Spinal Cord Injury: Overview, Issues and Rehabilitation

Kessler Institute for Rehabilitation
September 7, 2017

Presented by: Jay Rosenberg, MSN, CRRN, CNML
Chief Nursing Officer
Kessler Institute for Rehabilitation, NJ
Spine Anatomy

Axial (Overhead) View

Lateral (Side) View
Spine Anatomy

- 7 Cervical vertebrae
- 12 Thoracic vertebrae
- 5 Lumbar vertebrae

Cervical Nerves: Head, neck, breathing, upper arms, wrists, hands.

Thoracic Nerves: Chest and abdominal muscles, internal organs.

Lumbar Nerves: Leg muscles.

Sacral Nerves: Bathroom capabilities, ability to become parents.

Sacrum
Spine Anatomy

- Vertebral Body
- Spinal Cord
- Nerve Root
- Neuroforamen
DEFINITION OF SPINAL CORD INJURY

• The occurrence of an acute traumatic lesion of neural elements in the spinal canal (spinal cord and cauda equina), resulting in temporary or permanent sensory and/or motor deficit.

• The clinical definition of spinal cord injury excludes intervertebral disc disease, vertebral injuries in the absence of spinal cord injury, nerve root avulsions and injuries to nerve roots and peripheral nerves outside the spinal canal, cancer, spinal cord vascular disease, and other non-traumatic spinal cord diseases.
Spinal Cord Injury Data (February 2015)

- Incidence: 12,500 per year (40 cases per million)
- Prevalence: 276,000
- Average age: 42
- Gender: 80% male
- Ethnicity
  - Caucasian 64%
  - African American 23%
  - Hispanic/Native American/Asian/Other 13%
Spinal Cord Injury Data
(February 2015)

- Marital Status at time of injury
  - Single: 51.6%
  - Married: 32.7
  - Divorced: 9.5
Nontraumatic SCI

- *Spinal Stenosis
- *Cancer
- Transverse Myelitis
- Radiation myelopathy
- Motor neuron disease
- Vascular ischemia
- Multiple Sclerosis
- Vitamin B12 deficiency
- Infectious abscess
- Syringomyelia
Nontraumatic SCI

• More likely to be older, married, female and retired
• Have shorter length of stay in rehabilitation
• Commonly presents with paraplegia (73%) and incomplete injuries (90%)
• Lower incidence of medical complications
  – spasticity, orthostasis, pressure ulcers, dysreflexia, DVT and pneumonia
What Is a Traumatic Spinal Cord Injury?

- Sudden, traumatic blow to the spine that fractures or dislocates vertebrae.

- The damage begins at the moment of injury when displaced bone fragments, disc material, or ligaments bruise or tear into spinal cord tissue.
Why Is This a Problem?

• Changes in blood flow cause ongoing damage
• Excessive release of neurotransmitters kills nerve cells
• An invasion of immune system cells creates inflammation
• Free radicals attack nerve cells
• Nerve cells self-destruct
• Secondary damage takes a cumulative toll
Etiology  (Since 2005)

- MVA: 36.5%
- Falls: 28.5%
- Violence: 14.3%
- Sports: 9.2%
- Others: 11.4%

-In 1990’s Violence Peaked, Accounting for 24.8%
-Falls Is Most Common Cause in Persons >45 Y.O.
Sports Injuries

- Diving (most common)
- Football
- Snowboarding
- Horseback riding
- Surfing
- Gymnastics
- Trampoline
- Wrestling
Violence
Individual (usually elderly) falls forward, striking chin or face, causing forceful hyperextension and backward thrust of neck.
Average Length of Stay in days

- Acute Care: 11 (was 24) –aka “onset days”
- Rehab: 36 (was 98)

Financial Implications of SCI

<table>
<thead>
<tr>
<th>Severity of Injury</th>
<th>Average Yearly Expenses (in February 2013 dollars)</th>
<th>Estimated Lifetime Costs by Age At Injury (discounted at 2%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First Year</td>
<td>Each Subsequent Year</td>
</tr>
<tr>
<td>High Tetraplegia (C1-C4) AIS ABC</td>
<td>$1,044,197</td>
<td>$181,328</td>
</tr>
<tr>
<td>Low Tetraplegia (C5-C8) AIS ABC</td>
<td>$754,524</td>
<td>$111,237</td>
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<tr>
<td>Paraplegia AIS ABC</td>
<td>$508,904</td>
<td>$67,415</td>
</tr>
<tr>
<td>Incomplete Motor Functional at Any Level AIS D</td>
<td>$340,787</td>
<td>$41,393</td>
</tr>
</tbody>
</table>

**Life Expectancy**

Life expectancy is the average remaining years of life for an individual. Life expectancies for persons with SCI are still significantly below life expectancies for those with no SCI and have not improved since the 1980's. Mortality rates are significantly higher during the first year after injury than during subsequent years, particularly for severely injured persons.

<table>
<thead>
<tr>
<th>Age at Injury</th>
<th>No SCI</th>
<th>AIS D - Motor Functional at Any Level</th>
<th>Para</th>
<th>Low Tetra (C5-C8)</th>
<th>High Tetra (C1-C4)</th>
<th>Ventilator Dependent - Any Level</th>
<th>AIS D - Motor Functional at Any Level</th>
<th>Para</th>
<th>Low Tetra (C5-C8)</th>
<th>High Tetra (C1-C4)</th>
<th>Ventilator Dependent - Any Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>59.0</td>
<td>52.0</td>
<td>44.6</td>
<td>39.6</td>
<td>35.3</td>
<td>18.6</td>
<td>52.4</td>
<td>45.1</td>
<td>40.4</td>
<td>36.6</td>
<td>24.9</td>
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<tr>
<td>40</td>
<td>40.0</td>
<td>33.7</td>
<td>27.2</td>
<td>23.1</td>
<td>19.7</td>
<td>8.4</td>
<td>34.0</td>
<td>27.7</td>
<td>23.7</td>
<td>20.7</td>
<td>12.3</td>
</tr>
<tr>
<td>60</td>
<td>22.7</td>
<td>17.5</td>
<td>12.7</td>
<td>9.9</td>
<td>7.8</td>
<td>2.0</td>
<td>17.7</td>
<td>13.0</td>
<td>10.3</td>
<td>8.4</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Common Neurological Levels of Injury
Cause by Gender
Employment after SCI

• 12.2% at 1 year
• 34.4% at 20 years post-injury
• Slightly higher for paraplegia
• If person returns to work:
  – within 1 year - same job
  – after 1 year - different job
Causes of Death in SCI

• Leading COD used to be renal failure.
• Significant improvement in urological management have resulted in dramatic decrease of this.
• Currently, the leading causes of death are:
  – Pneumonia
  – Septicemia
MRI in SCI

• MRI depicts the structure of the cord.
• MRI findings correlate with the degree of functional deficit at the time of injury and the capacity for neurologic recovery.
• The ultimate clinical value of MRI in SCI:
  – Selection and monitoring of patients for novel forms of therapeutic intervention.
Negative Prognosticators on MRI

- Presence of spinal cord hemorrhage
- Length of spinal cord hemorrhage
- Length of spinal cord edema
- Spinal cord compression
Predicting Outcome

- Fundamental is the knowledge and skill of performing an accurate examination based on the *International Standards*
- Provides basic definitions of the most common terms used by clinicians in SCI
- Describes the neurological examination
- Allows prognostication for outcome
Importance of Comprehensive Neurological Exam - ASIA

• Evidence-based
• Valid, reliable, consistent
• Allows for prognosis
  – Neurological
  – Functional (Rehabilitation goals)
• Allows study of interventions
  – Rehabilitation
  – Drugs
Neurologic Examination

• **American Spinal Injury Association (ASIA)**
  - A = Complete – No Sacral Motor / Sensory
  - B = Incomplete – Sacral sensory sparing
  - C = Incomplete – Motor Sparing (<3)
  - D = Incomplete – Motor Sparing (>3)
  - E = Normal Motor & Sensory
Definitions

- Sensory level
- Motor level
- Neurological level of injury (NLI)
- Complete vs. Incomplete injury
ASIA IMPAIRMENT SCALE

- **A = Complete**: No motor or sensory function is preserved in the sacral segments S4-S5.
- **B = Incomplete**: Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5.
- **C = Incomplete**: Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.
- **D = Incomplete**: Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.
- **E = Normal**: Motor and sensory function are normal

CLINICAL SYNDROMES

- Central Cord
- Brown-Sequard
- Anterior Cord
- Conus Medullaris
- Cauda Equina
Sensory Examination

- 28 key dermatomes
- Tested for light touch and PP modalities
- Face as a control point
- S4-5 is a single dermatome
- Deep anal sensation
- 3 point scale (0-2)
Pin Sensory Examination

- Clean safety pin
- Must be able to distinguish between the pin (sharp) and dull edge
- **Absent** (0) = includes the inability to distinguish b/w sharp and dull
- **Impaired** (1) = can distinguish, but the pin is not felt as sharp as on the face
- **Normal** (2) = pin is as sharp as on the face
Light Touch Sensory Scoring

- A cotton tip applicator
- Stroke across the skin moving over a distance **not** to exceed 1 cm
- For dermatomes C6-C8, the dorsal surface of the proximal phalanx is tested
- Testing the chest & abdomen at the midclavicular line.
STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

C5  R  L
Elbow flexors (scoring on reverse side)

C6  R  L
Wrist extensors

C7  R  L
Elbow extensors

C8  R  L
Finger flexors (median phalanges of middle finger)

T1  R  L
Finger abductors (little finger)

UPPER LIMB

TOTAL (MAXIMUM) 25

Sensory Points:

KEY SENSORY POINTS

T2  R  L

T3  R  L

T4  R  L

T5  R  L

T6  R  L

T7  R  L

T8  R  L

T9  R  L

T10 R  L

T11 R  L

T12 R  L

L1 R  L

L2 R  L

L3 R  L

L4 R  L

L5 R  L

L6 R  L

L7 R  L

S1 R  L

S2 R  L

S3 R  L

S4-5 R  L

Voluntary anal contraction (Yes/No)

Any anal sensation (Yes/No)

PIN PRICK SCORE (max: 112)

LIGHT TOUCH SCORE (max: 112)

LOWER LIMB

TOTAL (MAXIMUM) 25

NEUROLOGICAL LEVEL

Sensory Motor

COMPLETE OR INCOMPLETE?

ZONE OF PARTIAL PRESERVATION

SENSORY MOTOR

ASIA IMPAIRMENT SCALE

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Sensory Testing

• The S4-5 dermatome tested for both pin and light touch; represents the most caudal aspect of the spinal cord.

• *Deep anal sensation* - on rectal digital examination the patient is asked to report any sensory awareness.
  
  – Recorded as either “present” or “absent”.

The sensory level of injury is the last intact level on both sides of the body for both pin prick and light touch.
Motor Examination

• 10 key muscle groups on each side
• Other muscles are optional
• Tested in the supine position
• 6 point scale (0-5)
• Anal sphincter exam
Motor Level

- Level at which strength is $\geq 3/5$, with the levels above it normal (5/5)
- Last normal motor level, right and left
Neurological Level

• Lowest level with normal motor and sensory function
  – Motor > 3/5, with level above 5/5
  – Sensory intact bilaterally
Complete vs Incomplete

• Complete = No sensory or motor function in the lowest sacral segments (S4-5)

• Incomplete = Preserved motor or sensory function that includes the lowest sacral segments (S4-5)
Complete Vs. Incomplete Injury

“Sacral Sparing”

- Light touch sensation at S4/5
- Pin at S4/5
- Deep anal sensation
- Voluntary anal contraction
Complete Injuries (ASIA A)

- Patients usually recover 1 level of function.
- Most recovery occurs within the first 6 months; the greatest rate of change within the first 3.
- Motor recovery can continue, with lesser gains seen in the second year.
Incomplete Injuries

• Greater recovery than for a complete injury
• Recovery is highest in the first 3 months
• “The sky’s the limit!”
SCI Incomplete Syndromes

- Central Cord
- Brown-Sequard
- Anterior Cord
- Conus Medullaris
- Cauda Equina
ASIA Classification

- Incomplete tetraplegia - 29.5%
- Complete paraplegia - 27.9%
- Incomplete paraplegia - 21.3%
- Complete tetraplegia - 18.5%

- Increasing incomplete injuries
Upper Motor Neuron Injury

- Injury **above** the sacral spinal cord segments, resulting in spastic paralysis.

Lower Motor Neuron Injury

- Injury involving the sacral segments of the spinal cord, usually resulting in flaccid paralysis.
Zone of Partial Preservation

- Segments below the NLI with preservation of sensory or motor findings

- Only used in ‘complete’ injuries
C1-C4 Levels

- Often requires assisted ventilation
- Dependent in care
  - ADLs, bowel and bladder
- Independent in instructing others in care
  - (i.e. ROM, transfers)
- Mechanical lifts
- Power mobility
- Use of technology to control their environment
- Discharge to home
Environmental Control Units

• A way to control the environment through the use of a technological adaptation such as a switch or voice command.

• Low Tech vs High Tech
Mouthstick & Docking Station

Hands Free Phone
RadioShack ($60)

Peg in cuff for page turning

Book Holder
InVoca Hands Free Voice Activated Remote

Commands TV, VCR, DVD, & Cable satellite
Accepts 54 voice commands
Performs multi-step functions with a single command
Recognizes 4 voices
Cost $50
Sold through Brookstone.com
C5 Level

- Gains biceps muscle
- Functional skills with splints (universal cuff)
- Transfers with assistance
- Propel manual wheelchair on level surfaces
- Power wheelchair
- Power assist wheelchair
- Van driving
Feeding Equipment

- Universal cuff
- Adaptive utensils
  - Weaved and straight forks
- Cuff type knife
- Plate guard
- Dycem under dish
- Long straw with straw holder
C6 Level

- Gains wrist extensors
- Independent feeding
- Assists with upper body dressing
- Transfers with assist
- Wheelchairs
  - manual
  - power assist
  - power
Transfer Boards

Writing Utensils

Universal Cuff
Power Assist Wheelchairs

- Push rim activated power assist for manual wheelchair
- No wires or cables
- Motor & batteries in wheel hubs or under w/c
- Doesn’t interfere with seating systems
C7 - T1 Levels

- C7 - Gains elbow and finger flexors
- C8 - long finger flexors
- T1 - finger abductors

**C7 is the key level for functional independence**
- feeding, grooming, dressing, transfers, and wheelchair mobility
Advanced Wheelchair Training

- curbs
- ramps
- wheelies
- floor to wheelchair transfers
- escalators
- rough terrain
Standing

• Improves self concept
• Decreases spasticity
• Reduces urinary calcinosis and hypercalcemia
• Aides digestion and bladder function
• Improves orthostasis
• Prevents pressure ulcers
• Does not decrease bone mineral loss
Nursing Assessment of the Spinal Cord Injured Patient
INITIAL ASSESSMENT
Nursing History

• Level, type, and degree of completeness of the spinal cord injury
• Cognitive status
• Co-morbidities and associated injuries
• Previous medical/surgical history
• Pre-injury level of function
• Current medication regimen including allergies
Nursing History

• History of smoking, alcohol use, or use of any other OTC or recreational drug

• Normal elimination pattern pre-injury

• Pre-injury nutritional status and usual dietary practices
Adjustment to SCI

- Psychologists see patients on a regular basis for private counseling sessions.
- Screening, assessment, and treatment for depression, anxiety, suicide
- Provide strategies for coping and promoting control, self-esteem, and independence.
- Equally important, the psychologists also consult with the families and friends of the patients.
- Assess family roles, social support, and community reintegration
Physical Examination

- Neurological
- Musculoskeletal
- Nutrition
- Elimination
- Respiratory
- Cardiovascular
- Psychosocial
- Integumentary
- Sexual
Determinants of Recovery

- *Complete vs incomplete injury*
- Initial level of injury
- Initial strength of the muscles
The Road to SCI Care

• “an ailment not to be treated”
  – Ancient Egyptian physician

• Prior to WWII, life expectancy was < 2 years
Spinal Cord Injury: Rehabilitation

• Goal is to maximize
  – medical
  – physical
  – psychological
  – social/recreational
  – vocational

... function of the patient
Rehabilitation Program

• Not a recipe to achieve the goals
• Using neurological status as a starting point
• Patient should be aware of the goals
• Shift from the “sick participant” to the “active consumer”.
SCI Rehabilitation

1. Medical issues
2. Mobility
3. ADL
4. Adjustment
5. Driving
6. Vocational
7. SCI Education
8. Equipment
9. Family training
10. Recreation
11. Peer support
Spinal Cord Injuries

• More people are surviving a SCI
  – older age (>10% over age 65)
  – higher level of injury
• Greater Return to Functional Activities
  – Improved medical and surgical management
  – Rehabilitation interventions
  – Research and technology
Respiratory Considerations After SCI
Respiratory Complications

• Many reasons:
  – Paralysis of muscles of ventilation
  – Loss of ability to cough (abdominals)
  – Injuries to chest
  – Pulmonary injuries

• Phrenic Nerve innervates the diaphragm at C3-5. Injury to that area will lead to ventilatory compromise!
Respiratory Complications in SCI

- In a prospective study the incidence of respiratory complications overall is 67%
  - Atelectasis (36.4%)
  - Pneumonia (31.4)
  - Ventilatory failure (22.6%)
  - Pleural effusion (22.2%)
  - Pulmonary edema (13.4%)
  - ARDS (7.3%)
Respiratory Dysfunction After SCI

- C2 and higher
  - Need ventilation
  - Need initial ventilation
  - Potential to wean (51-83%)
  - Breathe independent
  - May need initial vent
  - Passive expiration
  - Weak cough
  - Quiet respiration affected
  - Weak cough
  - No impairment

- C3-C4

- C5 and below

- T1-T5

- T6-T12

- L1 and below
Ventilator Usage in Rehabilitation
Phrenic Nerve Pacing

• Need intact Phrenic Nerve
• May allow 24 hour vent free time & decannulation
• Benefits:
  • Breathing is more physiologic
  • Resumes sense of smell, taste and nl speech
  • Cost savings in the long term
  • Improved quality of life
  • Lower infection rate
  • Increased patient mobility
Diaphragmatic Pacing

- Electrodes inserted into each motor point of diaphragm
- Electrode wires are brought out through the epigastric port tunneled to the chest, and attached to a connecting circuit.
- 12- to 14-week period of gradual strengthening and toning of musculature
Respiratory Complications

• Manually Assisted “quad” Cough
  – If VC<1500 ml precede by deep breath
  – Give an abdominal thrust with cough
  – Produces 5-7 L/sec peak cough flow
  – Applied frequently/labor intensive
  – May be inadequate during URI
  – Caution with newly placed vena cava filter
Respiratory Complications: Mechanically assisted cough

In-exsufflator, by Emerson Co - (Cof-flator)

- positive pressure insufflation cycle
- negative pressure exsufflation cycle
- anesthesia type mask or trach/ET tube
- 80 cm H2O pressure drop in <0.2 seconds
- sustained for 3 seconds
- 7-11 L/sec PCEF
Coughhalator: Mechanism
Alteration in Skin Integrity After SCI
Pressure Ulcers

• High frequency
• Increased morbidity
• Increased mortality
• High cost
  – Direct and indirect
Pressure Ulcers in SCI

**Supine**: sacrum, heels, occiput, scapula, elbows

**Sitting**: ischial tuberosities, gluteal folds, ventral foot

**Side-lying**: greater trochanters, malleoli, ears

**Prone**: knees, shins
Necrotic Tissue in a Wound
Weight Shifts

• Every 15-30 minutes for >90 secs
  – (not 30-45 secs)

• C5 and above:
  – Anterior with loops
  – power tilt

• C6 – lateral or anterior wt shift

• C7 – lateral, anterior or push-up wt shift
Temperature Regulation After SCI
Temperature Regulation

• After SCI, the body often loses ability to maintain homeostasis of internal temperature.

• Why?
  – When we are cold, we shiver to increase muscle activity and raise core temperature. This is not possible for a SCI person.
  – When we are warm, our vascular system vasodilates, and we also perspire. This is not possible for a SCI person.
Temperature Regulation

- So what happens?
  - The SCI person’s body temperature becomes dependent on the ambient temperature.
  - When the ambient temperature is cool, the core temperature drops.
  - When the ambient temperature is warm, the core temperature rises.
- This is called *poikilothermia.*
Temperature Regulation

How do we fix it?

- Hyperthermia
  - Cooling blankets
  - Fans
  - Ice Packs
  - Air conditioning
  - Appropriate clothing

- Hypothermia
  - Warm blankets
  - Heated room
  - Appropriate clothing
Common Complications of Spinal Cord Injury
Autonomic Dysreflexia
Autonomic Dysreflexia

- Syndrome of massively uncontrolled sympathetic nervous system discharge that occurs in patients with SCI above T6

- Initiating stimulus is below T6

- The most common causes are bowel and bladder
1. Full bladder or stimulus from bowel

2. Afferent stimulus

3. Massive sympathetic response

4. Widespread vasoconstriction

5. Hypertension

6. Baroreceptors in blood vessels detect hypertensive crisis — signal brain

7a. Heart rate slowed

7b. Descending inhibitory signals blocked at spinal cord injury

Level of spinal cord injury = T6 or above
Autonomic Dysreflexia: Signs & Symptoms

“The triad of headache, sweating, and cutaneous vasodilation is almost diagnostic of autonomic dysreflexia”

(Eltorai 2001)
"I have this terrible ice cream headache all the time."
Autonomic Dysreflexia: Signs & Symptoms

- Hypertension (SBP can be 300 mmHg!)
- Piloerection
- Blurred vision
- Nasal congestion
- Anxiety
- Bradycardia
- “Ice Cream Headache”
Autonomic Dysreflexia: Complications

- Hemorrhage
  - Retinal, Sub-Arachnoid, Intra-Cranial
- Seizure
- Myocardial Infarction
- Death

- **CAN BE FATAL IF NOT TREATED**!
Autonomic Dysreflexia: Causes

- **Bladder** - Most common cause
  - Kinked Catheter, UTI, retention, non-adherence to Intermittent Catheterization Program
  - Accounts for 75-82% of cases

- **Bowel**
  - Distension, fecal impaction, hemorrhoids
  - Accounts for up to 20% of cases
Autonomic Dysreflexia: Causes

- Pressure Sores
- Tight Clothing
- Fractures
- Ingrown Toenail
- DVT or PE
- Body Positioning
- Invasive Procedures

- Acute Abdomen
- Heterotopic Ossification
- Labor and Delivery
- Menstruation
- Intercourse
- Pain
- Functional Electrical Stimulation
Autonomic Dysreflexia: Treatment

- Recognize symptoms
- **Raise the head**, loosen tight clothing and leg bags
- Check catheter
- Evaluate bowel
- Remove precipitating stimuli
- Use topical anesthetic for bowel program/ IC’s as indicated
Autonomic Dysreflexia: Treatment

• Monitor BP q 2-5 minutes

• For systolic BP > 150 mmHg, pharmacological management may be necessary. (Nitro paste above the level of injury or “bite and swallow” Nifedipine)

• Monitor patient after episode for possible recurrence, and for rebound hypotension if Nitro paste is used
Bradycardia
Bradycardia

- Bradyarrhythmias are very common but cardiac arrest is rare
- Proposed mechanism: Disruption of cardiac sympathetic influences because of spinal shock
- Reflex vagal activity (tracheal suctioning, defecation, belching) can cause sinus pauses because it is unopposed by sympathetic activity
Spinal Shock

- State of transient reflex depression of cord function, below the level of injury
- Flaccid paralysis, including bladder
- At T6 and above, decreased vascular tone
- Cervical levels – Lack of sympathetic response
- Usually lasts for weeks to months
Bradycardia
Bradycardia

- Not clinically significant if there are no symptoms, BP is stable, and HR>45
- The higher the injury, more likely to have cardiac disturbances
- Monitor closely when suctioning, turning in bed, defecating
- Most pronounced 2-3 weeks after injury
- Resolves as spinal shock resolves
- Normal rhythm usually by about 6 weeks
Bradycardia: Management

• Prevention and close monitoring
• If severe, may need pre-treatment with atropine 0.1 to 1 mg IV 10 – 15 minutes prior to suctioning, or hyperventilation immediately before
• Treat symptomatic bradyarrhythmia with atropine
Bradycardia

- Transvenous pacing if other options fail. Some patients may require a permanent demand pacemaker
Orthostatic Hypotension
Orthostatic Hypotension

• A fall in blood pressure as patient is positioned towards upright

• More likely in high injuries, complete injuries, and those with NLI above T6
Orthostatic Hypotension: Symptoms

- Lightheadedness
- Dizziness
- Nausea
- Pallor
- Syncope
- “Tilt me back, Tilt me back !!”
Orthostatic Hypotension: Mechanism

• In uninjured person, a decrease in BP after sitting up would be sensed by aortic and carotid baroreceptors which would cause sympathetic response of increased HR and vasoconstriction

• This response is absent in certain SCI patients

• Also, venous pooling occurs which limits venous return and cardiac output
Orthostatic Hypotension: Symptoms

• Will lessen with:
  – Time
  – Repeated postural challenges
  – Onset of spasticity
Orthostatic Hypotension: Symptoms

• In time, symptoms lessen due to development of:
  – Vascular wall hypersensitivity
  – Spinal postural reflexes that cause vasoconstriction
  – Improved autoregulation of CV circulation in presence of low perfusion pressure
  – Adaptation of renin-angiotensin system
Orthostatic Hypotension: Prevention

- Careful monitoring of BP in supine and sitting positions
- Slow position changes to the upright
Orthostatic Hypotension: Treatment

• Daily tilting sessions with gradual change to upright (recliner w/c or tilt table)
• Abdominal binders
• Elastic stockings and/or Ace wraps
• Adequate hydration
• Pharmacological Intervention
Orthostatic Hypotension: Treatment

• Pharmacological interventions:
  – Salt tabs 1 GM PO Q.I.D.
  – Midodrine 2.5mg to 10mg PO T.I.D.
  – Fludrocortisone 0.05mg to 0.1mg PO Daily

• Treat patients who are susceptible to Autonomic Dysreflexia very cautiously!
Thromboembolic Disorders in Spinal Cord Injury
Thromboembolic Disorders in Spinal Cord Injury

• 10-64% of SCI patients develop DVT, 80% within first two weeks

• Up to 7% incidence of PE, which is the leading cause of death in acute SCI

• Most develop from deep veins of the LE’s, and are not influenced by degree or level of injury
Thromboembolic Disorders in SCI: Risk Factors

• Virchow’s Triad:
  • Endothelial Damage
  • Venous Stasis
  • Hypercoagulability

• LE fracture

• Peripheral Vascular Disease

• Diabetes Mellitus
• Immobilization
• Obesity
• History of thrombosis
• Malignancy
Consequences of DVT

- Post thrombotic syndrome
- Prolonged edema
- Pressure ulceration
- Pain
- Source of spasticity
- Source of Autonomic Dysreflexia
DVT: Prevention and Treatment

• Clinical Monitoring is difficult due to lack of sensation. Edema and calf size can be good indicators if closely followed.

• “Because the first pulmonary embolism is often fatal, prophylaxis is of critical importance.” (Eltorai 2001)

• Early initiation of prophylaxis is crucial since the highest risk period is during first 2 weeks.
DVT: Prevention and Treatment

• Mechanical
  – External Compression Devices

• Anticoagulation Prophylaxis
  – Low molecular weight Heparin (eg. Lovenox, Fragmin) used

• Vena Cava Filter
DVT: Prevention and Treatment

• Duration of prophylaxis
  – Until discharge for person with incomplete injury or up to 8 weeks
  – 8 weeks for uncomplicated complete motor injury
  – 12 weeks or discharge from rehab for certain complete motor injuries and other risk factors
Vena Cava Filters

- Indications
  - Failed anticoagulation prophylaxis
  - Anticoagulation is contraindicated
  - High level complete Tetra with poor cardiopulmonary reserve
Vena Cava Filters

- Not a substitute for prophylaxis (Clots can still form, this just catches them before PE occurs)

- Low incidence of complications

- PE rate with IVC filter is 2 to 5%
Clinical Practice Guidelines for DVT Prevention in SCI

• Mechanical devices for first 2 weeks (not mandatory)
• Anticoagulation should be started within 72 hours of injury if possible (be aware of black box warning for LMWH)
• Patients who have even minimal motor deficits should be prophylaxed
• Duration of prophylaxis is individualized
• IVC filter in high risk and failed prophylaxis patients
• Reinstitution in chronic patients at high risk (prolonged immobilization, pneumonia)
Spasticity
Spasticity

• “Disruption of the spinal cord interrupts tracts from the cerebral cortex and from the brain stem that inhibit various spinal reflexes. One result of this loss of inhibition is the emergence of spasticity and spasms.” (Eltorai 2001)

• One of the most common and potentially disabling disorders affecting SCI patients.
Spasticity

• Over 70% are “spastic” one year after injury
• Most commonly experienced as a bending of the elbow (flexor) or straightening of the leg (extensor). This is often mistaken as a return of movement by the patient
• Spasms start distally and head proximally (e.g. Stopping finger spasms may decrease spasm of that arm)
Spasticity

• Not all patients require treatment

• Benefits may include:
  – increased stability standing/sitting
  – increased venous return
  – decreased risk of DVT
  – improved functional capability
  – maintenance of muscle bulk
  – increased cough strength
  – reduced bone loss
Spasticity: Consequences

- Mobility
- Hygiene
- Self-care
- Sleep
- Cosmesis
- Self-esteem
- Affect/Mood
- Sexual function
- Functionality
- Pain
Spasticity

• Assessment tools
  – There is no one “gold standard” in use
  – Modified Ashworth (degree of tone)
  – Penn Spasm Frequency (frequency of spasms over past 24 hours as reported by patient)
Spasticity: Treatment Options

• Physical Measures
  – Positioning and stretching
  – Modalities (ice, TENS, biofeedback)
  – Therapeutic exercise (standing, tilt table)
  – Orthotic management
    • Serial casting
    • Extension splints
    • Finger spreaders
    • Pressure plates in shoes
Spasticity: Treatment Options

• Pharmacologic intervention if:
  – Patient has meaningful, functional, realistic goals
  – Physical treatment is ineffective
  – There are no contraindications
Spasticity: Treatment Options

• The medications used most often are:
  – Baclofen (Lioresal)
  – Tizanidine (Zanaflex)
  – Diazepam (Valium)
  – Dantrolene (Dantrium)
Spasticity: Treatment Options

• Injection Techniques
  – Peripheral Nerve Blocks
    • Work on a functional unit of spasticity (arm, leg)
    • Affect all sensory and motor neurons injected
    • Uses local anesthetics (‘Caine drugs)
  – Motor and/or Nerve Blocks
    • Phenol or Alcohol Injection (last longer than ‘Caines)
    • Botulinum Toxin Injection
Botulinum Toxin Injection
Spasticity: Treatment Options

• Intrathecal Baclofen
  – Allows for smaller dose of drug with fewer side effects
  – Therapeutic doses are 1% of oral dose
  – Drug delivered to the fluid surrounding the spinal cord
  – Indications:
    • No response to other treatments
    • Intolerable side effects to oral medications
    • No other alternative except surgery
Spasticity: Treatment Options

- Intrathecal Baclofen (continued)
  - Procedure is surgical (but reversible)
  - A depot pump is implanted into a subcutaneous abdominal pocket and the catheter is threaded directly into the canal below L3 and up to T8 to T10
  - Drug can be infused continually or via bolus
  - Pump is refilled easily and periodically
Spasticity: Treatment Model

- Myelotomy
- Cordectomy

- Neurectomy
- Rhizotomy

- Tenotomy
- Myotomy

- Intrathecal Baclofen

- Selective Posterior Rhizotomy

- Motor Point Blocks

- Nerve or Subarachnoid Blocks

- Medications:
  - Baclofen
  - Dantrolene
  - Diazepam
  - Clonidine

- Physical Modalities:
  - Muscle Cooling
  - Electrical Stimulation
  - Vibration

- Prevent Nociception
- Stretching Program
Bone Loss After Spinal Cord Injury
SCI-induced Osteoporosis

• Multifactorial
  – Hypercalciuria due to imbalance between bone formation and bone resorption
  – Minimal osteoblastic activity, but largely increased osteoclastic action (Bone is being broken down far quicker than it is being made)
  – Lack of muscle traction on bone

• Resembles model of bone loss seen in postmenopausal women.
Bone Loss After SCI

• Below the level of injury there is significant loss
• Complete Injuries > Incomplete Injuries
• Rapid 1-2 % per month occurs in LE, but not vertebral spine
• Stabilizes 1-3 years post injury
Bone Loss After SCI
Fractures With SCI

• 90% of bone fractures occur in the LE’s
• Usually non-traumatic in etiology
• Secondary to loss of bone mineral density
• Occurs in up to 25% of susceptible patients, and increases with duration of injury
Therapeutic Intervention to Prevent Bone Loss

• Weight bearing
  – Tilt table (No documented effect)
  – Weight Supported Ambulation (possible effect)

• Functional Electrical Stimulation
  – Most studies done in chronic patients
  – Most have shown no improvement
  – Positive effect on muscle mass
  – May itself cause a fracture

• No real proof that these modalities are effective at this time.
Therapeutic Intervention to Prevent Bone Loss

• Pharmacological
  – There may be some benefit from the use of bisphosphonates in acutely injured individuals (eg. Fosamax and Actonel)
  – Work by slowing the bone resorption portion of the bone remodeling process, without slowing the bone formation. This gives the body a chance to increase bone density
  – Benefit may be seen in those with incomplete injuries
Neurogenic Heterotopic Ossification
Neurogenic Heterotopic Ossification

- Definition: The formation of new bone outside of its normal location.
- “Hetero” = Different, “Topic” = location, and “Ossify” = to form new bone.
- Formation of mature lamellar bone in soft tissues.
- Not connected to periosteum.
- Pathologically similar to fracture callus and forms in connective tissue between the muscle planes, but not within the muscle itself.
Neurogenic HO: Pathogenesis

- Inflammation and increased blood flow to soft tissue
- Deposition of Calcium Phosphate into IM tissue
- Ossification occurs when the calcified material goes on to form hydroxyapatite crystals
Neurogenic HO: Differential Diagnosis

- DVT
- Fracture
- Hematoma
- Infection
- Tumor
- Arthritis
- Benign Knee Joint Effusion
Neurogenic HO: Incidence

• In SCI patients: In up to 53%

• 10-20% of these are clinically significant

• 3-5% of SCI patients acquire ankylosis (fusion and loss of movement at a joint)

• Most common sites in SCI in order of frequency are: Hip, Knee, Shoulder
Neurogenic HO: Risk Factors

- Spasticity
- Severity of Injury
- Trauma or Prior Surgery to the Joint
- Pressure Ulcer Near the Proximal Joints
- Completeness of SCI
- Age
Neurogenic HO: Clinical Presentation

- Below level of lesion
- Starts 1-4 months post-injury
- Unusual after 1 year
- *Most common physical finding is a decrease in Range of Motion*
- Swelling
- Erythema
- Warmth
- Increasing spasticity
- Low grade fever
Neurogenic HO: Diagnosis

- Triple Phase Bone Scan
  - Detects HO about 10 days earlier than regular X-Rays
- X-Rays
- Lab work
  - Rising Serum Alkaline Phosphatase
  - Creatine Phosphokinase
  - C-Reactive Protein
  - ESR
Neurogenic HO: Treatment

- **Etidronate Disodium**
  - Dosage varies based upon the amount of HO, as well as lab results.

- **Indomethacin**
  - 25 mg PO TID for 3 to 6 weeks after surgery
  - Helps prevent re-growth after excision
  - Not currently used as primary prophylaxis because of risk of ulcers
Neurogenic HO: Treatment

• Warfarin
  – Not frequently used
  – Often difficult to maintain therapeutic levels

• Radiation Therapy
  – Useful after surgery to prevent re-growth

• Physical Therapy
Neurogenic HO: Treatment

• Surgery
  – Used if there is loss of function at joint
  – If done before bone matures, re-growth is likely
  – Wedge resection v. complete resection
  – Wedge resection often has better outcomes for patient, both during surgery and functionally later
  – ROM to be started slowly after surgery
  – Etidronate Disodium and Indomethacain used afterwards
Pain After SCI
Pain

• Neurogenic Pain:
  – Possibly results from damage to nerves in the spinal cord.
  – Actual causative factors are unknown.
  – For some, pain or an intense burning or stinging sensation is unremitting due to hypersensitivity in some parts of the body.
Pain

• Musculoskeletal Pain:
  – E.g. Shoulder pain due to overuse of the shoulder joint from pushing a wheelchair and using the arms for transfers.
Pain

- Treatments include medications, acupuncture, spinal or brain electrical stimulation, and surgery.
- Nursing’s role: Regular assessment of pain on all patients, with appropriate interventions and modalities as needed.
Sexuality after Spinal Cord Injury
Sexuality after SCI

• One of the first thoughts a newly injured person will have is “Can I still have sex?”
• The answer is “Yes!”, but maybe not in the exact same way he or she had it before.
Sexuality after SCI

- The nerves at the level of the spinal cord that control bowel and bladder function also control sexual function. So, if there is bowel or bladder impairment, there will probably be sexual impairment.
Sexuality after SCI

• What kind of impairment might there be?
• First, a quick overview of normal sexual response
  – There are 2 types of sexual responses
    • Psychogenic (response based on sensory input such as a sight, sound or smell that excites)
    • Reflexogenic (response based on direct stimulus to an area of the body such as touching of the genitals)
• In men, the response is erection, and in women, the response is lubrication
Sexuality after SCI

- In a complete Cervical or Thoracic injury, the pathway between brain and spinal cord is severed. Therefore, there is a loss of psychogenic response.

- However, the area below the lesion is intact, so a reflex response is possible (and probable)

Sexuality after SCI

- In a complete Sacral injury, the brain-cord connection is still present, but the Lower Motor Neuron pathway is blocked. Therefore, there is loss of reflexogenic response.
- However, because the local nerve fibers can be bypassed, an adequate sexual response can be achieved psychogenically.
Sexuality after SCI

• People with incomplete spinal cord injuries can usually have some degree of both types of responses.

• Up to 95% of SCI individuals can achieve some sort of sexual response.
Fertility after SCI

• In women, 85% experience amenorrhea for about 6 months immediately after injury.

• Menstruation almost always returns and pregnancy is then possible at approximately the same rate as uninjured women
Fertility after SCI

• *Birth control is absolutely necessary!!*
Fertility after SCI

• In injured men, there are many concerns:
  – Loss of ability to control erection
  – Loss of ability to ejaculate (only 3-20% can)
  – Decreased quantity of sperm in ejaculate
  – Decreased motility of sperm
    • 20% of SCI sperm is motile, as opposed to uninjured male rate of 70%
Fertility after SCI

• Can extract semen 3 ways:
  – Application of vibrator to genital area
  – Electroejaculation
  – Surgical aspiration from testicle or epididymis

• Once semen is obtained, female can be inseminated in various ways (home, clinic, IVF)

• Overall, 40% of men with SCI who have attempted to father children have been successful!
Sexuality and SCI: Patient Teaching Tips

• Empty bowel and bladder prior to sexual activity, but remember that accidents may still occur.

• The risk of STDs is the same for injured and non-injured people. Use protection!

• It has been reported that after orgasm, there is often cessation of spasticity for up to 8 hours!
Sexuality and SCI: A Model of Thought

- As long as a couple mutually agrees, anything is acceptable between them.
- Must experiment and discover what works with your new lifestyle and what may not.
- Communication is essential. Anger, depression and uncertainty are all to be expected, and must be discussed with your partner.
- More essential than anything is a sense of humor! This should be new and fun territory, not a chore.
Sexuality and SCI: A Model of Thought

• Learn to focus on enhancing remaining capacities, and not be preoccupied with lost ones:
  – “Before I was paralyzed there were 10,000 things I could do. Now there are 9,000. I can either dwell on the 1,000 I've lost or focus on the 9,000 I have left.” - W. Mitchell

• Sex may no longer be spontaneous
  – Bowel/Bladder issues, fatigue, spasticity, privacy, time
## Sexuality and SCI: Notions and Myths

<table>
<thead>
<tr>
<th>Sex means sexual intercourse</th>
<th>Sex is for younger people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men should initiate sexual activities</td>
<td>Talking about sex is not natural, proper, or necessary</td>
</tr>
<tr>
<td>You shouldn’t start what you can’t finish</td>
<td>Sex should be spontaneous</td>
</tr>
<tr>
<td>A firm penis is essential for satisfying sex</td>
<td>Good sex must end with orgasm</td>
</tr>
</tbody>
</table>
• These notions must be discarded before one can achieve an optimal healthy sexual lifestyle post-SCI!
By Popular Demand:
Sexuality and SCI: Final Thoughts

• Spinal Cord Injury does not diminish a person’s sexuality.

• Sexuality is *not* just a matter of “Can I or can’t I?”

• It encompasses all of the feelings, attitudes, and behaviors that contribute to a person’s own sense of manhood or womanhood.
If It Feels Good, Do It!
Who Cares What Others Think?
Research and New Interventions in Spinal Cord Injury
What’s Hot (and What’s Not)

Recently Completed or on-going Trials

1980
- NASCIS I, II, III

1990
- GM-1
- Macrophages
- Proneuron

2000
- Cethrin
- Bioaxone

2010
- OPCs
- Geron
- Riluzole
- NACTN

2013
- SUN 13837
- Asubio
- Hu-CNS-SC
- Stem Cells, Inc.
- Schwann Cell
Theory from Animal Models

• The spinal cord learns.
• It learns what you teach it.
• No definitive therapeutic window
• Human studies in incomplete, acute & chronic, injuries have shown improvement in:
  – walking over ground
  – walking speed and endurance
  – head and trunk control
  – with a positive carryover effect
Activity Based Therapy

- Rehabilitative concepts of ‘compensation’ changing to strategies that ‘stimulate the nervous system’ to optimize recovery.

- After spinal cord transection, cat partially supported to provide rhythmic step-like movements of the hind limbs.

  - These neurons are known as locomotor or spinal central pattern generators (CPG).
Manual and Robotic BWS Suspension Systems

• Manual Systems
  • LiteGait
  • Robomedica
  • Therastride
  • Andago
  • Zero G

• Robotic System
  • Lokomat
The Promise of Stem Cell Research

- Identify drug targets and test potential therapeutics
- Toxicity Testing
- Cultured Pluripotent Stem Cells
  - Study cell differentiation
  - Tissues/Cells for Transplantation
- Bone marrow for leukemia & chemotherapy
- Nerve cells for Parkinson’s & Alzheimer’s disease
- Heart muscle cells for heart disease
- Pancreatic islet cells for diabetes
- Understanding prevention & treatment of birth defects

Executive Order 13505—Removing Barriers to Responsible Scientific Research Involving Human Stem Cells Memorandum of March 9, 2009—Presidential Signing Statements Memorandum of March 9, 2009—Scientific Integrity
Advances in Adaptive Technology

R-net Omni
A Joystick Module or Specialty Input Device that is connected to an Omni as a remote control for devices
Smart Drive

• Power up the steepest slopes
• Wheel is 11 lbs and battery is 8lbs.
• Push to go, brake to stop
• Wheelies and curbs are no problem
• Easy to put on and take off
• Goes over carpet and grass
• Lasts days on a single charge
  • Max Mobility
Exoskeletons in SCI

- **REX** (REX Bionics)
- **ReWalk** (Argo Medical Technologies)
- **Indego**
- **Ekso** (Ekso Bionics)
- **Others**: HAL, Mina
### REX Bionics

- **Robot EXoskeleton**
- Hand-controlled joystick
- Battery powered (5 hr)
- Weighs 85 lbs (soon ~ 44 lbs)
- Allows negotiation of stairs
- Brain computer interface
ReWalk

- Argo Medical Technologies
- Uses “tilt sensor” technology
- 45 lbs, user does not feel the weight
- Sit-to-stand; Walking; Stairs
- Approved for rehabilitation
- Also now approved for home use
Ekso

- Reciprocal gait pattern with assistive devices
- 1 Torso
  - 2 Batteries; 1 computer; LCD controller
- 2 legs (Adjustable lengths)
BIO-MECHANICAL ENGINEERING HAS CAUGHT UP WITH HUMAN GRIT.
Indego

- Slim design (27 pounds)
  - Transportable
- Pelvic/low back pouch
- Sit-to-stand; Walking; Stairs
- Now completing clinical trials at Kessler and a few other rehabilitation centers
Neural Interface Technology

Turns thought into action.

• Communication

• Environmental control

• Robotics / Mobility devices

• Neuroprosthetics
4) Nov. 30, 2012 - Jan feeds herself string cheese
We’ve come a long way

- Improved medical care of acute SCI
- Improved function for level of injury
- Increased life expectancy and QOL
- New technology to take advantage of

  ➢ *but*

- Trends of shortened LOS
- “Medical necessity” vs luxury item
- Non-specialized rehabilitation centers
For patients with SCI... it is not *only* about the future and the cure!

• It’s about today!
• Lives to live
• Children to raise
• Work to do
• Potentials to realize
What we all want is a cure.

What we have is

Hope, Technology,

and Rehabilitation.
MURDERBALL

“Mesmerizing. Creates a new definition of courage.”
— Peter Travers, ROLLING STONE

“One of the most powerful films of the year”
— WASHINGTON POST

“An inspirational crowd pleaser.”
— NEW YORK TIMES

DREAM. BELIEVE. ACHIEVE.
“I play Wheelchair Rugby. What’s the worst that can happen—I’ll break my neck? Again?”

-Mark Zupan
“Learning to live with paralysis is a tremendous adjustment, but now there is every reason to believe it’ll be a temporary one.

We must. We can. We will.”

*Christopher Reeve*