Aging after Spinal Cord Injury

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Learning Objectives

Upon completion of this program, participants will be able to:

- Understand the interaction of aging and spinal cord injury (SCI) on mortality and morbidity
- Identify risk factors for secondary health conditions in persons with SCI
- Promote health maintenance and wellness for persons with SCI

Outline

- Demographics of Aging
- Mortality
- Morbidity
- Specific Health Conditions
  - Cardiovascular
  - Respiratory
  - Gastrointestinal
  - Genitourinary
  - Musculoskeletal
  - Neurological
  - Skin
- FES Systems
Aging in the U.S. (U.S. Census Bureau)

Age over Time in SCI (SCISC 2003)

Trends in the Distribution of Mean Age for Individuals with acute SCI (Groah 2012)
Etiology of SCI over Time (SCISC 2003)

Age and Etiology (SCIMS 2012)

Trends in Life Expectancy in SCI (Shock 1984, Groah 2012)
Life expectancy for persons that survive the first 24 hours (NSCISC 2012)

<table>
<thead>
<tr>
<th>Age at Injury</th>
<th>No SCI</th>
<th>Motor Functional at any Level</th>
<th>Para Low Tetra (C5-8)</th>
<th>High Tetra (C1-4)</th>
<th>Ventilator Dependent at any Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 yrs</td>
<td>58.8</td>
<td>52.1</td>
<td>44.8</td>
<td>39.6</td>
<td>35.3</td>
</tr>
<tr>
<td>40 yrs</td>
<td>39.9</td>
<td>33.8</td>
<td>27.4</td>
<td>23.2</td>
<td>19.7</td>
</tr>
<tr>
<td>60 yrs</td>
<td>22.5</td>
<td>17.5</td>
<td>12.8</td>
<td>10.0</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Life expectancy for persons who survive 1 year post injury (NSCISC 2012)

<table>
<thead>
<tr>
<th>Age at Injury</th>
<th>No SCI</th>
<th>Motor Functional at any Level</th>
<th>Para Low Tetra (C5-8)</th>
<th>High Tetra (C1-4)</th>
<th>Ventilator Dependent at any Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 yrs</td>
<td>58.8</td>
<td>52.5</td>
<td>45.4</td>
<td>40.5</td>
<td>36.9</td>
</tr>
<tr>
<td>40 yrs</td>
<td>39.9</td>
<td>34.1</td>
<td>27.9</td>
<td>23.9</td>
<td>21.0</td>
</tr>
<tr>
<td>60 yrs</td>
<td>22.5</td>
<td>17.7</td>
<td>13.2</td>
<td>10.4</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Aging with SCI in the U.S.

- Mean age at Injury is higher
- Life expectancy is improved
- Life expectancy is affected by
  - Level of injury
  - Severity of injury
  - Age of injury
  - Time since injury
  - Decade of injury
Mortality following SCI

- Etiology of death in all people
  - Cancer
  - Ischemic Heart Disease
  - Non-ischemic Heart Disease
- Etiology of deaths in people with SCI
  - Pneumonia
  - Non-ischemic Heart Disease
  - Septicemia
- Unique causes of death in people with SCI obtained from the SMR: SCI/All People
  - Septicemia
  - Pulmonary Emboli
  - Pneumonia

Etiology of Death in the General Population versus SCI (Clinical Outcomes from the Model System 1995)

<table>
<thead>
<tr>
<th></th>
<th>Death (N) (All people)</th>
<th>Death (N) (SCI)</th>
<th>SMR (SCI/All people)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer</td>
<td>82</td>
<td>71</td>
<td>0.9</td>
</tr>
<tr>
<td>Ischemic Heart Dz</td>
<td>78.4</td>
<td>91</td>
<td>1.2</td>
</tr>
<tr>
<td>Non-ischemic Heart Dz</td>
<td>26.7</td>
<td>171</td>
<td>6.4</td>
</tr>
<tr>
<td>Dz of Urinary System</td>
<td>4.5</td>
<td>49</td>
<td>10.9</td>
</tr>
<tr>
<td>Suicide</td>
<td>16.6</td>
<td>80</td>
<td>4.8</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>6.4</td>
<td>228</td>
<td>35.6</td>
</tr>
<tr>
<td>Dz of Digestive System</td>
<td>17.8</td>
<td>67</td>
<td>3.8</td>
</tr>
<tr>
<td>Pulmonary Emboli</td>
<td>2.4</td>
<td>113</td>
<td>47.1</td>
</tr>
<tr>
<td>Septicemia</td>
<td>1.9</td>
<td>122</td>
<td>64.2</td>
</tr>
</tbody>
</table>

Morbidity following SCI

- Survival with SCI is associated with many chronic health conditions
- Physician: Readmission following initial discharge
  - Frequency
  - Length of Stay
  - Occurrence Rates
- Patient: Self reported health conditions
  - Paraplegic
  - Tetraplegic
Patterns of Morbidity and Rehospitalization following SCI (Middleton 2004)

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Readmissions (%)</th>
<th>Persons (%)</th>
<th>Total Bed-days</th>
<th>ALOS (median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genitourinary</td>
<td>235 (24.1)</td>
<td>125 (28.9)</td>
<td>2248</td>
<td>9.6 (3)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>107 (11.0)</td>
<td>69 (16.0)</td>
<td>589</td>
<td>5.5 (1)</td>
</tr>
<tr>
<td>Skin</td>
<td>87 (8.9)</td>
<td>40 (9.3)</td>
<td>4432</td>
<td>50.9 (28)</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>84 (8.6)</td>
<td>60 (13.9)</td>
<td>880</td>
<td>10.2 (4)</td>
</tr>
<tr>
<td>Neurological</td>
<td>30 (3.1)</td>
<td>18 (4.2)</td>
<td>775</td>
<td>25.8 (8)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>44 (4.5)</td>
<td>28 (6.5)</td>
<td>632</td>
<td>14.4 (7)</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>47 (4.8)</td>
<td>40 (9.3)</td>
<td>879</td>
<td>18.7 (6)</td>
</tr>
<tr>
<td>Endocrine</td>
<td>7 (0.7)</td>
<td>5 (1.2)</td>
<td>68</td>
<td>9.7 (8)</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>66 (6.8)</td>
<td>37 (8.6)</td>
<td>802</td>
<td>12.2 (4)</td>
</tr>
<tr>
<td>Other</td>
<td>270 (27.6)</td>
<td>96 (22.2)</td>
<td>3830</td>
<td>14.2 (5)</td>
</tr>
<tr>
<td>Total</td>
<td>977 (100)</td>
<td>265 (58.6)</td>
<td>15127</td>
<td>15.5 (5)</td>
</tr>
</tbody>
</table>

Overall causes of Rehospitalization (N=4675) (SCIMS Annual Report 2010)

Top 6 Causes (N=4675) of Rehospitalization by Post-injury Year (SCIMS Annual Report 2010)
Rates of Secondary Medical Conditions
(NSCISC 1995)

<table>
<thead>
<tr>
<th>Medical Condition</th>
<th>1st year</th>
<th>20th year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Ulcers</td>
<td>15%</td>
<td>26%</td>
</tr>
<tr>
<td>UTI</td>
<td>62%</td>
<td>95%</td>
</tr>
<tr>
<td>DVT</td>
<td>12-20%</td>
<td>&lt; 3%</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>12-20%</td>
<td>&lt; 3%</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>12-20%</td>
<td>&lt; 3%</td>
</tr>
</tbody>
</table>

Medical Problems of Aging by years since injury, N = 347 (Krause 2000)

<table>
<thead>
<tr>
<th>Medical Problem</th>
<th>&lt;10 years</th>
<th>30+ years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kidney or Bladder Stones</td>
<td>15%</td>
<td>59%</td>
</tr>
<tr>
<td>Infection other than UTI</td>
<td>24%</td>
<td>50%</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>30%</td>
<td>55%</td>
</tr>
<tr>
<td>Fracture</td>
<td>19%</td>
<td>41%</td>
</tr>
<tr>
<td>Contractures</td>
<td>14%</td>
<td>32%</td>
</tr>
<tr>
<td>Rectal bleeding</td>
<td>49%</td>
<td>39%</td>
</tr>
<tr>
<td>Drug Abuse</td>
<td>9%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Medical Problems of Aging by onset year of injury, N=347 (Krause 2000)

<table>
<thead>
<tr>
<th>Medical Problem</th>
<th>&lt;18</th>
<th>18-25</th>
<th>26-39</th>
<th>40+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart problems</td>
<td>5%</td>
<td>11%</td>
<td>7%</td>
<td>23%</td>
</tr>
<tr>
<td>Bowel obstruction</td>
<td>13%</td>
<td>30%</td>
<td>31%</td>
<td>40%</td>
</tr>
<tr>
<td>Kidney/bladder stones</td>
<td>63%</td>
<td>37%</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td>Burns</td>
<td>59%</td>
<td>6%</td>
<td>46%</td>
<td>40%</td>
</tr>
<tr>
<td>Skin sores</td>
<td>50%</td>
<td>54%</td>
<td>51%</td>
<td>26%</td>
</tr>
<tr>
<td>Sweats or chills</td>
<td>78%</td>
<td>78%</td>
<td>73%</td>
<td>52%</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>56%</td>
<td>43%</td>
<td>38%</td>
<td>26%</td>
</tr>
<tr>
<td>Rectal bleeding</td>
<td>40%</td>
<td>59%</td>
<td>48%</td>
<td>40%</td>
</tr>
<tr>
<td>Calcium deposits</td>
<td>25%</td>
<td>24%</td>
<td>37%</td>
<td>10%</td>
</tr>
<tr>
<td>Headaches</td>
<td>53%</td>
<td>63%</td>
<td>63%</td>
<td>33%</td>
</tr>
<tr>
<td>Stress</td>
<td>85%</td>
<td>76%</td>
<td>68%</td>
<td>56%</td>
</tr>
</tbody>
</table>
### Self-reported Prevalence of Secondary Health Complications by Impairment, N=781 (Hitzig 2008)

<table>
<thead>
<tr>
<th>Health Complication</th>
<th>Total &gt; 30%</th>
<th>Health Complication</th>
<th>Total &lt; 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spasticity</td>
<td>71.3</td>
<td>Pressure Ulcers</td>
<td>28.7</td>
</tr>
<tr>
<td>Shoulder Pain</td>
<td>58.6</td>
<td>High BP</td>
<td>22.8</td>
</tr>
<tr>
<td>Chronic Pain</td>
<td>58.0</td>
<td>Autonomic Dysreflexia</td>
<td>20.1</td>
</tr>
<tr>
<td>Bladder Infections</td>
<td>56.5</td>
<td>Respiratory</td>
<td>15.6</td>
</tr>
<tr>
<td>Arthritis/Joint Pain</td>
<td>53.4</td>
<td>Bladder/kidney</td>
<td>13.4</td>
</tr>
<tr>
<td>Bowel</td>
<td>42.9</td>
<td>Neurological Deterioration</td>
<td>13.1</td>
</tr>
<tr>
<td>Depression</td>
<td>34.6</td>
<td>Cardiac</td>
<td>7.2</td>
</tr>
<tr>
<td>Psychological Distress</td>
<td>33.0</td>
<td>Fractures</td>
<td>6.9</td>
</tr>
<tr>
<td>Bowel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Self-reported Prevalence of Secondary Health Complications by Impairment (> 30%) (Hitzig 2008)

<table>
<thead>
<tr>
<th>Health Complication</th>
<th>Total (n=781)</th>
<th>CT (n=103)</th>
<th>IT (n=255)</th>
<th>CP (n=167)</th>
<th>IP (n=256)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spasticity</td>
<td>71.3</td>
<td>88.3</td>
<td>77.3</td>
<td>62.9</td>
<td>64.1</td>
</tr>
<tr>
<td>Shoulder Pain</td>
<td>58.6</td>
<td>68.9</td>
<td>56.1</td>
<td>67.1</td>
<td>51.6</td>
</tr>
<tr>
<td>Chronic Pain</td>
<td>58.0</td>
<td>57.3</td>
<td>53.3</td>
<td>61.7</td>
<td>60.5</td>
</tr>
<tr>
<td>Bladder Infections</td>
<td>56.5</td>
<td>70.9</td>
<td>46.3</td>
<td>71.3</td>
<td>51.2</td>
</tr>
<tr>
<td>Arthritis/Joint Pain</td>
<td>53.4</td>
<td>46.6</td>
<td>52.9</td>
<td>53.3</td>
<td>56.6</td>
</tr>
<tr>
<td>Bowel</td>
<td>42.9</td>
<td>34.9</td>
<td>40.0</td>
<td>44.3</td>
<td>48.4</td>
</tr>
<tr>
<td>Depression</td>
<td>34.6</td>
<td>34.0</td>
<td>34.1</td>
<td>34.1</td>
<td>35.5</td>
</tr>
<tr>
<td>Psychological Distress</td>
<td>33.0</td>
<td>35.0</td>
<td>30.2</td>
<td>33.5</td>
<td>34.8</td>
</tr>
</tbody>
</table>

### Self-reported Prevalence of Secondary Health Complications by Impairment (< 30%) (Hitzig 2008)

<table>
<thead>
<tr>
<th>Health Complication</th>
<th>Total (n=781)</th>
<th>CT (n=103)</th>
<th>IT (n=255)</th>
<th>CP (n=167)</th>
<th>IP (n=256)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Ulcers</td>
<td>28.7</td>
<td>42.7</td>
<td>20.4</td>
<td>44.9</td>
<td>20.7</td>
</tr>
<tr>
<td>High BP</td>
<td>22.8</td>
<td>11.7</td>
<td>20.0</td>
<td>21.6</td>
<td>30.9</td>
</tr>
<tr>
<td>Autonomic Dysreflexia</td>
<td>20.1</td>
<td>48.5</td>
<td>20.4</td>
<td>18.0</td>
<td>9.8</td>
</tr>
<tr>
<td>Respiratory</td>
<td>15.6</td>
<td>15.5</td>
<td>17.3</td>
<td>13.2</td>
<td>15.6</td>
</tr>
<tr>
<td>Bladder/kidney</td>
<td>13.4</td>
<td>17.5</td>
<td>12.9</td>
<td>12.0</td>
<td>13.3</td>
</tr>
<tr>
<td>Neurological Deterioration</td>
<td>13.1</td>
<td>10.7</td>
<td>13.3</td>
<td>10.2</td>
<td>15.6</td>
</tr>
<tr>
<td>Cardiac</td>
<td>7.2</td>
<td>6.8</td>
<td>5.1</td>
<td>9.6</td>
<td>7.8</td>
</tr>
<tr>
<td>Fractures</td>
<td>6.9</td>
<td>5.8</td>
<td>4.7</td>
<td>11.4</td>
<td>6.6</td>
</tr>
<tr>
<td>Heterotopic Ossification</td>
<td>5.8</td>
<td>3.9</td>
<td>6.7</td>
<td>8.4</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Effects of Aging with SCI by Organ System

- Cardiovascular
- Respiratory
- Gastrointestinal
- Genitourinary
- Musculoskeletal
- Neurological
- Skin

Spinal cord

Vertebral column
Spinal ligaments

Arteries of the spinal cord

Arteries of the spinal cord
Veins of the spinal cord

Corticospinal tract

Spinothalamic tract
Posterior columns
Organ System effects of aging with SCI

- Cardiovascular
- Respiratory
- Gastrointestinal
- Genitourinary
- Musculoskeletal
- Neurological
- Skin

Cardiovascular

- 2nd leading causes of death in SCI.
- Risk factors in SCI:
  - Diabetes: 30% ↑ incidence of glucose intolerance and diabetes (Bauman 1994)
  - Obesity: ↓ lean muscle mass and ↑ fat mass (Bauman 1999)
  - Inactivity: ↓ Activity level
  - Lipid Disorders: Insufficient evidence that adults with SCI are at greater risk of carbohydrate and lipid disorders
  - Lipid: low HDL, total cholesterol and LDL are not different from controls (Wilt 2008)
Acute Cardiovascular Complications (NSCISC 2006)

Asymptomatic Pulmonary Embolism

Table 45. Number of patients developing secondary medical complications during the initial hospitalization for persons admitted to the system within 24 hours of injury. (n = 6,928; 20.5% had none of the listed medical complications.)
IVC Filter

- IVC filter placement is not a substitute for DVT prophylaxis.
- IVC filter placement increases the risk for future development of DVT

Incidence of PE following DVT (Decousus 1998).

<table>
<thead>
<tr>
<th>N</th>
<th>Evaluation Day 12</th>
<th>Evaluation Day 720</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC Filter</td>
<td>200</td>
<td>1.1% PE</td>
</tr>
<tr>
<td>No IVC Filter</td>
<td>200</td>
<td>4.8% PE</td>
</tr>
</tbody>
</table>

Chronic Cardiovascular Complications (NSCISC 2006)

- Autonomic Dysreflexia

- This is a disorder of autonomic homeostasis as a result of a disconnection of the brain with the spinal cord.
- Due to loss of supraspinal control and exaggerated sympathetic nervous system reflex activity.
- Triggered by noxious stimuli below the level of injury (significant above T6 SCI Level)
- Can lead to dangerously high blood pressures.
Management of Autonomic Dysreflexia

**Symptoms:** pounding headache, flushed skin & sweating above level of injury, blurred vision, nasal stuffiness, goose bumps, nausea, and BP.

**Etiology:** Any painful stimulus below level of injury. Full bladder, blocked foley, UTI, or bowel impaction, skin ulcers, trauma, tight clothing, tests & procedures, ingrown toenails.

**Treatment:**
1. Sit patient up.
2. Eliminate the cause!
3. Treat elevated systolic blood pressure (>150)
5. Treat symptomatic hypotension by laying down the individual and elevating the legs.
6. Monitor symptoms and BP for at least 2 hrs after the resolution of an AD episode.
7. Admit the patient if response to treatment is poor or cause has not been identified. AD can lead to seizures, stroke or death.

Modification of Risk Factors

- Identify and treat AD
- Identify HTN
- Promote exercise
- Weight management
- Healthy diet (lipid profile, HgbA1c)
- Avoid Narcotics
- Stop smoking
- Reduce alcohol intake

Respiratory System

- Pneumonia: (leading cause of death in SCI)
- Mucous Plugging
- Aspiration
- Hypoventilation
- Sleep Apnea
Secondary Medical Complications - Annual Report for the Model SCI Care Systems, SCI Statistical Center 2006

<table>
<thead>
<tr>
<th>Complication</th>
<th>Paraplegia</th>
<th>Tetraplegia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>308</td>
<td>685</td>
<td>2,312</td>
</tr>
<tr>
<td>Pressure ulcers</td>
<td>16.6</td>
<td>33.4</td>
<td>69.4</td>
</tr>
<tr>
<td>Deep vein thrombosis</td>
<td>210</td>
<td>232</td>
<td>442</td>
</tr>
<tr>
<td>Pulmonary Embolism</td>
<td>36.2</td>
<td>21.3</td>
<td>57.5</td>
</tr>
<tr>
<td>Post-op Wound Infection</td>
<td>5.5</td>
<td>1.9</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Table 45. Number of patients developing secondary medical complications during system by neurologic impairment for persons admitted to the system within 24 hours of injury

Mucous Plug

Respiratory System

- Risk Factors
  - ↑ Body weight
  - ↓ Muscle strength
  - ↓ Muscle tone (narcotics)
  - ↓ Pulmonary compliance (elasticity)
  - Dehydration
  - Infection
  - Aspiration
  - Level and completeness of Injury
Modification of Risk Factors

- Monitor vital capacity
- Immunization – Pneumovax, flu shot
- Weight loss
- Stop smoking and reduce alcohol
- Maintenance of pulmonary therapies
  - Inhalers, aerosols, ezPAP
  - Chest percussion/vest
  - Suctioning
  - Assisted cough
  - Coughulator
  - Hydration
- Pulmonary Rehabilitation

Respiratory System

- Sleep Apnea
  - Incidence: 40% in SCI
  - Increases with age, tetraplegia, and tracheostomy
  - Pulmonary hypertension can lead to non-ischemic heart disease (2nd leading cause of death)

Modification of Risk Factors

- Weight loss
- Restrict alcohol and tobacco
- Avoid narcotics
- O/N sleep oximetry
- Polysomnography
- CPAP
- BiPAP
Gastrointestinal

- 2nd leading cause of readmission
- Continues to be a problem with aging
- Less efficiency of bowel program
  - ↓ Peristalsis
  - ↑ Constipation
  - ↑ Hemorrhoids

Modification of Risk Factors

- Bowel Program:
  - Attention to details
  - Diet
  - Medications (avoid narcotics)
  - Hydration
  - Activity
  - Bedside commode
  - Colostomy

Genitourinary

- Urinary tract complications:
  - Formerly leading cause of death in people with SCI
  - As one ages it continues to be a problem
  - Currently #1 cause of readmission following SCI
Genitourinary

- Infections
  - Cystitis
  - Pyelonephritis
- Kidney/Bladder Stones
  - 36% of SCI survivors develop calculi within 8 years following injury
- Renal Failure
  - today only 3.8-5.4%
- Bladder cancer
  - Foley or suprapubic catheter
  - cancer latency 20 years.

Modification of Risk Factors

- Adequate hydration
- Avoid high volume and high pressure bladders
- Surveillance
  - Cystometrogram
  - Bladder/Kidney Ultrasound
  - Cystoscopy

Musculoskeletal

- Pain
- Osteoporosis
- Osteoarthritis
- Disuse muscle atrophy
- Tendon/ligament
  - Contractures
  - Injuries (RTC)
Musculoskeletal

- Pain is the #1 Self-reported secondary health complications
- Progresses with age
- Types
  - Neuropathic
  - Nociceptive

Bryce/Ragnarsson Classification of Pain 2001

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
<th>Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above - level (3 levels or more above the neurologic level of SCI)</td>
<td>Nociceptive</td>
<td>1 Mechanical/Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 A.D. Headache</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Other</td>
</tr>
<tr>
<td></td>
<td>Neuropathic</td>
<td>4 Compressive Neuropathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Other</td>
</tr>
<tr>
<td>At - level (2 levels above or below the neurologic level of SCI)</td>
<td>Nociceptive</td>
<td>6 Mechanical/Musculoskeletal</td>
</tr>
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<td></td>
<td></td>
<td>7 Visceral</td>
</tr>
<tr>
<td></td>
<td>Neuropathic</td>
<td>8 Central</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 Radicular</td>
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<tr>
<td></td>
<td></td>
<td>10 Compressive Neuropathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 Complex Regional Pain Syndrome</td>
</tr>
<tr>
<td>Below - level (3 levels or more below the neurologic level of SCI)</td>
<td>Nociceptive</td>
<td>12 Mechanical/Musculoskeletal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 Visceral</td>
</tr>
<tr>
<td></td>
<td>Neuropathic</td>
<td>14 Central</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 Other (Inc SCI or pain w/in ZPP)</td>
</tr>
</tbody>
</table>

Neuropathic Pain

- Pain is located in a region of impaired sensation
- Described as shooting, electric or burning.
- Worse at night or with inactivity
- Better during the day
- Exacerbated by stress, sleep dysfunction, depression, and inactivity.
- Treatment: Activity, TENS, Neurontin, Elavil.
Nociceptive Pain

- Pain is located in a region of preserved sensation
- Described as dull and aching and worse with activity.
- 50-70% (shoulder > wrist)
- Tendon/ligament injury/arthrosis
- Causes: Overuse, transfers, pressure relief, wheelchair propulsion, wheelchair fit, maneuvers, abnormal posture.

Modification of Risk Factors

- Proper Wheelchair
- Proper Wheelchair fit
- Proper Wheelchair Propulsion technique
- Balanced shoulder strengthening
- Weight reduction

Generation of Forces on various Obstacles using the SmartWheel

*Measures*
- Push Forces
- Push Frequency
- Push Length
- Speed

*Wheelchair Skills Test*

- 10m tile
- 10m carpet
- Soft surface
- 5° incline
- 10° incline
- 2cm curb
- 5cm curb
- 15cm curb
Forces Generated Smart Wheel
(Nagy, Nemunaitis 2011)
Forces Generated Smart Wheel: BMI
(Mejia, Nemunaitis 2012)

Forces Generated Smart Wheel: Rigid versus Folding (Winslow, Nemunaitis 2012)

Musculoskeletal
- Osteoporosis:
  - Present in 60-90% of patients confined to a wheelchair.
  - Increases with age.
  - Stable 16 months after SCI w/ 33% bone loss.
  - Fractures
Modification of Risk Factors - Osteoporosis

- Follow DEXA
- Stop Smoking
- Avoid alcohol
- Vitamin D, 25 OH levels
- Standing and walking
- FES
- Bisphosphonates

Loss of BMD over time since SCI (Garland 2005)

Risk of Fracture in SCI (Lazo 2001)
Vitamin D Level (Nemunaitis 2009)

Vitamin D, 25-OH

- Subject data
- Mean (14.9 ng/dL)
- Low normal (32 ng/dL)
- High normal (80 ng/dL)

Nervous System

- Neurogenic muscle atrophy:
  - Age related loss of Ant Horn Cells
    (10%/decade after age 60 (Tomlinson))
- Compressive neuropathies
  - Median Nerve: Carpal tunnel syndrome
    60% (Boringer 2009)
  - Ulnar Nerve: Ulnar Neuropathy 20%
    (Burnham 1993)
- Syringomyelia
  - Incidence 60% but progressive 3%
    (Biyani 1996)

Neurogenic Muscle Atrophy

- Root injuries
  - At the level of injury
  - Cauda Equina injury
  - Peripheral nerve injury
Modification of Risk Factors

- Treatment:
  - Activity modification
  - Splints
  - Wheelchair
  - Power
  - power-assist w/c
  - Low impact exercises
  - Water Therapy
  - Surgery
  - Tendon transfers

Nervous System

- Syringomyelia
  - ↑ pain
  - ↑ spasticity
  - ↓ pain/temperature
  - ↑ weakness
  - ↑ autonomic dysreflexia

- Treatment:
  - Monitoring
  - Surgical intervention

Skin: Pressure Ulcers

- #1 Cost-related etiology of readmission following SCI (Middleton 2004)
- Physiological Changes
  - Decreased collagen production
  - Decreased elastin production
  - Decreased vascularity
- Incidence (SCIMS 1995)
  - Pressure ulcers at Yr-1 = 15%
  - Pressure ulcers at Yr-20 = 30%
- Pressure ulcers in tetraplegics at Yr-20 = 40%
Skin: Locations of Pressure Ulcers

- Lying in Bed
  - Back of Head
  - Shoulder Blade
  - Sacrum
  - Greater Trochanter
  - Heel (back)
- Sitting
  - Ischium
  - Toes
  - Heel (bottom)
Pressure sensitive areas

Skin: Modification of risk factors
- Monitor cushion (type, placement and inflation)
- Daily skin inspection.
- Taking immediate action if skin breakdown develops.
- Changes when necessary (manual→power chairs, bed-type, home health aides, etc.)

Sacral Interface Pressures with Gurney Backrest Elevation, N=30 (Atluri, Nemunaitis 2011)
Priorities for persons with SCI (Anderson, 2004)

Rank the following functional recovery in order of importance to you, 1 being most important and 7 being least important:

A) arm/hand function  
B) upper body/trunk strength and balance  
C) bladder/bowel function, elimination of Dysreflexia  
D) sexual function  
E) elimination of chronic pain  
F) normal sensation  
G) walking movement
Priorities for persons with SCI N=681

Highest Priority to Quad’s

Highest Priority to Para’s

UE System: 2nd Generation – 12 Channel

Priorities for persons with SCI N=681

Highest Priority to Quad’s

Highest Priority to Para’s

UE System: 2nd Generation – 12 Channel
Case presentation - CH

- 26 year old male
- C6 ASIA C Tetraplegia
  - C6 sensory (86); C7 motor (55)
- Non-ambulator
- 12 weeks robotic assisted BWSTT gait training

Pre and Post implanted FES - CH

- No FES
- FES
**Cough System: FES Components**

![Diagram of Cough System: FES Components]

References