Physical Therapy Management for People With Acute Traumatic Spinal Cord Injury

A spinal cord injury (SCI) may be caused by trauma, disease processes, or congenital defects of the spinal cord. SCI affects conduction of sensory and motor synapses across the site of the lesion. Clinical manifestations resulting from the SCI vary greatly depending on the level, location, and size of insult to the spinal cord. This lesson will focus on physical therapy management for people who acquire an SCI due to a traumatic event.

Advancements of SCI care are evident from the scene of a traumatic accident through the long-term management of medical or psychosocial issues. As a result, survival rates are increasing and morbidity is decreasing. The role of the rehabilitation team is to contribute to the care of individuals with SCI along the health care continuum to enable these individuals to achieve maximal outcomes. Effective rehabilitation of the person with an acute traumatic SCI requires an interdisciplinary team.

An interdisciplinary team consisting of clinicians with experience in managing this complex, catastrophic injury best serves the patient with an SCI. The core health care team should include a physician, nurse, physical therapist, occupational therapist, therapeutic recreation therapist, psychological services, dietitian, education instructor, and case manager. In addition to the core team, other health care professionals are consulted based on the needs of the individual. These additional health care professionals include a speech therapist, respiratory therapist, chaplain, assistive technology specialist, seating clinic specialist, and brace clinic specialist. It is essential that all team members work with the patient and family/caregiver to progress the patient toward achieving the desired outcomes.

The body of knowledge regarding care for persons with SCI is extensive and well beyond the scope of this lesson. Further study beyond this lesson is strongly encouraged prior to managing or providing services for individuals with SCI. The purpose of this lesson is to present critical elements of the rehabilitative process for people with traumatic SCI during acute care, rehabilitation, and post-discharge care. At the completion of this lesson, the participant will be able to:

1. Describe the ascending and descending tracts of the spinal cord and how they relate to determining the level and extent of SCI;
2. Identify essential components of a physical therapy examination/evaluation for the patient with SCI;
3. Identify and recognize the signs, symptoms, and intervention strategies for common medical and secondary complications associated with SCI;
4. Identify the primary intervention strategies for the acute care phase of SCI physical therapy management;
5. Identify the primary intervention strategies for the rehabilitation phase of SCI physical therapy management;
6. Identify the primary goals and intervention strategies for the post-acute phase of SCI physical therapy management; and
7. Identify resources for further study in the management of individuals with SCI.

Basic Anatomy of the Spine and Spinal Cord

The vertebral column contains 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral, and 4 fused coccygeal vertebrae. The spinal cord extends from the medulla oblongata to the
level of L1. Derived from the spinal cord are 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. The spinal nerves C1-7 exit the vertebral foramen above the corresponding numbered vertebrae. Spinal nerves from C8 and below exit the vertebral foramen below the corresponding numbered vertebrae. Because the spinal cord is shorter than the vertebral column, the nerve roots in the lumbar region descend more vertically to exit from the bony vertebral canal. The collection of lumbosacral nerve roots is referred to as the cauda equina.

A cross-section of the spinal cord reveals an H-shaped internal section of gray matter surrounded by white matter. The gray matter is divided into two major components: motor and receptor. The motor component consists of the anterior and lateral columns that give rise to the anterior roots. The receptor component consists of posterior columns. Most of the fibers from the cells of this column enter the white matter, giving rise to ascending and descending branches.

The white matter consists of nerve fibers that link different segments of the spinal cord and connect the spinal cord with the brain. There are ascending tracts and descending tracts. The major ascending tracts of the spinal cord that will be discussed are the dorsal column, the lateral spinothalamic tract, and the ventral spinothalamic tract. The major descending tract that will be discussed is the lateral corticospinal tract.

The dorsal column of the spinal cord contain the fasciculus gracilis and the fasciculus cuneatus. The dorsal column carries information regarding conscious proprioception, deep touch and pressure, two-point discrimination, and vibration sense. The impulse passes along the sensory neuron into the medial division of the posterior root of the spinal cord. The synapse travels up its designated tract to the medulla oblongata, where it crosses over and is carried up to the thalamus.

The lateral spinothalamic tract carries information regarding pain and temperature. The impulse passes along the sensory neuron into the lateral division of the posterior root of the spinal cord. It then synapses in the posterior gray horn. From the synapse, the impulse crosses over to the opposite side and enters the lateral spinothalamic tract. It then is carried up to the thalamus and then to the sensory cortex of the parietal lobe.

The ventral spinothalamic tract is located in the anterior portion of the white matter. This tract carries information regarding light touch. The impulse passes along the sensory neuron into the medial division of the posterior root of the spinal cord and into the posterior gray horn. It then crosses over to the opposite side into the ventral spinothalamic tract. The impulse is carried up to the thalamus, then to the sensory cortex of the parietal lobe.

The lateral corticospinal tract carries information to provide voluntary motion. The lateral corticospinal tract descends down from the precentral motor cortex through the medulla oblongata. In the level of the lower medulla, the fibers cross over to the opposite side. The impulses leave their respective tracts and synapse in the anterior gray horn. The impulse is picked up by the anterior horn cells and is carried out along the efferent root to the muscles. The fibers in the lateral corticospinal tract are situated so that the upper-extremity fibers are more medial than the lower-extremity fibers.

**Spinal Cord Injury**

According to the National Spinal Cord Injury Statistical Center (NSCISC), the annual incidence of SCI is 40 cases per million people in the United States. This equates to approximately 11,000 new cases each year. The number of people in the United States who are alive today with an SCI is estimated to be between 183,000 and 230,000. Spinal cord injury primarily affects young adults, with 55% of spinal cord injuries occurring among people between the ages of 16 and 30 years. The average age of patients at the time of injury is 32.1 years. Of those patients sustaining traumatic SCI, approximately 81.6% are male.

The most frequent cause of traumatic SCI is motor vehicle accidents (38.5%), followed by acts of violence (24.5%), falls (21.84%), and sporting events (7.2%). Interesting trends show the proportions of injuries due to motor vehicle accidents and sporting events have declined and the percentage of injuries due to acts of violence has increased since 1973.

The International Standards for Neurological and Functional Classification of Spinal Cord Injury published by the American Spinal Injury Association (ASIA) established standardized definitions of common terms used in the diagnosis of SCI. Knowing these definitions is important when working with patients with SCI, and many of these definitions will be referred to throughout this lesson.

"Tetraplegia (preferred to ‘quadriplegia’) : This term refers to impairment or loss of motor and/or sensory function in the cervical segments of the spinal cord due to damage of neural elements within the spinal canal. Tetraplegia results in impairment of function in the arms as well as in the trunk, legs, and pelvic organs..." According to NSCISC, 51.6% of traumatic SCIs result in tetraplegia.
"Paraplegia: This term refers to impairment or loss of motor and/or sensory function in the thoracic, lumbar, or sacral (but not cervical) segments of the spinal cord, secondary to damage of neural elements within the spinal canal. With paraplegia, arm functioning is spared, but depending on the level of injury, the trunk, legs, and pelvic organs may be involved. Data show that 46.3% of traumatic SCIs result in paraplegia.

"Complete injury: This term is used when there is an absence of sensory and motor function in the lowest sacral segments." Forty-five and a half percent of traumatic SCIs are complete injuries, with 27.3% classified as complete paraplegia and 18.6% classified as complete tetraplegia.

"Incomplete injury: If partial preservation of sensory and/or motor functions is found below the neurological level and includes the lowest sacral segment, the injury is defined as incomplete. Sacral sensation includes sensation at the anal mucocutaneous junction as well as deep anal sensation. The test of motor function is the presence of voluntary contraction of the external anal sphincter upon digital examination. Approximately 50.2% of traumatic SCIs result in an incomplete injury, with incomplete tetraplegia accounting for 29.6% and incomplete paraplegia accounting for 20.6%. Trends over time indicate an increase in people with incomplete paraplegia and a decrease of people with complete tetraplegia.

Medical Management

Medical management begins at the site of the accident. Paramedics arriving at the scene incorporate initial spinal stabilization using cervical collars and spinal boards. These measures prevent further damage to the spinal cord while transporting the patient to an emergency department.

Standard procedure for all people who have experienced an acute traumatic SCI requires that they receive high doses of methylprednisolone. Methylprednisolone suppresses the secondary injury process caused by lipid peroxidation and hydrolysis, which destroys neuronal and microvascular membranes. The dosage recommended by the NASCIS 2 study is 30 mg/kg of methylprednisolone followed by an infusion of 5.4 mg/kg/h for 23 hours. The physical therapist must be aware of side effects patients may experience with such high doses of steroids, including gastric ulcers, decreased wound healing time, hypertension, cardiac arrhythmias, and alteration in mental status.

Prior to spinal stabilization, the physical therapist must follow guidelines to prevent further damage to the spinal cord. Guidelines for the cervical spine may include maintaining head and neck alignment, maintaining spinal traction as prescribed, and performing active/passive upper-extremity exercises symmetrically. For the thoracic or lumbar spine, hip flexion beyond 90 degrees or stretching the hamstring muscles is contraindicated. Spinal precautions vary from facility to facility, but generally involve supine positioning in bed combined with the log roll method for periodic repositioning for pressure relief. Prior to any examination or treatment, a thorough review of the hospital’s guidelines for medical precautions prior to stabilization procedures is indicated.

Early operative spinal fusion followed by segmental immobilization using a spinal orthosis usually results in full mobility of the patient within a week of the injury. If signs or symptoms of spinal instability (midline neck/back pain, radiating pain, changes in tingling or numbness, decreased strength of innervated muscle) are noted, the physician must be consulted prior to proceeding with treatment.

Examination/Evaluation

The examination and evaluation provides baseline neuromuscular and musculoskeletal information useful to determine the level and extent of the SCI. The neuromuscular assessment provided by the physical therapist gives critical information reflecting changes in neurologic function that can influence medical intervention in the early stages of SCI. The examination/evaluation also determines the extent of the

Table 1. American Spinal Injury Association Impairment Scale

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Complete</td>
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<td>No sensory or motor function is preserved in the lowest sacral segments of S4-5.</td>
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<tr>
<td>B</td>
<td>Incomplete</td>
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<td></td>
<td>Sensory function, but not motor function, is preserved below the neurological level and includes the lowest sacral segments.</td>
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<tr>
<td>C</td>
<td>Incomplete</td>
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<tr>
<td></td>
<td>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.</td>
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<tr>
<td>D</td>
<td>Incomplete</td>
</tr>
<tr>
<td></td>
<td>Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade greater than or equal to 3.</td>
</tr>
<tr>
<td>E</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Sensory and motor function is normal</td>
</tr>
</tbody>
</table>

injury by confirming whether the SCI is complete or incomplete. Table 1 describes injury patterns as described by the ASIA Impairment Scale. Table 2 depicts the commonly seen incomplete SCI syndromes.

**Neurological Level**

The neurological level of patients with an SCI reflects the motor and sensory function of nerve fibers and neurons along the spinal distribution. The ASIA defines the neurological level of injury as the most caudal segment that is normal for both motor and sensory function. Identifying the motor level and sensory level within and between both sides of the body is necessary to determine the neurological level. Neurological motor and sensory levels commonly differ between the right and left sides of the body. For example, a patient may have a right motor level of C5 and a right sensory level of C6 with a left motor level of C6 and a left sensory level of C7. In this example, the neurological level for this patient would be C5 on the right and C6 on the left. These levels represent the segments where both motor and sensory functions are intact. A thorough sensory and motor evaluation must be completed to determine the neurological level correctly. Use of the ASIA worksheet is invaluable when determining the neurological level (Figure 1).

**Cranial and Peripheral Nerve Integrity and Sensory Integrity**

The sensory test is one of the most important tools for determining the level and extent of neurological insult. Sensory information from various receptors is transmitted from the periphery by afferent fibers to the spinal cord. A dermatome is the area of skin innervated by the afferent or sensory axons that come together in one spinal nerve. The sensory information is transmitted via the ascending tracts to the cortex. Functionally, the sensory assessment determines the integrity of these ascending spinal cord tracts.

Sensory evaluation includes assessing pain and temperature carried along the lateral spinothalamic tract; tactile sensation of light touch and pressure carried along the ventral spinothalamic tract; and localized touch, vibration, and position sense carried along the dorsal columns. Sensory testing is usually performed in a caudal to rostral direction. The physical therapist must be sure to block the patient's vision during the testing procedures.

Pain and temperature are tested through the ability of the patient to discriminate between sharp and dull sensations. Sharp/dull discrimination is tested using a safety pin. First, an area of known intact sensation (e.g., the face) is tested on the patient. This point acts as a reference for the patient to compare against when testing the rest of the dermatomes. It is important to alternate testing between the sharp and dull ends of the pin in an irregular pattern to minimize guessing from the patient. Each key sensory point (Table 3) is tested to determine the sensory status at each dermatome for both sides of the body. In questionable cases, 8 out of 10 correct responses is the standard for accuracy. Because the lateral spinothalamic tract conveys information for both pain and temperature, it is not necessary to repeat the dermatome assessment using hot and cold stimuli.

Light touch is tested using a tapered wisp of cotton at each key sensory point. The tapered tip of the cotton is lightly brushed over each key sensory point (not to exceed 1 cm). An area of known intact sensation is used to compare the sensation the patient feels at each key sensory point.

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**Table 2. Clinical syndromes (Adapted from International Standards for Neurological and Functional Classification of Spinal Cord Injury. Chicago, Ill: American Spinal Injury Association; 1996)**

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Description</th>
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<tbody>
<tr>
<td>Central Cord Syndrome:</td>
<td>A lesion involving the central gray matter and the more medial white matter producing greater weakness in the upper limbs than in the lower limbs and sacral sensory sparing. Usually results from hyperextension injuries.</td>
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<tr>
<td>Posterior Cord Syndrome:</td>
<td>A lesion involving the dorsal columns that produce loss of proprioception while preserving other sensory and motor function. This syndrome is very rare. Usually a result of compression caused by a tumor or infarction of the posterior spinal artery.</td>
</tr>
<tr>
<td>Brown-Séquard Syndrome:</td>
<td>A lesion primarily involving one side of the cord, which produces ipsilateral paralysis, loss of proprioception, and contralateral loss of pain and temperature sensation. Usually a result of a penetrating injury such as a gunshot or stab wound.</td>
</tr>
<tr>
<td>Anterior Cord Syndrome:</td>
<td>A lesion involving the anterior two thirds of the cord that produces paralysis and loss of pain and temperature sensations, while preserving proprioception. Usually caused by flexion injuries that compromise the anterior spinal artery.</td>
</tr>
</tbody>
</table>
STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

C2 R L Elbow flexors
C3 R L Wrist extensors
C5 R L Elbow extensors
C6 R L Finger flexors (distal phalanx of middle finger)
C7 R L Finger abductors (little finger)
T1 R L Hip flexors
T2 R L Knee extensors
T3 R L Ankle dorsiflexors
T4 R L Long toe extensors
T5 R L Ankle plantar flexors
T6 R L
T7 R L
T8 R L
T9 R L
T10 R L
T11 R L
T12 R L

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
NT = not testable

LIGHT TOUCH

PIN PRICK

SENSORY

KEY SENSORY POINTS

0 = absent
1 = impaired
2 = normal
NT = not testable

0 Any anal sensation (Yes/No)

TOUCH SCORE

PRICK SCORE

(max: 112)

(max: 112)

NEUROLOGICAL LEVELS

SENSORY R L

COMPLETE OR INCOMPLETE?

ZONE OF PARTIAL PRESERVATION

SENSORY R L

ASIA IMPAIRMENT SCALE

COMPLETE OR INCOMPLETE?

ZONE OF PARTIAL PRESERVATION

SENSORY R L

ASIA IMPAIRMENT SCALE

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Last, proprioception is tested. Proprioception is the patient's ability to perceive joint position and is evaluated at all major joints of both the upper and lower extremities (shoulder, elbow, wrist, fingers, hips, knees, ankles, and toes). Proprioception is not a required component for ASIA testing; however, is recommended in order to establish appropriate functional outcomes. When testing proprioception, the therapist must laterally grasp the bony prominences of the extremity to reduce the effects of sensory input from the other ascending tracts of the spinal cord.

The sensory status for all three modalities, as recommended per the ASIA standards, is documented as follows:

1. Normal: The patient recognizes sensations accurately and indicates the sensations as the same as consistent with the reference point.

2. Impaired: The patient is inconsistent in perception of the sensation or the sensation is perceived as different (hypersensitive or hyposensitive) from the reference point.

3. Absent: The patient has no perception of the sensation or cannot discriminate between the sharp and dull sensations.

The sensory level, as described by ASIA, is the most caudal consecutive neurologic segment of normal sharp/dull discrimination and light touch (note that proprioception is not included in determining the sensory level). This sensory level may differ between left and right sides of the body and may also differ from the motor level. An example of ASIA sensory scoring using the worksheet is as follows (Figure 2): the patient has normal sensation for sharp/dull discrimination and light touch from C2 to C6, but impaired sensation for both modalities at C7. Sensation is absent from the C8 dermatome and below. In this example, the sensory score is 22 for both light touch and pinprick. The sensory neurologic level on the left and right sides of the body is C6.

Although sensory testing of the patient with SCI is administered along the dermatomes, physical therapists must be aware of the peripheral sensory distribution. Sensory loss that is incompatible with dermatomal orientation or that is localized in discrete areas often reflects damage to nerve roots or peripheral nerve fibers. Because of the traumatic nature of most SCIs, evidence of peripheral nerve injuries such as brachial plexus injury, nerve root avulsions, or other peripheral nerve involvement associated with limb fractures/dislocations is common.

**Muscle Performance**

The SCI physical therapy examination/evaluation also includes a thorough assessment of motor function for each myotome. The myotome is the collection of muscle fibers innervated by the motor axons from a spinal cord segment. Each spinal segment innervates more than one muscle; therefore, most muscles are innervated by more than one segment. Because of this overlapping innervation, the motor level is determined by testing key muscles along the myotomal distribution (Table 4). Motor testing should occur in a rostral to caudal direction, starting with the head/neck musculature and proceeding down toward the lower extremities. The ASIA recommends that testing occur in the supine position to allow for valid comparison of a patient's scores obtained during the acute period and throughout the continuum of care. In addition to ASIA motor testing, use of

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**Table 3. Key Sensory Points**

<table>
<thead>
<tr>
<th>C2</th>
<th>Occipital protuberance</th>
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<tbody>
<tr>
<td>C3</td>
<td>Supraclavicular fossa</td>
</tr>
<tr>
<td>C4</td>
<td>Top of the acromioclavicular joint</td>
</tr>
<tr>
<td>C5</td>
<td>Lateral side of the antecubital fossa</td>
</tr>
<tr>
<td>C6</td>
<td>Thumb, dorsal surface, proximal surface</td>
</tr>
<tr>
<td>C7</td>
<td>Middle finger, dorsal surface, proximal phalanx</td>
</tr>
<tr>
<td>C8</td>
<td>Little finger, dorsal surface, proximal phalanx</td>
</tr>
<tr>
<td>T1</td>
<td>Medial side of the antecubital fossa</td>
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<tr>
<td>T2</td>
<td>Apex of the axilla</td>
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<tr>
<td>T3</td>
<td>Third intercostal space at midclavicular line</td>
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<tr>
<td>T4</td>
<td>Fourth intercostal space (nipple line) at midclavicular line</td>
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<tr>
<td>T5</td>
<td>Fifth intercostal space at midclavicular line</td>
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<tr>
<td>T6</td>
<td>Sixth intercostal space at midclavicular line</td>
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<td>T7</td>
<td>Seventh intercostal space at midclavicular line</td>
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<tr>
<td>T8</td>
<td>Eighth intercostal space at midclavicular line</td>
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<td>T9</td>
<td>Ninth intercostal space at midclavicular line</td>
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<tr>
<td>T10</td>
<td>Tenth intercostal space at midclavicular line (umbilicus)</td>
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<td>T11</td>
<td>Eleventh intercostal space at midclavicular line</td>
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<tr>
<td>T12</td>
<td>Inguinal ligament at midpoint</td>
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<td>L1</td>
<td>Half the distance between T12 and L2</td>
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<tr>
<td>L2</td>
<td>Mid-anterior thigh</td>
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<td>L3</td>
<td>Medial femoral condyle</td>
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<tr>
<td>L4</td>
<td>Medial malleolus</td>
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<tr>
<td>L5</td>
<td>Dorsum of the foot at the third metatarsophalangeal joint</td>
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<tr>
<td>S1</td>
<td>Lateral heel</td>
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<tr>
<td>S2</td>
<td>Popliteal fossa in the midline</td>
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<tr>
<td>S3</td>
<td>Ischial tuberosity</td>
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<tr>
<td>S4-5</td>
<td>Perianal area</td>
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</tbody>
</table>

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

<table>
<thead>
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<th>Level</th>
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<td>S4-5</td>
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</tbody>
</table>

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
NT = not testable

Voluntary anal contraction (Yes/No)

TOTALS □ + □ = □ MOTOR SCORE

(MAXIMUM) (50) (50) (100)

SENSORY

KEY SENSORY POINTS

<table>
<thead>
<tr>
<th>Level</th>
<th>Right</th>
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<td>L3</td>
<td></td>
<td></td>
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<tr>
<td>L4</td>
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<tr>
<td>L5</td>
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<tr>
<td>S1</td>
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<td>S2</td>
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<tr>
<td>S3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4-5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0 = absent
1 = impaired
2 = normal
NT = not testable

Any anal sensation (Yes/No)

TOTALS □ + □ = □ MOTOR SCORE

(MAXIMUM) (50) (50) (100)

LIGHT TOUCH SCORE

(MAXIMUM) (56) (56)

PIN PRICK SCORE

(MAXIMUM) (50) (50)

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STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

**MOTOR**

**KEY MUSCLES**
- C2: Elbow flexors
- C3: Wrist extensors
- C4: Elbow extensors
- C5: Finger flexors (distal phalanx of middle finger)
- C6: Finger abductors (little finger)
- C7: Hip flexors
- C8: Knee extensors
- T1: Ankle dorsiflexors
- T2: Long toe extensors
- T3: Ankle plantar flexors
- T4: Any anal sensation (Yes/No)
- T5: Voluntary anal contraction (Yes/No)
- T6: Any sensation (Yes/No)
- T7: Sensation to pin prick (max: 112)
- T8: Motor score (max: 100)
- T9: Tactile or light touch (max: 112)
- T10: Complete or incomplete?
- T11: Zone of partial preservation
- T12: Sensory levels

**SENSORY**

**KEY SENSORY POINTS**
- Voluntary anal contraction (Yes/No)
- Any anal sensation (Yes/No)
- Sensation to pin prick (max: 112)
- Motor score (max: 100)
- Tactile or light touch (max: 112)

**NEUROLOGICAL LEVELS**
- Complete or incomplete?
- Zone of partial preservation
- Sensory levels
- Motor levels

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traditional muscle testing described by Daniels and Worthingham or Kendall and McCreary is recommended once the patient is able to assume the correct testing positions. The motor level is determined by the most caudal segment where the key muscle is grade 3 and the next most rostral key muscle tests as a 5. The determination of strength grades of each key muscle is on a six-point scale.

- 0 = total paralysis determined by no palpable or visible contraction
- 1 = palpable or visible contraction, but no movement detected at the joint
- 2 = active movement, full range of motion (ROM) with effects of gravity eliminated
- 3 = active movement, full ROM against gravity
- 4 = active movement, full ROM moderate resistance
- 5 = (normal) active movement, full ROM against full resistance

The manual muscle test in the acute phase is mainly limited to the key muscles for motor level classification. As the patient's endurance and tolerance for activity increase, a more specific manual muscle test can be incorporated into the examination/evaluation process, especially if the patient has an incomplete injury. Patterns of weakness, atrophy, or compensation reflect nerve root or peripheral nerve damage. An example of motor scoring will be described using the ASIA worksheet (Figure 3). The patient scored 5 for bilateral biceps and wrist extensor muscles. For the triceps muscle, the patient scored 2 on the left and 3 on the right. There was no volitional movement noted below the level of C7. In this example, the motor score on the left is 12 and the motor score on the right is 13, for a total motor score of 25. The motor level is C6 on the left and C7 on the right. In addition, this patient has an ASIA impairment scale of "A" as determined by the absent sensory/motor in the lowest sacral segments.

**Additional Assessments**

In addition to the assessments of the musculoskeletal and neuromuscular systems, other areas of the examination/evaluation are vital prior to establishing outcomes. The Guide to Physical Therapist Practice recommends that additional areas be thoroughly evaluated for people with SCI (Table 5). Numbers 1 through 13 in the table represent areas obtained during the history, and numbers 14 through 36 are recommended specific tests and measures.

<table>
<thead>
<tr>
<th>Level</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1-4</td>
<td>No key muscle; use the sensory level</td>
</tr>
<tr>
<td>C5</td>
<td>Elbow flexors (biceps, brachialis)</td>
</tr>
<tr>
<td>C6</td>
<td>Wrist extensors (extensor carpi radialis longus and brevis)</td>
</tr>
<tr>
<td>C7</td>
<td>Elbow extensors (triceps)</td>
</tr>
<tr>
<td>C8</td>
<td>Finger flexors (flexor digitorum profundus) to the middle finger</td>
</tr>
<tr>
<td>T1</td>
<td>Small finger abductors (abductor digiti minimi)</td>
</tr>
<tr>
<td>T2-L1</td>
<td>No key muscle; use the sensory level</td>
</tr>
<tr>
<td>L2</td>
<td>Hip flexors (iliopsoas)</td>
</tr>
<tr>
<td>L3</td>
<td>Knee extensors (quadriceps femoris)</td>
</tr>
<tr>
<td>L4</td>
<td>Ankle dorsiflexors (tibialis anterior)</td>
</tr>
<tr>
<td>L5</td>
<td>Long toe extensors (extensor hallucis longus)</td>
</tr>
<tr>
<td>S1</td>
<td>Ankle plantar flexors (gastrocnemius/soleus)</td>
</tr>
<tr>
<td>S2-5</td>
<td>No key muscle; use the sensory level</td>
</tr>
</tbody>
</table>

Along with the physical therapy examination/evaluation, other team members are also involved with the evaluation process. Once the evaluation is complete, specific short- and long-term outcomes can be established with input from the entire rehabilitation team. When establishing expected outcomes, it is necessary to review them with the patient and family/caregiver. This review helps the rehabilitation team in prioritizing specific goals and modifying interventions based on patient/family/caregiver input.

**Acute Care Intervention**

Physical therapy management of the patient with SCI begins in the intensive care unit. Due to the presence of multiple medical issues and limited endurance for patients in the acute phase, this phase is extremely important to set the stage for the success of the rehabilitation phase. The main goals of this phase are to prevent secondary complications, maintain/improve ROM, maintain/improve strength through active exercises, increase sitting tolerance, and improve the patient's endurance for activities.

**Impairments**

Following a SCI, patients will be left with impairments that predispose them to secondary medical complications. Each
Table 5. Additional Assessments Recommended by the Guide to Physical Therapist Practice*  

1. General demographics  
2. Social history  
3. Employment/work (job/school/play)  
4. Growth and development  
5. Living environment  
6. General Health Status (Self report, family report, caregiver report)  
7. Social/health habits (past and current)  
8. Family history  
9. Medical/surgical history  
10. Current condition(s)/chief complaint(s)  
11. Functional status and activity level  
12. Medications  
13. Other clinical tests  
14. Aerobic capacity and endurance  
15. Anthropometric characteristics  
16. Arousal, attention, and cognition  
17. Assistive and adaptive devices  
18. Circulation (arterial, venous, and lymphatic)  
19. Cranial and peripheral nerve integrity  
20. Environmental, home, and work (job/school/play)  
21. Ergonomics and body mechanics  
22. Gait, locomotion, and balance  
23. Integumentary integrity  
24. Joint integrity and mobility  
25. Motor function (motor control and motor learning)  
26. Muscle performance (including strength, power, and endurance)  
27. Neuromotor development and sensory integration  
28. Orthotic, protective, and supportive devices  
29. Pain  
30. Posture  
31. Range of motion (including muscle length)  
32. Reflex integrity  
33. Self-care and home-management (including ADL and IADL)  
34. Sensory integrity  
35. Ventilation and respiration/gas exchange  
36. Work (job/school/play), community, and leisure integration or reintegration (including IADL)  

Cardiovascular/Pulmonary  

Lesions above C4 result in paralysis of the diaphragm. People with a SCI above C4 require artificial ventilation, whereas people with injuries from C4 through T12 are able to breathe independent of mechanical ventilation but have respiratory compromise due to intercostal and abdominal muscle paralysis. The extent of ventilatory impairment is directly proportional to the amount of inspiratory and expiratory muscle involvement.

To reduce respiratory complications, the physical therapist, along with other members of the rehabilitation team, should incorporate the following techniques:

1. Postural drainage and percussion/vibration for the management of secretions in dependent sections of the lung.
2. Instruction to patient and caregiver in correct performance of assisted cough techniques. In addition, the respiratory therapist instructs the patient and caregiver in the correct procedure for suctioning the trachea of the patient who has an artificial open airway.
3. Incorporate breathing exercises that promote coordination of breathing patterns, increase vital capacity, increase forced expiration, and maintain chest wall mobility.
4. Maintain chest wall mobility. Improved chest wall mobility contributes to the movement of greater air volume, resulting in improved inspiratory and expiratory ability. Mobility of the chest wall can also be maintained by performing ROM to the trunk and rib cage in conjunction with promoting deep breathing exercises through the use of incentive spirometry or facilitated deep-breathing patterns.
5. Provide an abdominal binder to all patients with injury levels above T12. The abdominal binder is fitted so that the upper margin covers the lower floating ribs and the lower margin is below the superior iliac spine. The abdominal binder assists by increasing intra-abdominal pressure that pushes the diaphragm to a higher resting level. This results in a greater excursion for each contraction of the diaphragm, resulting in a larger inspiratory volume.

The cardiovascular system is also impaired as a result of an SCI. Sympathetic outflow to the heart is located between T3 and T5. For injuries of T5 and above, cardioacceleration becomes dependent on withdrawal of vagal tone. This leads to an alteration in heart rate response during exercise.
Spinal cord injuries above L1 have impaired vasoresponsiveness to the lower extremities. The lack of arterial vasoconstriction to the lower-extremity muscles during active upper-extremity exercise can lead to a decrease of blood pressure during exercise. This drop in blood pressure during exercise is called exercise hypotension. Exercise hypotension can lead to cardiac arrest in severe cases. In addition, venous pooling in the lower extremities caused by the lack of a muscle pump leads to a decreased amount of circulating blood. This decreased volume in circulating blood leads to a decrease in stroke volume and cardiac output.

Antiembolism stockings along with an abdominal binder are used to reduce complications during intervention sessions. Hydration prior to heavy exercise is also recommended. The physical therapist must carefully monitor blood pressure responses to exercise and cease the exercise if a drop of more than 20 mg of mercury is noted.

Thrombophlebitis

Thromboembolic events are a leading cause of mortality and morbidity following an acute SCI. Thromboembolism is described as "displacement of thrombi (clots) from the leg veins to the arteries of the lung (pulmonary embolism). If there is a hole in the heart, the clots may cross into the arterial circulation and deposit in the brain, causing a stroke." The factors predisposing people with SCI to venous thromboembolism include venostasis, activation of blood coagulants, immobilization, and endothelial damage. Due to the life-threatening consequence of thromboembolism, prevention and early detection are essential to prevent death.

The most effective pharmacological means of prevention is a 12-week regimen of low-molecular heparin initiated within 72 hours after the acute SCI. Devices that are used as a means of prevention include pneumatic pumps placed on each lower extremity, providing an artificial muscle pump, while the patient is in bed and antiembolism stockings while the patient is out of bed. In addition, the physical therapist can assist with prevention by early mobilization and passive ROM exercises that are initiated as early as medically possible.

Early detection of thromboembolism can save a patient's life. The most common clinical signs and symptoms include: 1) increased circumference of the calf or thigh (unilaterally), 2) increased venous pattern of collateral veins in the affected extremity, 3) pain, tenderness, or heaviness of the affected extremity, and 4) low-grade fever of unknown origin. If any of these symptoms occur, the therapist should stop all active and passive exercises to the lower extremities and contact the physician immediately.

Integumentary

A pressure sore can increase the length of stay in the hospital as well as affect the potential functional abilities of the patient. Pressure sores are caused by prolonged pressure over body parts, especially over bony prominences. This prolonged pressure compromises circulation to the skin and leads to ischemia, mechanical damage, and subsequent tissue death. Other factors associated with skin breakdown include friction or shearing forces, poor bed mobility or transfer techniques, poor nutrition, atrophy of underlying tissue, and excessive moisture caused by incontinent bowel and bladder. The physical therapist works closely with the health care team to incorporate strict skin care guidelines to prevent pressure sores from occurring.

A pressure relief program must be initiated within the first hour of arriving at the acute care or rehabilitation center. If the patient is limited to bed activities, a strict turning schedule established by the nursing staff must be instituted. The patient must be turned every 30 minutes to prevent prolonged pressure over any area of the body. The patient should be alternately turned from side to side, prone, and supine. A thorough check of the skin occurs after each turn. If the skin is red, the patient is left off this area until the redness subsides. If redness is present, it should subside within 5 to 10 minutes. If the redness does not subside within 5 to 10 minutes, the turn time is not increased until the redness does subside within this time frame. If the skin tolerates, the time between turns is gradually increased until 4 to 6 hours per side is achieved. Along with turning, the bony prominences must be completely relieved of pressure by bridging the area off with pillows to prevent excess pressure over these areas.

Once the patient is medically stable to begin sitting in a wheelchair (WC), a separate pressure relief (weight shift) program is initiated. A pressure relief cushion must be used at all times if there is any sensory loss in the buttock or sacral areas. The cushion, along with a weight shift program, is the best defense against skin breakdown. There are several methods of performing weight shifts. Individuals with high-level tetraplegia (C1–4) perform weight shifts by manually reclining with the assistance of another person, or mechanically reclining using a power recline/tilt WC. Individuals with lower-level tetraplegia (C5–8) can perform weight shifts using the side-to-side method (Figure 4) or the forward lean method (Figure 5). The most common method of weight shifts for individuals with paraplegia or strong lower-level tetraplegia is the depression weight shift, where the bottom is completely lifted off of the sitting surface (Figure 6). Each weight shift, regardless of the method, should relieve pressure from the sitting surfaces of the body for a minimum of...
Figure 4. Side-to-side weight shift. Recommended for individuals with C5-6 tetraplegia. This weight shift requires that each side of the buttocks to be relieved of pressure for a minimum of 1 minute.

Figure 5. Forward lean weight shift. Recommended for individuals with C7-8 tetraplegia.

Figure 6. Depression weight shift. This weight shift requires the greatest amount of upperextremity strength of all the weight shifts described. This type of weight shift is recommended for individuals with paraplegia.

Education to the patient/family/caregiver is essential. Instruction on weight shift performance, correct padding and positioning techniques while in bed and in the WC, appropriate hygiene considerations, and cushion care is needed. In addition, education on proper identification and intervention when a pressure sore initially appears is also very important in order to prevent the wound from progressing. Skin reconstructive surgery is a costly procedure that can easily be prevented if all measures are taken.

Neuromuscular

Hypertonicity. Hypertonicity, or spasticity, is defined as “a motor disorder characterized by velocity-dependent increase in tonic stretch reflexes ('muscle tone') with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex, as one component of the upper motor neuron syndrome.”7 Hypertonicity is common for individuals who have a vertebral injury level of T12 or above (upper motoneuron lesion) and can often lead to pain, decreased ROM, and decreased functional outcomes. Hypertonicity is medically managed through pharmacological means; however, it is imperative that the physical therapist be involved to assist the physician on the most appropriate dosage of medication. Physical therapists can communicate to the physician when hypertonicity is at a level that inhibits functional abilities. When patients experience side effects of hypertonicity medication that interfere with treatment and functional gains (eg, drowsiness, nausea), the physician needs to be notified to adjust the dosage of medication. In addition, some common therapeutic procedures can be used to decrease the effects of hypertonicity, including prolonged stretching, inhibitive casting, weight bearing, biofeedback, transcutaneous electrical nerve stimulation, aquatic therapy, and ice.

Hypotonicity. Hypotonicity is common for individuals who have a vertebral injury level of L1 or below (lower motoneuron lesion). When a lower motoneuron injury occurs, all peripheral motor fibers supplying a muscle are destroyed. In this instance, all voluntary, postural, and reflex movements are lost. Hypotonicity can lead to muscle atrophy, with the muscle decreasing to 20% to 30% of its original bulk within 3 months. Once atrophy occurs, special care must be taken to protect the skin, especially over bony prominences of the body.8

Neurogenic bowel. A neurogenic bowel is common following a SCI. The neurogenic bowel is described as a life-altering impairment of gastrointestinal and anorectal func-
Complications due to a neurogenic bowel include reflex ileus, peptic ulcers, pancreatitis, and fecal impaction.

Bowel function after an SCI varies based on the level of the injury. An upper motoneuron lesion results in a bowel that reflexively eliminates stools, and the patient does not have volitional anal sphincter control. A lower motoneuron lesion results in an areflexive bowel where no spinal cord mediated reflex peristalsis occurs. Both the reflexic and areflexic bowel function can lead to uncontrolled bowel evacuation that can be a great source of embarrassment. The nurse, occupational therapist, and physical therapist must work together to establish the most appropriate bowel program. The team works along with the patient and family to determine the best time of day for elimination, the equipment used, and the procedure used for the bowel program. The goal of the bowel program is to develop a predictable method and time of elimination to reduce complications and improve life satisfaction.

**Neurogenic bladder.** The disruption in the neural pathways caused by the SCI also affects the storage and elimination capabilities of the bladder. A bladder program must be initiated as soon as possible to prevent urinary tract infections, renal calculus, and kidney failure. In addition, an overdistended bladder can lead to autonomic dysreflexia in people with a lesion of T6 or higher (refer to next section for specifics).

A reflexive bladder occurs with an upper motoneuron lesion, whereas an areflexive bladder occurs with a lower motoneuron lesion. The rehabilitation team establishes a strict regimen of emptying the bladder. A reflexive bladder is generally managed via external collection devices (eg, condom catheter) and/or intermittent catheterizations (IC). Upon admission to the hospital, an indwelling catheter may be used to empty the bladder, but should quickly be replaced with alternate methods due to the increased risk of urinary tract infections.

**Autonomic dysreflexia (hyperreflexia).** Autonomic dysreflexia is described as “an uninhibited sympathetic nervous system response to a variety of noxious stimuli occurring in people with SCI at the T6 level and above.” Autonomic dysreflexia is a medical emergency and considered a life-threatening condition, as blood pressure may become extremely elevated. Symptoms include pounding headache, profuse sweating above the level of the lesion, flushed skin, blurred vision, spots in the patient's visual field, feelings of apprehension, cardiac arrhythmias, and elevated blood pressure of 20 to 40 mm Hg above baseline.

Once autonomic dysreflexia is recognized, the patient should immediately be placed in an upright sitting position. The next step after placing the patient in this position is to identify the cause of the noxious stimulus. The most common cause of autonomic dysreflexia is bladder distention. The patient's catheter must be checked to ensure that there is no loss of urine flow due to a bent or obstructed catheter. Other causes may be a urinary tract infection, bladder or kidney stones, bowel impaction, ingrown toenail, or any painful or irritating stimuli below the level of the injury. Generally, relieving the cause of autonomic dysreflexia will restore the blood pressure and pulse back to normal. If the blood pressure is not returned to normal, immediate medical care must be obtained for the patient.

At times, a therapist may notice early signs of autonomic dysreflexia during various treatments. For example, while performing ROM activities below the level of the lesion (ie, hamstring muscle stretch for a person with T4 paraplegia), the patient may experience a headache or flushed skin. If these types of reactions are noted, the activity that is causing these reactions must be terminated.

**Thermoregulation.** A disruption of temperature control below the level of injury occurs due to the autonomic nervous system dysfunction caused by SCI. The absence of thermoregulatory sweating and vasoconstriction below the lesion implies that the body temperature of the client with SCI is influenced by the temperature of the environment. This may result in hypothermia in cooler weather and hyperthermia in warmer weather. To prevent hypothermia, the patient should dress appropriately in cooler weather. To prevent hyperthermia in warmer weather, a fan can be used to cool off the patient or the patient can be sponged with water to act as an artificial sweating mechanism. Education regarding proper clothing and precautions in extreme weather is essential for the patient.

**Musculoskeletal**

**Joint contractures.** Joint contractures can result from many factors, including hypertonicity, immobility, muscle imbalance, and pain. Contractures can be prevented by daily ROM exercises and proper positioning while in bed or in the WC. In addition, custom-made orthoses may need to be fabricated to further help prevention of joint contractures. For optimal rehabilitation of the individual with SCI, contractures must be avoided to allow the flexibility of the shoulders, trunk, and legs that is required to perform functional activities. Refer to the “Range of Motion” section for particular ROM techniques to use for individuals with SCI.

**Heterotopic ossification (HO).** Heterotopic ossification is defined as the deposition of calcium in the muscles, usually occurring after injury and nerve damage. The clinical signs of HO include a decrease in joint ROM with a hard, bony
end-feel, swelling, local heat, erythema, and nonseptic fever. Pharmacologically, HO is treated with calcium chelators and anti-inflammatory agents. The most common areas for HO to occur are the hips, knees, and elbows. Range-of-motion exercises are continued to maintain existing ROM but do not always prevent severe decreases in the available ROM. The resultant decrease of a joint's ROM can be devastating to desired functional outcomes. For example, if HO is severe in the hips, it may limit hip flexion to 20 degrees. In this instance, the patient is unable to sit in a functional position in a WC. If the bone formation is severe enough to limit functional abilities, the physician may perform a wedge resection of the bone after it has matured.

**Early Interventions**

**Range of Motion**

Expected outcomes are enhanced by early ROM intervention. Physical therapists and occupational therapists need to be aware of special ROM requirements for patients with SCI that affect independence in activities of daily living. Individuals with tetraplegia are particularly at risk for shoulder and elbow limitations. Positioning the patient while in bed can assist with ROM. For example, placing the arms across the chest or abdomen may result in shortened elbow flexors, shoulder abductors, and external rotators. Shortening of these muscles can be extremely detrimental to function, especially for an individual with a C5 or C6 injury. Positioning of the shoulder in extension with external rotation is required to sustain biomechanical locking of the elbow in the absence of triceps brachii muscle function. Another example of positioning in bed to assist ROM is placing patients in a prone position. The prone position is ideal to maintain hip and knee extension, which is important for all levels of injuries.

Critical ROM requirements for people with a SCI include full elbow extension, supination, and wrist extension for upper-extremity weight bearing; ankle dorsiflexion at neutral for proper foot placement on a footplate of a WC; hip and knee flexion to a minimum of 90 degrees; and full external rotation for lower-extremity dressing, transfers, and WC positioning; and, full hip and knee extension for functional ambulation.

Selective muscle length of some muscle groups is critical for achieving long-term functional outcomes. The concept of selective muscle length implies achieving a balance in muscle lengths to provide a level of stability and function that cannot be provided by voluntary muscle force. For example, selective shortening of the long-finger flexors for patients with a C6 injury is required to provide a functional grasp through the action of tenodesis. Tenodesis is a normal biomechanical response that results in finger flexion when the wrist is extended and finger extension when the wrist is...
flexed. This action can be incorporated into hand motions that will result in a functional grasp and release (Figures 7A and 7B). Although full normal finger joint mobility is a desired outcome, ROM exercises should be performed in such a manner that preserves some shortening in the long-finger flexors so that a natural tenodesis can be achieved. It is recommended the long-finger flexors be ranged only to the point where full finger extension is possible when the wrist is in a neutral position. It would be inappropriate to stretch the finger flexors with the wrist in full extension. When performing upper-extremity weight-bearing activities for individuals with C6 injuries, the therapist should be careful that the fingers are flexed (Figure 8) to assist in preventing overstretching of the long-finger flexors.

Another example of selective muscle lengthening is seen with the long-sitting position without normal trunk muscle function (ie, for people with an injury above T12). Stability in sitting can be enhanced through lengthening of hamstring muscles while shortening the muscles of the low back. Hamstring muscles should be stretched to achieve 100 to 110 degrees of hip flexion with full knee extension. Hamstring muscles that are too tight will result in a tendency to fall backward during the long-sitting position, and the patient will compensate by overstretching the low back muscles in order to maintain balance while sitting. This selective lengthening of the hamstring muscles and the shortening of the low back muscles is required to provide the balance between length for mobility yet tightness for stability needed in transfers and other functional activities (Figure 9).

It is imperative for physical therapists to recognize the importance of proper ROM exercise for both joint integrity and muscle length. Long-term function can be seriously impaired as a consequence of inadequate ROM techniques applied early to the rehabilitation of the person with SCI.

**Therapeutic Exercise**

The goal of active exercise in the early acute care phase is to maintain muscle strength of the fully innervated musculature and improve strength in the partially innervated musculature. Compromised respiratory function, unstable vital signs, and inability to properly eat and digest food are all complications in the early acute care phase that prevent the patient from tolerating muscle strengthening exercises. Prior to surgical stabilization, resistance should be minimal and given in a symmetrical manner to reduce any rotational forces on the spine. As the patient’s endurance and tolerance for activity increase, exercises can be incorporated to improve strength in functioning muscles. Active exercise can be incorporated into activities of daily living and should be performed throughout the acute, rehabilitation, and postdischarge care. Cuff weights, neuromuscular electrical stimulation, proprioceptive neuromuscular facilitation, weight-bearing activities, and use of arm ergometers are all strengthening/endurance modalities that are used with good success for individuals with SCI.

**Sitting Program**

Tolerating upright sitting is a goal that should be started during the acute care phase. The patient should be introduced to sitting activities once spinal and medical stability is achieved. Orthostatic hypotension is a common complication that results from periods of prolonged bed rest and the loss of vasomotor control. As the patient is brought to an upright position, blood pools in the dependent lower extremities and abdominal cavity, resulting in decreased blood pressure, dizziness, and fainting. Factors contributing to orthostatic hypotension can be minimized by use of an abdominal binder and pressure-gradient lower-extremity hose. If further pressure support is needed for the lower extremities, the legs can be wrapped from the foot to the upper thigh using an elastic bandage.

Upright activities can begin in the bed by raising the head of the bed incrementally while monitoring the patient’s blood pressure, heart rate, and subjective complaints. If the patient can tolerate sitting at 60 degrees of inclination from the horizontal plane, he or she is ready to be transferred to a recliner WC with adjustable leg rests. If the patient complains of dizziness or feeling faint, the chair can be reclined backward and the leg rests elevated. The back angle is progressively moved up and leg rests are lowered as the patient tolerates.

![Figure 9. A balance of hamstring muscle length to 100°-110° of straight leg raise and selective shortening of the low back muscles results in stability within the long-sitting position.](image-url)
<table>
<thead>
<tr>
<th>Injury Level</th>
<th>Muscles Innervated Anticipated</th>
<th>Outcome Potential</th>
<th>Anticipated Equipment Needed to Achieve Functional Outcomes</th>
</tr>
</thead>
</table>
| CI-C4        | Facial muscles, neck muscles, diaphragm (C4) | Bed mobility: dependent  
Transfers: dependent  
Feeding: dependent  
Grooming: dependent  
Dressing: dependent  
Bowel/bladder management: dependent  
WC locomotion: modified independent with power WC  
Weight shift: modified independent with power recline WC | Portable ventilator (C1-3)  
Bedside ventilator (CI-3)  
Electric hospital bed  
Power recline/tilt WC  
Reclining shower/commode chair  
Hydraulic patient lift  
Manual WC for transport/backup  
WC cushion  
Environmental control unit |}
| C5           | Above muscles, biceps, brachialis, brachioradialis, deltoid, infraspinatus, subscapularis | Bed mobility: moderate to maximal assist  
Transfers: maximal assist  
Feeding: minimal assist  
Grooming: minimal assist  
Dressing: dependent/Bathing: dependent  
Bowel/bladder management: dependent  
WC locomotion: modified independent with power WC  
Weight shift: modified independent | Electric hospital bed  
Transfer board  
(strong C5)  
Hydraulic patient lift  
(weak C5)  
Adaptive ADL equipment  
Roll-in shower/commode chair  
Power upright WC  
(strong C5)  
Power recline WC  
(weak C5)  
Manual WC for transport/backup  
WC cushion  
Environmental control unit |}
| C6           | Above muscles, extensor carpi radialis, serratus anterior | Bed mobility: minimal assist to independent  
Transfers: minimal assist to independent (except loading WC into car and floor transfers)  
Feeding: modified independent  
Grooming: modified independent equipment  
Dressing: independent  
Bathing: independent/Bowel/bladder management: moderate assist  
Power WC locomotion: modified independent  
Manual WC locomotion: minimal assist to modified independent depending on strength of scapular muscles  
Weight shift: modified independent | Electric hospital bed  
Transfer board  
Adaptive ADL equipment  
Shower/commode chair  
Power upright WC  
Manual upright WC for transport/backup  
WC cushion  
Tenodesis hand brace  
Hand controls for automobile |
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<tr>
<th>Injury Level</th>
<th>Muscles Innervated Anticipated</th>
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<th>Anticipated Equipment Needed to Achieve Functional Outcomes</th>
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<tbody>
<tr>
<td>C7-8</td>
<td>Above muscles C7: triceps, flexor carpi ulnaris, finger extensors C8: finger flexors</td>
<td>Bed mobility: independent</td>
<td>Hospital bed</td>
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<tr>
<td></td>
<td></td>
<td>Transfers: bed, tub/toilet independent; car with minimal assist to independent; floor with maximal assist</td>
<td>Transfer board</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Feeding: independent</td>
<td>Adaptive ADL equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grooming: independent</td>
<td>Shower/commode chair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dressing: independent</td>
<td>Power upright WC (weak C7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bathing: independent</td>
<td>Manual upright WC (strong C7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bowel/bladder management: independent</td>
<td>WC cushion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power WC locomotion: modified independent</td>
<td>Hand controls for automobile</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manual WC locomotion: modified independent; 6-in curb with moderate assist; ascend/descend stairs dependent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight shift: modified independent</td>
<td></td>
</tr>
</tbody>
</table>

Paraplegia

<table>
<thead>
<tr>
<th>Muscles Innervated Anticipated</th>
<th>Outcome Potential</th>
<th>Anticipated Equipment Needed to Achieve Functional Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All UE muscles, trunk muscles up to level of injury, LE muscles depending on level of injury</td>
<td>Bed mobility: independent</td>
<td>Manual WC</td>
</tr>
<tr>
<td></td>
<td>Transfers: independent including car and floor</td>
<td>WC cushion</td>
</tr>
<tr>
<td></td>
<td>All ADL are independent</td>
<td>Appropriate orthoses for LE if ambulation is a realistic goal</td>
</tr>
<tr>
<td></td>
<td>Manual WC propulsion independent for all surfaces including ramps, curbs, and rough terrain; ascend/descend stairs with handrail with minimal-to-moderate assist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ambulation possible for the lower levels (T12 and below) with appropriate assistive devices and orthoses; higher-level ambulation is difficult</td>
<td></td>
</tr>
</tbody>
</table>

Outcomes for Common Incomplete Syndromes as Described in Table 2

<table>
<thead>
<tr>
<th>Central cord syndrome (Assuming limited UE function, normal LE function, mild impairment of trunk muscles and minimal spasticity)</th>
<th>Outcome Potential</th>
<th>Anticipated Equipment Needed to Achieve Functional Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed mobility: minimal assistance to independent</td>
<td>Electric hospital bed</td>
<td></td>
</tr>
<tr>
<td>Transfers: requires setup assistance, but performs using stand pivot type transfer</td>
<td>Power recline/tilt WC</td>
<td></td>
</tr>
<tr>
<td>Feeding: dependent/Grooming: dependent</td>
<td>Manual WC for backup and some locomotion</td>
<td></td>
</tr>
<tr>
<td>Bathing: dependent</td>
<td>Shower/commode chair</td>
<td></td>
</tr>
<tr>
<td>Dressing: dependent</td>
<td>WC cushion</td>
<td></td>
</tr>
<tr>
<td>Bowel/bladder management: has full bowel/bladder control, but will need full assistance for clothing management and cleanup</td>
<td>Environmental control unit</td>
<td></td>
</tr>
<tr>
<td>Power WC locomotion: modified independent with mouth, chin, or head controls if unable to ambulate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual WC locomotion: modified independent using hemi-height WC propelled by the LEs if unable to ambulate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambulation: independent if trunk and LE muscles have strength of 4 to 5 throughout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight shift: modified independent using power tilt/recline or by performing a standing weight shift</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Outcomes for Common Incomplete Syndromes as Described in Table 2 (continued)

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Outcomes</th>
</tr>
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<tbody>
<tr>
<td>Brown-Séquard syndrome</td>
<td>Bed mobility: independent</td>
</tr>
<tr>
<td>(Assuming one side of the body</td>
<td>Transfers: independent</td>
</tr>
<tr>
<td>with normal motor function and</td>
<td>Feeding: independent</td>
</tr>
<tr>
<td>absent sensory function and the</td>
<td>Grooming: independent</td>
</tr>
<tr>
<td>other side with absent motor</td>
<td>Bathing: modified independent</td>
</tr>
<tr>
<td>function and intact sensory</td>
<td>Dressing: modified independent</td>
</tr>
<tr>
<td>function)</td>
<td>Bowel/bladder management: independent</td>
</tr>
<tr>
<td></td>
<td>Power WC locomotion: modified independent</td>
</tr>
<tr>
<td></td>
<td>Manual WC locomotion: modified independent using a hemi-height WC for one</td>
</tr>
<tr>
<td></td>
<td>Ambulation: minimal assistance to modified independent using assistive</td>
</tr>
<tr>
<td></td>
<td>devices and long-leg brace (KAFO) on side with absent motor function of</td>
</tr>
<tr>
<td></td>
<td>LEs</td>
</tr>
<tr>
<td></td>
<td>Weight shift: independent</td>
</tr>
<tr>
<td></td>
<td>Orthoses and assistive devices if strength allows ambulation</td>
</tr>
<tr>
<td>Anterior cord syndrome</td>
<td>Only proprioception is spared; the functional outcomes and</td>
</tr>
<tr>
<td></td>
<td>anticipated equipment needs are the same as for complete injuries of the</td>
</tr>
<tr>
<td></td>
<td>same vertebral level</td>
</tr>
</tbody>
</table>

As discussed earlier, pressure relief is a mandatory component of the sitting program and begins with proper WC cushioning. Various WC cushions are available, and recommendations concerning cushion selection should be based on functional need, height, weight, current skin condition, and long-term goals of the patient.

Rehabilitation Interventions

Health care in the 1990s is characterized by an ever-increasing emphasis on cost-effectiveness. The direct impact on SCI care is the consistently decreasing hospital length of stay. It is common for rehabilitation to begin within 7 days after injury, as soon as the patient's spine and medical status are stable. Currently, the typical inpatient rehabilitation length of stay averages 3 to 4 weeks for individuals with complete paraplegia and 6 to 8 weeks for individuals with complete tetraplegia. The average time spent in rehabilitation for individuals with incomplete injuries is often less than for individuals with complete injuries.

The constraints imposed by such limited hospitalization require an emphasis for inpatient rehabilitation on preparing for the patient's discharge to the home. The entire rehabilitation team must work together to establish and achieve the desired outcomes for each patient. Treatment priorities for physical therapy during rehabilitation include:

- developing the appropriate levels of strength, mobility, balance, and endurance required for function;
- teaching the patient and primary caregivers functional skills in bed mobility, pressure relief, transfers, and WC mobility and management (the patient should be proficient in instructing caregivers all care that is necessary); and,
- assessing the work (job/school/play) environment and equipment needs to facilitate management of the patient at work (job/school/play).

The physical therapist must quickly determine the appropriate transfer strategies and techniques to achieve safe functional care at home. Rehabilitation strategies for patients with SCI require an ability to correlate individual abilities with realistic functional expectations. The actual outcomes achieved depend on many variables such as the patient's level of injury, degree of completeness, body size and type, motivational status, social support systems, financial resources, and discharge location. Expected outcomes by level of injury provide frames of reference when projecting...
expected outcomes (Table 6). Intervention techniques for achieving these outcomes are numerous and varied. The reader is directed to the additional reading list for texts that provide in-depth discussion on various SCI intervention approaches. The following section reviews essential components of a comprehensive rehabilitation program to facilitate progression toward expected outcomes.

**Pre-functional Training**

Pre-functional training includes exercise programs directed toward achieving appropriate levels of mobility throughout the body and maximal levels of strength in innervated and partially innervated muscle groups. Mat programs are examples of exercise strategies that incorporate prerequisite skills in strength, mobility, and coordination with those skills required to achieve desirable functional outcomes. Progression in supine, rolling, long-sitting, and short-sitting activities are preparatory to more advanced skills such as transfers, dressing, and ambulation.

**Functional Training and Outcomes**

The emphasis on functional training by the physical therapist assists the patient with SCI in achieving the highest level of functional independence. Regardless of the level of injury, each patient should be educated on the safe performance of all components of each functional task. For people with higher levels of injury (ie, above C4), performance of each of the functional tasks listed will be performed by a caregiver; however, it is important for the patients to know the correct procedure for each component to reduce the chance of injury to themselves or the person assisting them. For people with lower levels of injury (ie, people with paraplegia), each of the functional skills should be performed independently. Refer to Table 6 for specific functional expectations for each level of injury. Below are the specific components to be considered when training the patient/caregiver in each of the major functional skills.

- **Bed mobility:** the ability to roll to and from supine to side lying, roll to and from supine and prone, move up/down and left/right, and move to and from a supine position to a long- or short-sitting position and back. Bed mobility can initially be instructed on a mat with a firm surface, and then the patient progresses to perform the skills on a bed.

- **Pressure relief:** the ability to relieve pressure in bed or in the WC with emphasis on pressure relief over bony prominences, including the ischial tuberosities, sacrum, greater trochanters, and heels; to reposition the body after a weight shift; and to self-monitor skin integrity for signs of potential problems.

- **Padding and positioning:** the ability to use appropriate padding to relieve pressure off of the bony prominences of the body while in bed.

- **Transfers:** The ability to manage all aspects of the transfer, including WC positioning, managing WC parts and equipment used to assist the transfer, and movement of the body from one surface to another, including lower-extremity movement to the desired final position. Transfer training to all surfaces is necessary (ie, bed, bath, tub [Figures 10A-D] or shower, toilet, car, sofa and floor). For people with lower-level injuries, there are many ways to perform each transfer. Transfers should be performed in different ways and in different settings to provide opportunities for the patient to solve problems.

- **WC mobility:** the ability to propel the WC indoors, over various surfaces, and to negotiate obstacles; the ability to propel the WC or direct others in outdoor management over various terrain and elevations, including ramps, curbs, and stairs; managing all WC parts; and opening and closing doors and maneuvering the WC through doorways. Performing WC mobility in as many different community settings as possible is also recommended.

- **Ambulation:** the ability to don and doff necessary orthoses; to move forward, backward, and sideways and to turn; to negotiate all surfaces and elevations, including ramps, curbs, and stairs; to negotiate elevators and escalators; to fall safely and return to a standing position; and to sit and return to a standing position from various surfaces. Customized lower-extremity orthoses are required for individuals with complete injuries and in some cases for individuals with incomplete injuries depending on the strength of existing musculature. Ambulation is difficult for individuals with complete paraplegia above L3. Guidelines for ambulation trials for complete injuries should include that the patient is independent in all transfers (including the floor), is able to lift his or her body weight a minimum of 20 repetitions, is free of joint contractions and pressure sores, and has medically controlled hypertonicity. Only if all these criteria are met does the person with a complete injury above the L3 level have a chance at successful functional ambulation.

**Seating and Positioning**

Because independent functional ambulation may not be achieved for patients with complete SCIs, the WC is the most important item of equipment prescribed to ensure some mode of locomotion. Prescribing the most appropriate WC requires the physical therapist to be aware of the patient's
Figure 10. In addition to moving from one surface to another, independence in transfers includes the ability to manage all aspects of the wheelchair (A), to move the lower extremities from one position to another (B, C), and to assume the desired final position (D).

abilities, desires, financial resources, and the latest technology and products available. If possible, patients should be referred to physical therapists with demonstrated expertise in this area.

The WC should be prescribed to include components that contribute to proper seating and positioning. Seating the individual with an SCI requires addressing posture, pressure relief, mobility, age, and environment the individual will encounter. For individuals with tetraplegia or high-level paraplegia, postural problems and poor balance attributable to weak or absent trunk musculature that can be corrected by providing a solid seat or back, lumbar support, contoured trunk support, or 5 to 10 degrees of posterior back tilt (Figure 11). Technological advances in frame construction and powered mobility provide the therapist with an array of equipment options that can promote the patient’s mobility. The selection of the WC should include consideration of the most energy-efficient system that maximizes the patient’s functional independence.

Once the WC is ordered and received, it is important to adjust the WC not only to maximize function, but also to prevent pressure sores, contractures, and trunk deformities. The back height should be supportive enough to maintain the trunk in an upright position but allow movement of the scapular in the presence of functional arm movement. Lateral trunk supports may need to be added to promote good trunk stability during upper-extremity functional activities. The armrests should be adjusted to allow support at the elbow without causing shoulder elevation or excessive shoulder depression. Leg rests are adjusted so the feet are placed flat on the footrest with the thighs parallel to the sitting surface. If the footrests are adjusted too high, pressure is increased over the ischia and sacrum. If the footrests are adjusted too low, it will be difficult for the feet to maintain their position on the footrest. In addition, pressure is placed over the popliteal fossa, which may cause decreased circulation to the lower extremities.

Pressure management through the use of an appropriate cushion is evaluated on an individual basis. Multiple cushion options are commercially available and should be selected based on the individual’s functional ability and body size. Physical therapists with patients who are at high risk for skin breakdown should order a cushion that will readily conform to the bony protuberances and resist “bottoming out” while
also providing postural support. The preferred cushions are air cushions, contoured foam, and viscous fluids in a contoured base. The patient should test each type of cushion to ensure optimal functioning and pressure relief.

Post-Acute Interventions

Due to the shortened lengths of stay stated earlier, individuals with SCI usually require some type of post-acute (previously referred to as “outpatient”) services to enable them to complete expected outcomes. Post-acute services are now necessary to continue basic functional training. No longer is the outpatient venue used only for the more advanced WC skills and/or ambulation training as it had been in the past. Post-acute care should be recommended only when the patient is medically stable. If the patient has not achieved the desired functional outcomes as outlined in Table 6 and has the motivation, body type and size, physical ability, financial resources, and social support to perform the skills, post-acute care should be recommended.

There are several options for post-acute care. The most intensive programs, which are becoming increasingly necessary, are called “day programs.” Day programs offer all the professional services that inpatient rehabilitation teams offer but on an outpatient basis. In addition to completing the necessary functional skills, a strong community re-entry component is stressed in day programs. Careful discharge planning is necessary to plan for a safe discharge environment, transportation, and attendant care while participating in day program. Third-party payers favor this option over inpatient rehabilitation due to the saved expense of costly nightly hospital stays. In addition, with the patients in their home environment, it allows them to practice their skills at home after therapy hours and address any problems encountered during the next therapy session.

The other options for post-acute services are the traditional single-service therapy provided in the clinic or home setting. Once the patient has mastered enough skills not to require a coordinated team effort, but still requires functional training, outpatient/home health services are recommended. In addition, regular outpatient follow-up visits are recommended to prevent or treat secondary complications that may arise.

Regardless of the venue used for outpatient care, it is the team’s responsibility to ensure a smooth transition through the continuum of care. Communication regarding the current status of the patient as well as the functional expectations must be initiated prior to the patient being referred. Each venue of care must be closely considered to match the needs of the patient with the appropriate setting.

Conclusion

The purpose of this self-study module was to present the critical elements affecting physical therapy management of the patient with a traumatic SCI. The additional reading list is strongly recommended by the author and represents a sample of the key texts available. Further study of these references will provide a more in-depth explanation of all concepts introduced in this self-study module.

Spinal cord injury care is a dynamic, exciting, and rewarding field for physical therapists. Advances in medical management, technology, and spinal cord injury research present the physical therapist with an opportunity to provide comprehensive, functionally oriented patient care to a relatively young and potentially productive segment of our population. As the stigma of being disabled decreases, the reintegration of the individual with SCI into the active working community becomes more likely. The challenge for the physical therapist is to continue to stay abreast of the issues and pursue creative alternatives within today’s health care system.
References


Additional Readings


### STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

#### MOTOR

<table>
<thead>
<tr>
<th>KEY MUSCLES</th>
<th>L</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>Elbow flexors</td>
<td>Elbow flexors</td>
</tr>
<tr>
<td>C3</td>
<td>Wrist extensors</td>
<td>Wrist extensors</td>
</tr>
<tr>
<td>C4</td>
<td>Elbow extensors</td>
<td>Elbow extensors</td>
</tr>
<tr>
<td>C5</td>
<td>Finger flexors (distal phalanx of middle finger)</td>
<td>Finger flexors (distal phalanx of middle finger)</td>
</tr>
<tr>
<td>C6</td>
<td>Finger abductors (little finger)</td>
<td>Finger abductors (little finger)</td>
</tr>
<tr>
<td>T1</td>
<td>Hip flexors</td>
<td>Hip flexors</td>
</tr>
<tr>
<td>T2</td>
<td>Knee extensors</td>
<td>Knee extensors</td>
</tr>
<tr>
<td>T3</td>
<td>Ankle dorsiflexors</td>
<td>Ankle dorsiflexors</td>
</tr>
<tr>
<td>T4</td>
<td>Long toe extensors</td>
<td>Long toe extensors</td>
</tr>
<tr>
<td>T5</td>
<td>Ankle plantar flexors</td>
<td>Ankle plantar flexors</td>
</tr>
</tbody>
</table>

#### KEY MUSCLES

- **0** = total paralysis
- **1** = palpable or visible contraction
- **2** = active movement, gravity eliminated
- **3** = active movement, against gravity
- **4** = active movement, against some resistance
- **5** = active movement, against full resistance
- **NT** = not testable

- **Voluntary anal contraction (Yes/No)**

#### SENSORY

<table>
<thead>
<tr>
<th>KEY SENSORY POINTS</th>
<th>L</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any anal sensation (Yes/No)</td>
<td>Any anal sensation (Yes/No)</td>
<td></td>
</tr>
</tbody>
</table>

#### PIN PRICK SCORE

- (MAXIMUM) (56) (56)

#### LIGHT TOUCH SCORE

- (MAXIMUM) (56) (56)

### NEUROLOGICAL LEVELS

- **SENSORY**
- **MOTOR**

### COMPLETE OR INCOMPLETE?

- Incomplete = Any sensory or motor function in S4-S5

### ASIA IMPAIRMENT SCALE

- Partially innervated segments

This form may be copied freely but should not be altered without permission form the American Spinal Injury Association.
Self-Examination Questions

Assessment of a patient who has sustained lumbar fracture reveals the motor and sensory results as shown in Figure 12.

1. The motor level of the injury for this patient is:
   a) L1. 
   b) L2. 
   c) Left L2, right L1. 
   d) Left L3, right L2.

2. The sensory level of the injury for this patient is:
   a) L1. 
   b) L2. 
   c) Left L2, right L1. 
   d) Left L3, right L2.

3. The neurological level of the injury for this patient is:
   a) L1. 
   b) L2. 
   c) Left L2, right L1. 
   d) Left L3, right L2.

4. A patient who complains of a sudden onset of a headache and blurred vision is showing signs of:
   a) Autonomic dysreflexia. 
   b) Deep vein thrombosis. 
   c) Orthostatic hypotension. 
   d) Respiratory failure.

5. Which of the following is a realistic functional outcome for an individual with complete C6 tetraplegia?
   a) Independent floor transfer 
   b) Independent weight shift 
   c) Independent bed mobility 
   d) Both b and c

6. An abdominal binder improves inspiratory and expiratory ability by:
   a) Increasing chest-wall mobility. 
   b) Providing support to the vertebral column. 
   c) Increasing stability in the short-sitting position 
   d) Supporting abdominal viscera for greater diaphragmatic excursion.

7. Symptoms of spinal instability may include all of the following except:
   a) Complaints of severe headache. 
   b) Midline neck or back pain. 
   c) A decrease of volitional motor control or sensation from the initial assessment. 
   d) A change in the amount of tingling or numbness.

8. Which of the following is not a realistic functional outcome for a patient with T1 complete paraplegia?
   a) Independent transfers to and from the floor. 
   b) Independent ambulation. 
   c) Independent wheelchair mobility on ramps and curbs. 
   d) Independent lower-extremity dressing.

9. An individual with T4 paraplegia is exercising and notices he is becoming dizzy. His blood pressure has dropped from his baseline reading. What may have contributed to this occurrence?
   a) Lack of vasoconstriction in the lower extremities during upper-extremity exercise 
   b) Venous pooling in the lower extremities 
   c) Orthostatic hypotension 
   d) All of the above

10. The insurance company of a patient with C7 tetraplegia is mandating that she be discharged prior to achieving the expected outcomes for her level of injury. What should the physical therapist do?
    a) Family training in all aspects of care 
    b) Referral for additional therapy 
    c) Discuss risks with insurance company of possible complications postdischarge 
    d) All of the above
University of Dayton, DPT Program
Neurology I, Class of 2010

Tutor: Christina Cooper

<table>
<thead>
<tr>
<th>TUTORIAL EVALUATION CRITERIA</th>
<th>Karen Vogel</th>
<th>Kirk Rhein</th>
<th>Ember Grant</th>
<th>Annie Graessle</th>
<th>Justin Lodge</th>
<th>Chrissy Kostura</th>
<th>Joanna Genter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Skills 20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Critical Appraisal/Resource Utilization 30%</td>
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<tr>
<td>Group Skills/Professional Behavior 30%</td>
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<td>Evaluation and Feedback Skills 20%</td>
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</tbody>
</table>

**COMMENTS:**

Karen Vogel:

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Kirk Rhein:

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Ember Grant:

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Annie Graessle:

__________________________________________________________________________

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Justin Lodge:

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Chrissy Kostura:

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Joanna Genter:

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