SCI EXAM & FUNCTIONAL PROGNOSIS

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SPINAL CORD INJURY
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PHYSICAL MEDICINE & REHABILITATION

OBJECTIVES
- Anatomy review
- ASIA Impairment Scale & SCI Examination
- Functional prognosis and outcomes
- Clinical Syndromes
- Clinical cases and examples
- Disclosures: none

FACTS & FIGURES
- Annual incidence: 40 cases per million population in the US
- 12,000 new cases per year
- Prevalence estimated ~275K persons
- Average age at injury: 42.6 years
- 80.7% male
- 76.8% Caucasian
- 56.5% MVC >> 28.5% Falls >> 14.3% Violence
- Incomplete tetraplegia 40.6% >> Incomplete paraplegia 18.7% >> Complete paraplegia 18.0% >> Complete tetraplegia 11.6%
- Estimated lifetime costs: $1.5 – 4.6 million

ANATOMY: SPINE
- Cervical: C1-C7
- Thoracic: T1-T12
- Lumbar: L1-L5
- Sacral: S1-S5 (fused)
- Coccyx

SCI MODEL SYSTEMS FACTS & FIGURES 2013

SCI EXAM & FUNCTIONAL PROGNOSIS 2015
ANATOMY: SPINE

- Spinal cord: foramen magnum to L1-L2 intervertebral level
- Conus medullaris and Cauda equina
- Cord enlargements: C5-T1 and L1-S2
- 31 pairs of nerve roots:
  - Cervical 8
  - Thoracic 12
  - Lumbar 5
  - Sacral 5
  - Coccygeal
- Cord segments do not always correspond to vertebral levels

GOALS OF SCI EXAMINATION

To provide an assessment tool that would:

- Standardize patient testing and classification
- Establish a common language for all clinicians
- Improve sensitivity to patient changes over time (improvement or deterioration)
- Prescribe treatment
- Evaluate outcomes
- Allow for prognostication
- Best exam at 72 hours

SPINAL CORD INJURY EXAMINATION

- The American Spinal Injury Association (ASIA) or Asia Impairment Scale (AIS)
  - Motor exam (key muscles)
    - graded 0-5
  - Sensory exam (key sensory points)
    - graded 0 (absent), 1 (impaired) or 2 (normal)
  - Pinprick and light touch
  - Sacral testing (S4-5)
    - voluntary anal contraction
    - DAP: deep anal pressure/sensation
Upper extremity:
- C5: elbow flexors
- C6: wrist extensors
- C7: elbow extensors
- C8: finger flexors
- T1: small finger abductors

Total motor score is 100
(5 points for each muscle)

Lower extremity:
- L2: hip flexors
- L3: knee extensors
- L4: ankle dorsiflexors
- L5: long toe extensors
- S1: ankle plantarflexors

Total motor score is 100
(5 points for each muscle)

All of the key muscles have innervation by two nerve segments.

A muscle has a strength of 3/5, it is considered to be innervated by the more rostral segment.

**Muscle Innervation**

- **Biceps:** C5 - C6
- **WE:** C6 - C7
- **Triceps:** C7 - C8

**Asia International Standards 2011**

**Positions for Strength Testing**
- C5: Elbow flexed at 90 deg, arm at patient’s side & forearm supinated (EF)
- C6: Wrist in full extension (WE)
- C7: Shoulder is neutral rotation, adducted and in 90 deg of flexion with elbow in 45 deg of flexion (EE)
- C8: Full flexed position of the distal phalanx with the proximal finger joints stabilized in extended position (FDP, digit 3)
- T1: Full abducted position (ADM)
ASIA INTERNATIONAL STANDARDS 2011

- L2 Hip flexed to 90 deg (HF)
- L3 Knee flexed to 15 deg (KE)
- L4 Full dorsiflexed position (AD)
- L5 First toe fully extended (EHL)
- S1 Hip in neutral rotation, the knee is fully extended and the ankle in full plantarflexion (AP)

MOTOR SCORING

- 6 point scale:
  - 0 = absent contraction/ total paralysis
  - 1 = palpable or visible muscle contraction without joint movement
  - 2 = full active range of motion in the gravity eliminated plane
  - 3 = full range of motion against gravity
  - 4 = full ROM against moderate resistance
  - 5 = normal full ROM against full resistance
  - NT = not testable

- Only whole numbers: no "+" or "-
- Use **" if other limiting factor

MOTOR LEVEL

- The motor level is the lowest muscle with a strength of at least 3/5, with the key muscles above it having full or normal (5/5) strength.
- Clarification for the myotomes that are not tested as part of key muscle groups:
  - C1-C4 (above C5)
  - T2 through L1
  - L2-S4/5 (below S1)
  - The motor level is considered to be the same as the sensory level

SACRAL TESTING (S4-5)

- Testing for:
  - voluntary anal contraction
  - Assess motor sparing (B vs. C)
  - perianal sensation to light touch and pinprick bilaterally
  - DAP: deep anal pressure
- Determines if injury is complete or incomplete
  = sacral sparing
SENSORY (DERMATOMAL) TESTING

• Testing of a key point in each of the 28 dermatomes on both sides of the body.
  • No C1 dermatome
  • S4-S5 tested together
• At each dermatome, testing modalities for light touch and sharp/dull discrimination.

SENSORY TESTING

• Demonstrate normal touch on face/cheek
• Stroke each dermatome region once lightly and briefly across 1cm of skin
• Three Point Scale for light touch and pinprick
  • 0 = absent
  • 1 = impaired (partial or altered appreciation, including hyperesthesia)
  • 2 = intact (same as face)
• Notes
  • Light touch is tested with cotton wisp
  • Pin point is tested with a disposable safety pin
  • In testing pin sensation (sharp), the inability to distinguish between the head and the point is graded as 0 (absent).
  • The sensory level is the last (most caudal) level with normal (2/2) sensation for both light touch and pin prick sensation, and will all normal rostral dermatomes.

ASIA IMPAIRMENT SCALE CLASSIFICATION

• Record motor level bilaterally
• Record sensory level bilaterally
• Record sacral (S4-5) results
• Neurological Level of Injury
  • The most caudal (lowest) level with normal motor and sensory function
• Single neurological level box added to bottom of ASIA sheet (new)
• Determine final ASIA Impairment Scale classification
ASIA IMPAIRMENT SCALE CLASSIFICATION

Terminology
- Paraplegia: loss of motor and/or sensory function in thoracic, lumbar, or sacral (but not cervical) segments
- Tetraplegia: loss of motor and/or sensory function in cervical segments
- Complete Injury: complete absence of sensory and motor function in the lowest sacral segment (S4/5)
- Incomplete Injury: presence of at least partial sensory or motor function in the lowest sacral segment (S4/5)

AIS A = complete injury
- No motor function (more than 3 segments) below motor level
- Partial or complete sensory preservation (S4/5), plus
- Motor function more than 3 segments below motor level
- Majority (>50% of key muscles) below injury level < 3/5

AIS D = incomplete injury
- Partial or complete sensory preservation (S4/5), plus
- Motor function more than 3 segments below motor level
- Majority (>50% of key muscles) below injury level >/= 3/5

AIS E = sensory and motor function returned to full function following SCI

Use motor level to distinguish between B and C
Use neurologic injury level to distinguish between C and D
Use non-key muscle groups to determine sensory vs. motor incomplete status
- B vs. C or D
- ZPP = zone of partial preservation
- Only in complete injuries = AIS A
- Motor = segments below the motor level that have partial sparing of strength
- Sensory = segments below the sensory level that have partial sparing of sensation
- Record for each side, R and L
- If there is no sparing of motor or sensory function below the motor or sensory levels, the levels themselves are documented in the boxes on the worksheet
- AIS A with sensory & motor level of T6 with no other sparing
- The ZPP recorded is T6

Can you be a motor incomplete if there is no VAC?
- AIS "C" vs. "D":
  - To be motor incomplete (AIS C & D):
    - need to be sensory incomplete with motor sparing more than 3 levels below the motor level on that side, OR
    - have VAC
  - *Do not need VAC if meet the criteria of motor sparing 3 levels below the motor level
  - For AIS D, need to have motor sparing of >/= 3/5 in at least 50% of muscles below the NLI.
AIS EXAM HISTORY SUMMARY

Frankel Classification - 1969
ASIA Standards – 1982
Revision – 1989
ASIA Impairment Scale – 1992
Revisions – 1996
Revisions – 2000
Revisions – June 2011

JUNE 2011 REVISIONS

7th edition of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)

ASIA INTERNATIONAL STANDARDS 2011

• Changes have been made to be consistent with the InStep training program.
  • A 6-module course enabling clinicians to perform accurate and consistent neurological examinations.
  • Available on the ASIA Learning Center website
• 2011 Reference Manual is currently available
• Next revision ?May 2015
• Pediatric considerations: WeeSteP

ASIA INTERNATIONAL STANDARDS 2011

Limitations
• Exam can change over time
• In presence of other disorders (plexus, peripheral neuropathy, diabetes, etc.) may be unable to have accurate results
• Does not test all muscle groups that impact function
• Does not test all sensory modalities (i.e. proprioception, vibration, temperature)
ASIA WORKSHEET CHANGES

KEY POINTS

- Use motor level to distinguish between B and C
- Use NLI to distinguish between C and D
- Use non-key muscle groups to determine sensory vs. motor incomplete status (B vs. C)
- Determination that if sensation is abnormal at C2, the level that should be designated as CI.
  - While further study is required, it was felt that this would allow for consistency amongst clinicians.
- In patients who have light touch or pin prick sensation at S4-5, examination for DAP is not required as the patient already has a designation for a sensory incomplete injury, although this is still recommended to complete the worksheet.
  - The rectal examination is still required however, to test for motor sparing (i.e. voluntary anal sphincter contraction).
FACTORS IMPACTING PROGNOSIS

Initial mechanism of injury
- Cord transection & hemorrhage >> worse
- GSW & bilateral facet dislocation >> worse
- Edema & contusion >> better
- Spinal stenosis & unilateral facet dislocation >> better

Neurological classification
- Incomplete injury >> better
- Pin sensory sparing >> better
- Presence of motor function below NLI >> better

Medical co-morbidities

Patient motivation

Support system

Availability of resources and services

SCI sequelae

FUNCTIONAL OUTCOMES BY AIS CATEGORY

<table>
<thead>
<tr>
<th>AIS D (at 1 year)</th>
<th>Admit AIS (72hr)</th>
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<tbody>
<tr>
<td>• A</td>
<td>• 0-5%</td>
</tr>
<tr>
<td>• B (light touch)</td>
<td>• 20-25%</td>
</tr>
<tr>
<td>• B (pin prick)</td>
<td>• 40-50%</td>
</tr>
<tr>
<td>• C</td>
<td>• 60-75%</td>
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</table>

FUNCTIONAL OUTCOMES BY AIS CATEGORY

- Most patients ~80% with complete injury recover 1 motor level
- For muscle grade of 0/5:
  - 25-50% will be at 3/5 in one year
  - 75-100% will be at 1 or 2/5 in one year
- For muscle grade of 1 or 2/5:
  - 90% will be at 3/5 in one year
- Greatest rate of change in first 6-9 months.
- Incomplete injury: recovery up to 2 years

FUNCTIONAL OUTCOMES BY AIS LEVEL

- C1 – C3: PWC, EUI, Ventilator, phrenic nerve stimulator
- C4: may need CPAP or BiPAP for nocturnal hypoventilation
- C5-C6: dependent for self-care and transfers
- C6: some ADLs with setup, i.e. feeding, dependent for transfers
- C7: tenodesis/grasp, more ADLs, i.e. upper body, feeding, assist with transfers and bed mobility, MWC for short distances
- C7: I with most ADLs and mobility, MWC, transfers, dressing, driving
  - Can live independently
- C8 – T1: bowel/bladder independence, improved grasp and dexterity, PWC or MWC, I with bed mobility and transfers, I for ADLs

WHITNEY ET AL. 1999
FUNCTIONAL OUTCOMES BY AIS LEVEL

- T2 – L1: MWC, abdominal strength beginning at T6, improved sitting balance, standing with bracing, some ambulation with KAFO and walker (energy consumption)
- L2 – L3+: ambulation >> least restrictive device +/- orthotics
  + Community ambulators

AMBULATION

- Age
- Spasticity
- Balance
- Proprioception (at least hip and ankle)
- LE muscle strength
  + Need bilateral hip flexor strength (at least one >/= 3/5) +
  + Unilateral knee extensor >/= 3/5
  + Bracing
    + 1 long leg brace (KAFO) +
    + 1 short leg brace (AFO)

AMBULATION

- Prognosis for community ambulation at 1 yr based on exam 30 days post injury (LEMS at 1 month)

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<th>1-9</th>
<th>10-19</th>
<th>20-29</th>
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</thead>
<tbody>
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<td>Complete tetraplegia</td>
<td>0%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Incomplete tetraplegia</td>
<td>21%</td>
<td>63%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Complete paraplegia</td>
<td>49%</td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Incomplete paraplegia</td>
<td>33%</td>
<td>70%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>


AMBULATION

- Ambulating at discharge from acute rehab
- AIS A < 1%
- AIS B 1-15%
- AIS C 26-40%
- AIS D 61-75%
- T12 level and above, do not expect community or household ambulation
- L2 and below, best prognosis for community ambulation
- Pinprick sensory preservation better prognosis for ambulation

KAY ET AL. 2007, BURNS ET AL. 1997
MECHANISMS FOR NEURO RECOVERY

- Remyelination – neuropraxia (0-3 months)
- Hypertrophy of innervated muscles (3-6 months)
- Peripheral sprouting from intact nerves to denervated muscles (3-6 months)
- Axonal regeneration (12-18 months)

CENTRAL CORD SYNDROME

Most common of spinal cord syndromes
Cervical injury to central part of cord
Hyperextension
Older patient, spondylosis, cervical stenosis
Osteophytic spine, Spondylosis
Arm weakness > leg weakness
"Walking Quad"
"Person in a Barrel"
Sacral sparing
Bladder and bowel dysfunction => good prognosis
Ambulation => good prognosis 30-86% return to ambulation
BROWN-SEQUARD SYNDROME
Cord hemisection injury
Ipsilateral loss of motor and proprioception
Contralateral loss of pain and temperature sensibility
crossing of pain and temperature fibers at spinal cord level
Usually penetrating injury, i.e. stabbing, GSW
Favorable prognosis for ambulation, ADL, independence, and bowel/bladder

ANTErior CORD SYNDROME
Anterior distribution cord injury
Vascular etiology
Anterior spinal artery: anterior 2/3 of spinal cord
AAA repair
Variable loss of motor and sensory function
Proprioception & vibration preserved
Poor prognosis for motor recovery

POSTERIOR CORD SYNDROME
Posterior spinal artery to posterior columns
Loss of proprioception, deep touch, and vibration
Temperature/pain less affected
Sparing of motor

CONUS MEDULLARIS
Spinal level, skeletal injuries T10 – L2
Lesions affecting lower sacral segments of spinal cord S1 – S5
Rare
Usually complete injury
Bowel, bladder, and sexual dysfunction
Lower motor neuron injury
Saddle anesthesia
Poor prognosis
CAUDA EQUINA SYNDROME

Lumbo-sacral nerve root injury: L2 and caudal
Pain
BLE polyradicular distribution
No spinal cord involvement
Usually incomplete injury
Asymmetric
Motor weakness
Areflexic bowel and bladder
Better prognosis

QUESTION 1

26yo M status post diving accident with cervical spine trauma. AIS exam performed and sensory level is C4. The elbow flexors are graded as R 4 and L 3. The motor level would be:

• C4
• C5
• C6
• Cannot Determine

QUESTION 1

C5:

Motor strength at C5 on both sides is > 3 with the corresponding ‘muscle function’ above it considered normal; presumably if there were a C4 key muscle to test, it would be graded as normal since the sensation at C4 is intact.
QUESTION 2

45yo M status post MVA with sensory level of C2. The C5 key muscles are 4/5. What is the motor level?

- C2
- C3
- C4
- C5

QUESTION 2

C2:

The presumed motor levels at C3 and C4 are not considered normal (since the C3 and C4 sensory dermatomes are not normal), and the rule of all levels rostral needing to be intact is not met.

QUESTION 3

37yo F status post skiing accident with sensory level of T12. Her arm strength is 5/5 bilaterally. Deep anal pressure sensation is present. Her leg strength is:

- Right
  - L2: 1
  - L3: 3
  - L4: 0
  - L5: 0
  - S1: 0
- Left
  - L2: 2
  - L3: 2
  - L4: 0
  - L5: 0
  - S1: 0

What is the motor level?

QUESTION 3

T12:

- Muscle strength in UE key muscles is 5/5
- Sensory level is T12, AIS B
- Note: how to grade the motor level when in the intervening levels, there is no key muscle group.
- Rule: defer to the sensory level
- Note: how to label AIS “B” vs “C”
- Rule: need to have motor sparing more than 3 levels below the motor level
QUESTION 4
Which AIS classification level includes a Zone of Partial Preservation (ZPP)?
- AIS A
- AIS B
- AIS C
- AIS D
- Both AIS C and D
- All of the above

QUESTION 4
ZPP = zone of partial preservation only in complete injuries = AIS A
- Motor = segments below the motor level that have partial sparing of strength
- Sensory = segments below the sensory level that have partial sparing of sensation
- Record for each side, R and L
- If there is no sparing of motor or sensory function below the motor or sensory levels, the levels themselves are documented in the boxes on the worksheet:
  - AIS A with sensory & motor level of T6 with no other sparing
  - The ZPP recorded is T6

QUESTION 5
A person with C5 AIS A spinal cord injury should eventually become independent in which of the following:
- Intermittent catheterization
- Transfer to level surfaces
- Feeding
- Bathing

QUESTION 5
A person with C5 AIS A spinal cord injury should eventually become independent in feeding, and in UE dressing with assistive devices, in driving a power wheelchair, and in propelling a manual wheelchair short distances on level surfaces.
EXAMPLE 1

EXAMPLE 2
NOTE

• If there is a sensory deficit in C5-T1, with no motor deficit, the rule (confirmed by ASIA committee) is that the motor level as T1 on that side.

• This reflects that you defer to the sensory for motor level where there is no myotome (i.e. at C2-4, T2-L1, S3-5). The problem in this case is that it would be misleading to say either the R motor level is C7 (because that muscle is fine) or that it's L3 (because the spinal cord has been altered at C6, as demonstrated by the altered sensation). So the solution is a bit of a compromise – you say the motor level is the last place where you are absolutely certain about motor function – T1.

• This situation would be different if the deficit in C8 right was pre-existing or for some reason not due to SCI (noted as 1*) – then it would be L3.

RESOURCES AND REFERENCES

• http://isncscialgorithm.com/
• http://www.academyscipro.org/
• http://www.uab.edu/medicine/sci/?durki=21392
• http://www.pva.org/site/c.sflw8xSLi/ct/s.6355817/s.3406/Spinal_Cord_Research_Education.htm
• http://asia-spinalinjury.org/
• http://www.academyscipro.org/