligaments are likely ruptured if ADI > 7 mm, and concern for cord compression with ADI > 10 mm.

Treatment

i. ADI 3-5 mm: halo (check flexion extension views after removing halo at 3 weeks)
ii. ADI > 5 mm: surgery (C1-C2 fusion)

c. Odontoid (C2) Fractures

Odontoid fractures constitute up to 18% of cervical spine injuries, with a bimodal distribution of high-energy trauma in the younger patients and low-energy older population.[1] Consult resident must recognize risk factors for non-union which will affect management of these patients including: > 4 mm displacement, Age (> 40), Type 2 fracture pattern, angulation (> 10 degrees), and posterior displacement.

- Review the Anderson-D'Alonzo classification.

Treatment

i. Type 1 injuries can be treated in a rigid cervical collar.
ii. Type 2 fractures have a higher risk of nonunion due to poor blood supply. Nondisplaced type 2 fractures can be potentially treated in a halo vest. Nondisplaced or minimally displaced type 3 dens fractures can also be treated in a halo vest.
iii. For displaced type 2 and type 3 dens fracture, surgical fusion versus odontoid screw fixation should be considered.

d. Traumatic Spondylolisthesis of Axis (Hangman's Fracture)

Due to the unique anatomy of the C2 as a transitional vertebra between upper and lower cervical spine, the pars interarticularis of C2 is subjected to disproportionally high stress that can lead to fracture.

- Review the Effendi classification.

Treatment

Based on the type of fracture according to the Effendi classification

i. Type I: collar
ii. Type II: halo-vest for 12 weeks.
iii. Type IIA: halo-vest for 12 weeks.
iv. Type III: surgery with C2–C3 fusion (possibly posterior C1–C3 fusion)

2. Subaxial Cervical Fractures

This constitutes the majority of cervical spine trauma injuries occur in the subaxial spine, likely due to the increase motion at these segments (most of which occurring at C5-C7). Several classification systems have been described including Allen and Ferguson Classification and the Subaxial Cervical Injury Classification (SLIC). The SLIC classification has attempted to standardize the spine trauma description and management, which is focused on three injury criteria: (1) injury morphology, (2) integrity of the disco ligamentous complex (DLC); both anterior and posterior structures, and (4) neurologic status.[2] Ultimately, variation in interobserver reliability persuaded AO spine to produce the validated "AO Spine subaxial cervical spine injury classification system" which is based on four criteria: (1) morphology of the injury, (2) facet injury, (3) neurologic status, and (4) case-specific modifiers.

Important imaging to obtain in the initial evaluation should include:

- 3-view C-spine XR (AP, lateral, open mouth) +/− swimmers view
- Flex-ex views often not typically ordered in the acute trauma situations and replaced by CT imaging.
- Evaluate for noncontiguous spine injuries (must be ruled out as it is present in up to 30% of patients).
- CT C spine
- CTA if concern for vertebral artery injury.[3]
- MR C-spine
- Must obtain in patients with neuro deficits

a. Facet fractures and dislocations

Stability depends on several factors including if unilateral versus bilateral, disco ligamentous integrity, size of the fracture fragments. High suspicion for floating lateral mass. When evaluating for unilateral versus bilateral on XR spondylolisthesis of up to 25% is present in unilateral facet fracture, while bilateral facet fracture dislocation will show > 50% spondylolisthesis. Unilateral facet fractures may be reduced on plain XR's if obtained supine, however, "naked facet sign" can be seen on CT scan axial view. There is a high incidence of herniated disk into the canal (therefore must obtain STAT MRI prior to reduction attempt). Facet dislocations can also occur. A jumped facet occurs when the inferior articular process of the superior vertebra is anteriorly locked in relation to the superior articular process of the inferior vertebra. A perched facet occurs when the inferior process of the superior vertebra appears to sit perched on the ipsilateral superior articular process of the inferior vertebra. These two entities can be unilateral or bilateral with bilateral indicating a higher level of instability.

b. Lateral Mass Fractures

There should be close attention to imaging to rule out the highly unstable injury of floating lateral mass—which is a subset of unilateral lateral mass fracture with fractures of the adjacent pedicle and lamina.

Thoracolumbar spine

Thoracic and lumbar fractures account for 50% of neurological spine trauma.[4] Injuries to this region of the spine are from high energy trauma in the younger population and low energy mechanisms elderly patients with osteoporosis. Although normally grouped together, can be thought of as three distinct regions, namely thoracic spine, thoracolumbar junction, and lumbar spine which each have special considerations.

Thoracic spine: Higher chance of cord injury in this region due to narrow spinal canal and watershed blood flow.[5] Enhanced stability of the spine due to the rib cage.

Thoracolumbar junction: About half of thoracolumbar fractures occur in this region due to high stress while transitioning from stiffer thoracic spine to more mobile lumbar spine.[6] Neural deficits can be upper or lower motor neuron depending on the relation of injury to the conus medullaris.

Lumbar spine: If neural deficits are present, they are unlikely to be complete injuries because the spinal canal is wider in this region and the cauda equina is more resistant to compression than the spinal cord. The spinal cord generally ends at the L1-L2 region.

Fractures about this region can be classified as minor or major injuries according to the Denis classification.

Minor fractures

Include fractures of the transverse process, spinous process, pars, or facet joints for example.

Treatment

Minor fractures in isolation can be treated with a thoracolumbosacral orthosis (TSLO). Care must be taken to ensure these fractures are not part of a constellation of a more unstable fracture pattern, however.

Major injuries

Include compression fractures, burst fractures, flexion/distraction injuries, and fracture dislocations of the spinal cord.

a. Wedge compression fractures

Often occur in elderly, osteoporotic females from a low energy mechanism.[7]

Treatment

Can be treated conservatively with TSLO or with vertebroplasty vs kyphoplasty (if conservative treatment fails) generally on a sub-acute basis for palliative purposes.

b. Stable burst fractures

Occurs due to trauma from a flexion and axial load that leads to compression failure of the anterior and middle columns. AP x rays will show increased distance between the pedicles. Sagittal radiographs will show a disruption of the posterior bodies of the vertebrae. Stable burst fractures are those that do not involve disruption of the posterior ligamentous complex (i.e., supraspinous ligament, interspinous ligament, ligamentum flavum, and facet capsule. MRI of disrupted posterior ligamentous complex (PLC) will show widening of the interspinous distance and separation of facet joints.

Treatment

Supportive in TSLO brace .

c. Unstable burst fractures

Involve compression failure of the anterior and middle columns and tensile failure of the posterior columns. MRI is indicated to evaluate the intervertebral disc damage.[8]

Treatment

Prior research showed that operative indications include $>$ 40% of canal compromise, $>$ 50% of vertebral height loss, and $>$ 50% kyphosis. They can be fixed with hook-rod systems, pedicle screws, or sublaminar wires. New research is showing success in non-operative treatment even with the above parameters. One of the deciding factors for operative versus non-operative management is whether the patient is having any neurological symptoms.

Flexion-Distraction injuries (Chance fractures)

The pattern of injury includes tension failure of the posterior column and distraction injury of the anterior/middle column. Can be classified as bony chance fractures or ligamentous chance fractures. These fractures are frequently accompanied by abdominal injuries.

a. Bony chance fractures

Occur when the injury force goes horizontally through bone.

Treatment

Can be treated with extension casting/bracing. Operative indications include kyphosis of $>$ 15 degrees as well as lack of neural deficit

b. Ligamentous chance fractures

Occur when the injury goes horizontally through the ligaments.

MRI is helpful to assess extent of ligamentous damage.

Treatment

Operative fixation

Translational injuries

Occur after an external force causes facet subluxation/dislocation either anteriorly or posteriorly. This is frequently accompanied by a rotational component as well. These are routinely accompanied with a dural tear.

Treatment

Operative with reduction and pedicle screw fixation with instrumentation spanning two levels above and below the site of injury.

Distraction of extension injury

This is a rare injury that is most common in stiff spines such as ankylosing spondylitis. Caused by an extension force to the back with resulting disruption of the anterior longitudinal ligament. Posterior complex may be involved with severe force.

Treatment

Operative if unstable fracture.[9]

Special considerations

Cauda Equina syndrome

Occurs due to compression of lumbar/sacral nerve roots. Only involves lower motor neurons. Can be acute or insidious in nature. Can be caused compression from fractures, disc herniations, etc. Has a constellation of symptoms included bowel/bladder dysfunction, saddle anesthesia, lower extremity sensory/motor deficits.

Needs a full neuro exam included rectal exam (assessing for sensation/tone/voluntary contraction). Be sure to discriminate between pinprick and light touch on exam. Red Flags: progressive back/leg pain refractory to analgesia, lower extremity weakness, urinary retention/incontinence, stool incontinence, recent paraspinal invasive procedures, and use of anticoagulants. MRI is useful tool for evaluation.

Treatment

Operative decompression within 48 hours of presentation. Fusion may be indicated depending on the type of injury

Ankylosing Spondylitis

This condition is an autoimmune spondyloarthropathy that creates a stiff spine due to joint ankylosis secondary to inflammation/bony erosion. Can be associated with other systemic manifestation.

This pathology and associated fractures are at times difficult to recognize. The consult resident needs to be sure to maintain the posture of the patient, obtain imaging of the entire spine, and limit amount of travel within the hospital as this can exacerbate the injury.

Plain films reveal a 'bamboo' spine. CT images will show bony changes but no evidence of active inflammation. CT has a higher sensitivity to aid in the diagnosis of cervical fractures in the setting of ankylosing spondylitis (AS).

Treatment

Can include non-op management/therapy for pain. All spinal fractures in a patient with AS are treated more aggressively due to the high risk for instability. Some operative indications include worsening neuro deficit, epidural hematoma, and unstable fractures of the spine. Even unimpressive appearing fractures in a neurologically intact AS patient may be stabilized operatively due to the high instability risk.

Infection

Important to have a high index of suspicion for infections of the spine as presentation may not be straightforward leading to a delay in diagnosis. 80% will present with back pain. Risk factors for spinal infections include malnutrition, diabetes, iv drug abuse, immunosuppression, bacteremia/sepsis, and recent invasive procedure.

The consult resident should ensure that labs/biopsy should be obtained before the administration of IV antibiotics if the patient is hemodynamically stable. Routine labs should include CBC w/ diff, CRP, ESR. Open biopsy is associated with the most accuracy followed by CT guided biopsy. Blood cultures are only positive in 20% of patients. MRI with gadolinium is the gold standard to assess for spinal infections. Soft tissues are difficult to see with CT scans and X-rays may show no evidence of change for several weeks.

a. Discitis

Involves infection of the intervertebral discs with S. aureus as the most isolated organism. X rays can reveal a loss of lumbar lordosis and disc space narrowing. MRI is the most sensitive for diagnosis.

Treatment

Antibiotics and serial inflammatory marker trend to note improvement. Operative indications include lack of response to antibiotics, progressive neurologic deficits, and late infection.

b. Vertebral osteomyelitis.

Most cases occur in the lumbar spine with S. aureus as the most common microorganism isolated. Fever is only present in 1/3 of patients. Symptoms of pain are insidious. X rays may show disc space destruction with concomitant disc space narrowing. MRI with contrast is the test of choice.

Treatment

Prolonged antibiotics versus operative neurological decompression and stabilization, irrigation and debridement. Operation needed for progressive neurological deficits, cervical vertebral osteomyelitis, and gross instability of the spine.

c. Epidural abscess

Involves an infection in superficial to the dura mater. Usually occurs secondary to hematogenous spread or from adjacent discitis with S. aureus as the most common culprit.[10] Systemic symptoms and fever are usually present. MRI of the entire spine is the best imaging modality for this condition and will show a ring enhancing lesion around the abscess.

Treatment

Surgical decompression +/- instrumentation, long term IV antibiotics.

Tumor

Tumors of the spine can occur in any age group. The overwhelming majority of spinal tumors are metastatic in a 9:1 ratio. Red flags for spinal tumors include night pain, a history of malignancy, as well as pathologic fracture after minor trauma.[11] Imaging of the concerned area should be obtained with Xray/CT with contrast/MRI with contrast. Primary screening consists of CT chest abdomen, and pelvis. ESR and CRP should be obtained as well.

Treatment

Depends on type of cancer, presence of metastasis, and the patient's overall condition/life expectancy. Surgical resection can be performed for an isolated lesion such as osteoid osteoma refractory to conservative management. For metastatic lesions, the tumor burden is primarily controlled with radiation and or chemotherapy.

The Obtunded patient

The obtunded patient can present with difficulty for proper evaluation for a consult resident. Not only are they unable to provide a reliable history, but they are unable to cooperate in a physical exam, therefore it is difficult to assess for neurologic injury leading to a delayed diagnosis.[12] One aspect of the physical exam can still be tested to evaluate for potential spinal shock, namely the bulbocavernosus reflex. This is elicited in males by squeezing the glans penis and assess for anal sphincter contraction. In females, this is assessed by manually squeezing the clitoris (or tugging on an indwelling foley catheter) and assessing for anal sphincter contraction. This patient population is also problematic because occult spinal injuries can have devastating neurological consequences at a higher percentage compared to injuries determined on initial evaluation.[13] Cervical collars should be kept in place until injury can be ruled out with a high-quality CT scan. If no injuries are detected, the C collar can be removed in order to prevent complications with prolonged use (such as pressure ulcers, aspiration pneumonia, venous thromboembolism, etc.[14]

Incomplete Spinal cord injuries

Incomplete cord injuries can also be present following a trauma.[15]

1. Central Cord Syndrome affects the motor, pain, and position sense. It affects the upper limbs more than the lower limbs.
2. Anterior Cord Syndrome involves bilateral loss of motor function and pain sensation below the injured segment. Position sense is preserved.
3. Posterior Cord Syndrome involves loss of position sense below the lesion level. Motor and pain sensation are preserved.
4. Brown Sequard Syndrome affects one side of the spinal cord. It causes loss of motor function and position sense on the same side as well as pain sensation on the opposite side.

Discussion

Spine trauma call can be a daunting proposition for the junior orthopedic surgery consult resident. Between

obtaining a detailed history, physical exam, review of the imaging, and formulation of an accurate assessment and plan amongst the pressure of time constraints and other pending consults, there are a number of things that the consult resident has to perform in order to ensure adequate care of the spine trauma patient. With a thorough knowledge of the anatomy and pathology of the spine, this will equip the consult resident with providing quality care for the spine trauma patient.

Conclusion

The spine trauma patient offers a myriad of learning opportunities for the junior orthopedic surgery consult resident. Once a proper understanding of spine anatomy and pathology is obtained, the consult resident can not only learn from their call experiences, but also positively impact the lives of patients in their time of need.

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