Lecture 6: Spinal Cord Injuries

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Part I  Overview

Spinal cord injury can be one of the most devastating calamities in human life both for the patient and his or her family and friends. Rehabilitation after a spinal cord injury seeks the fullest physical and psychological adjustment of individuals to their disability with a goal of reintegration into society.

The scope of the problem of SCI can be measured in terms of incidence, dollar costs, and revenue and productivity losses to the society. It can also be measured in terms of issues specific to each individual, such as chronic illness, repeated acute illness, loss of independence, emotional and social maladjustment, income losses and financial stresses, and overall quality of life concerns.

It is important that each member of the multidisciplinary allied health team appreciated that full scope of the problem for society and for the individual, as well as understand his or her own role within a defined management approach. A comprehensive rehabilitation program that provides a full range of services and maximum patient participation improves the chances for favorable outcomes, promotes the resumption of a meaningful life, and facilitates opportunities for community reintegration.

SCI are most commonly caused by motor vehicles, followed by falls, acts of violence and sporting injuries. Approximately half of all spinal cord injuries are cervical and one third are thoracic. The most frequently occurring neurological level of injury is the 5th cervical segment, with the 4th and 6th cervical and 12th thoracic levels following in frequency. Half of all SCI are complete.

Neural recovery can generally be predicted by the initial extent of injury and the time course of functional recovery. The majority of complete injuries remain complete upon discharge. Those admitted with sparing of motor function below the level of the injury have a better chance of being discharged with useful motor function compared with those admitted with only sensory sparing. Another guideline to recovery is the clinical course of the patient: The speed of return of motor function and its clinical course are good guidelines. As time progresses with little change, further major recovery outside the zone of injury is unlikely.
Part II  Anatomy of the Spine and the Spinal Cord

A. Anatomy

1. The spine:
The spine is comprised of vertebral bodies separated by intervertebral discs.

It is situated in the midline and forms the posterior portion of the trunk.

The vertebral column is divided into cervical, thoracic, lumbar, sacral and coccygeal regions.

There are 7 cervical vertebrae (C1 – C7), 12 thoracic vertebrae (T1 – T12), 5 lumbar vertebrae (L1 – L5), 5 fused sacral vertebrae (S1 – S5), and 4 fused coccygeal vertebrae.

a. The cervical vertebrae:
   - The cervical vertebrae are the smallest of the movable vertebrae.
   - They are distinguished from the thoracic and lumbar vertebrae by the presence of a foramen in each transverse process that allows passage of the vertebral artery and accompanying plexuses of the vertebral vein and sympathetic nerves.

b. The thoracic vertebrae:
   - The thoracic vertebrae are of intermediate size and increase in size from T1 to T12.
   - They differ from the vertebrae of other regions by the presence of demifacets on the later portions of the vertebral bodies that articulate with the ribs.
   - The vertebral bodies of the thoracic region are heart-shaped, and the long spinous processes project inferiorly.
c. The lumbar vertebrae:
- The lumbar vertebrae are particularly large and heavy and are distinguished from other vertebrae by the presence of accessory and mammillary processes.

d. The sacrum:
- The sacrum is triangular in appearance, and its central portion consists of the fused bodies of the sacral vertebrae.

- The cervical, thoracic and lumbar vertebrae are regarded as true or movable vertebrae.
because they are not fused in the mature adult as are the sacral and coccygeal vertebrae.

- The spinal canal, or vertebral foramen, is formed by the junction of the vertebral body and the neural arch.
- The supporting structures that give the spine stability include the anterior longitudinal ligament, the posterior longitudinal ligament, the intervertebral discs and the musculature of the neck and the trunk.

2. **The spinal cord:**
   - The spinal cord is a discrete, cylindrical mass of nerve tissue contained within the spinal canal.
   - It can be divided into cervical, thoracic, lumbar, sacral and coccygeal regions according to the segmental nature of spinal nerves originating from it.
   - The spinal cord is surrounded by three membranes, which are collectively referred to as meninges: the dura mater, the arachnoid and the pia mater.

![Fig. 6.7 Meninges](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.8)

3. **The spinal nerves:**
   - There are 31 pairs of spinal nerves that arise from the spinal cord at each level and exit through the intervertebral foramina.
   - Each nerve has an anterior or motor root (or ventral root) comprised primarily of motor fibers and a posterior or sensory root (or dorsal root) that is primarily comprised of sensory fibers.
Gray matter is located centrally, forming an “H” or butterfly shape. White matter surrounds the central gray and is divided into large bundles of fibers (also called columns). There are three large columns of white matter – anterior, lateral and posterior.

**B. Function of the spinal cord**

- Anterior column tracts mediate motor function, postural reflexes, light touch and pressure.
- Lateral column tracts mediate subconscious proprioception for control of locomotion, pain, temperature and motor function.
- Posterior white column tracts mediate proprioception, vibration, two-point discrimination, deep pressure and touch.
- In general, primary motor tracts are located in anterior and anterolateral portion, whilst primary sensory tracts are posterior and posterolateral.

**Part III — The Spinal Cord Injuries**

Spinal cord injury with neurological function loss represents the single most devastating survivable injury the physician will treat and the patient will suffer. Most of the injury factors have an effect on
long-term survival.

A. Incidence

- Traumatic SCI occurs at a yearly rate of 30 cases per million populations.
- There are between 7,000 and 10,000 new cases of traumatic SCI each year in the United States. Prevalence is estimated to be over 200,000 in the United States.

B. Demographics

![Fig. 6.10 SCI distribution by Age](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.19)

- Over 80% of all reported SCI cases occur in men
- The SCI population is markedly young. Half of the SCI population is between the ages of 15 and 30.

C. Etiology

- Most common causes of SCI in decreasing order of magnitude are vehicular accidents, falls, acts of violence, gunshot wounds, and diving accidents.
- Other causes include accidents resulting from persons being hit by falling objects, sports-related incidents (football, rugby, swimming, horseback riding, etc.), penetrating wounds other than gunshot wounds, medical surgical misadventures, and other miscellaneous events.
- Automobile accidents account for over 40% of all spinal cord injuries.
- The best means of prevention of a SCI is consideration of the potential consequences before undertaking any physical activity.

D. Extent of injury

The extent of the injury describes whether the lesion is complete or incomplete. A complete SCI is one in which all motor and sensory function is lost below the level of the injury.

1. Mechanism of injury:
   a. Hyperflexion:
- Force exerted toward the anterior surface of the body or forward contact with an immovable object can create the hyperflexion mechanism.
- In the cervical spine the greatest forward bending moment occurs at C5-6. The posterior longitudinal ligament can be stretched or torn, allowing the intervertebral disc to herniate or tear. Two or more vertebral bodies can be compressed against each other, causing fractures and / or dislocation (subluxation).

![Hyperflexion of the neck](image)

*Fig. 6.11 Hyperflexion of the neck*  

b. **Hyperextension ("whiplash"):**
   - Hyperextension frequently occurs when an individual is involved in an automobile accident in which the car is rear-ended.
   - The greatest bending moment in hyperextension of the cervical spine occurs at C4-5. If there is sufficient force, the anterior longitudinal ligament can be stretched or torn, the intervertebral disc may tear or herniate, the posterior elements of the spine may compress and fracture each other, and there may be subluxation.
c. Axial loading (Vertical compression):

- Occurs when sufficient force is exerted vertically through the vertebral column.
- If the force is sufficient, one or more vertebral bodies absorb the intensity of the force and literally "burst". The force of the exploding vertebral body is the force that damages the spinal cord.
- Axial loading injuries occur most frequently in cases where an individual dives headfirst into shallow water, striking the top of the head on the bottom.
- Axial loading injuries are also seen when a person jumps or falls from a height and lands on his or her feet. The injury that usually results is a burst fracture of T10, T11, or T12 with paraplegia.

2. Complete spinal cord injury:

- For complete SCI, all motor power, sensation, and reflexes are lost in those areas of the extremities and trunk that are mediated by the spinal nerves at and below the level of the injured cord.
- Flaccid paralysis occurs immediately and lasts throughout the initial phase of neurogenic shock.
In upper motor neuron lesions the resolution of spinal shock is determined by the return of deep-tendon reflexes. There is a concomitant loss of visceral function, including flaccid paralysis of the bowel and bladder.

When the spinal shock subsides, the flaccid paralysis is replaced by spasticity when the level of cord injury is above the level of conus medullaris.

3. **Incomplete spinal cord injury:**
   - If there is any function intact below the level of injury, the lesion is incomplete by definition.
   - There are 4 major incomplete spinal cord syndromes: anterior cord syndrome, posterior cord syndrome, central cord syndrome and Brown-Sequard syndrome.

   a. **Anterior cord syndrome:**
      - An anterior cord syndrome results primarily in a profound motor loss below the level of injury.
      - Destruction of the anterior portions of the white and gray matter of the spinal cord affects the major corticospinal (motor) tracts and to a lesser extent, the sensory tracts that mediate light touch and pressure.


   b. **Posterior cord syndrome:**
      - A posterior cord syndrome results primarily in a loss of sensory function below the level of injury.
      - Major motor tracts in the anterior portion of the spinal cord may be largely unaffected, whereas the sensory modalities of proprioception, discrimination, and vibration are severely impaired or lost.
c. Central cord syndrome:

- In a central cord injury, the neural elements of the upper extremities are more severely impaired than are those of the lower extremities when the pathophysiologic process is primarily limited to the central portions of the white and gray matter of the spinal cord.
- Motor and sensory function in the lower extremities may be affected, but to a lesser extent than in the upper extremities.

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d. Brown-Sequard syndrome:

- A Brown-Sequard syndrome results from an anterior-posterior hemisection of the spinal cord. It is primarily caused by a penetrating wound in which the foreign body or missile severs virtually half the neural elements of the spinal cord.
- There will be a characteristic loss of motor function, deep touch, proprioception, and vibration on the ipsilateral side below the level of lesion, with a loss of pain,
temperature, simple touch, and pressure on the contralateral side of the body.

Fig. 6.16 Brown-Sequard syndrome


4. Associated injury
   - Fracture (29.3%)
     - Distractive flexion injury
     - Vertical compression injury
     - Compression flexion injury

Fig. 6.17 Distractive flexion injury at the cervical region (left), vertical compression injury at the lumbar region (middle) and compression flexion injury at the thoracic region (right)


- Loss of consciousness (28.2%)
- Pneumohemothorax (17.8%)
E. **Level of injury**
The severity of the loss is determined by the level at which the injury occurs. Each level of the spinal cord innervates specific motor and sensory functions. The higher the level of lesion, the more profound is the loss of function.

- Quadriplegia results when an injury occurs to the spinal cord in the cervical region (between C1 & T1). The term “quadriplegia” refers to paralysis of all four extremities (complete SCI).
- Paraplegia refers to paralysis of the lower extremities and results from an injury to the spinal cord in the thoracic, lumbar, sacral or coccygeal areas of the spine. The terms “quadraparesis” and “paraparesis” refer to weakness, rather than total paralysis, and may be used when an injury is incomplete.
- The diaphragm is innervated by the phrenic nerve primarily via the C3 – 5 spinal nerves. Any injury to the spinal cord above the level of C4 may render the individual incapable of spontaneous, independent breathing. It also causes a loss of all voluntary control of all extremity and trunk musculature, as well as a loss of all sensation below the level of injury.
- If the C4 nerve is undamaged, diaphragmatic function may be intact, and the individual may be capable of independent abdominal breathing.

F. **Classification of neurological level**
Consistent classification of the level of spinal cord injury is important in the communication and understanding of the clinical significance of the injury. The use of impairment and disability measures to determine clinical outcomes in SCI is necessary for accurate prognosis, for determination of the effects of interventions, and for cost justification for hospital care.

The International Standards for Neurological Classification of SCI by the American Spinal Injury Association (ASIA) is to define for SCI a standard method of assessing the neurological status of the patient, as well as a standard approach to using such data for classifying / quantifying the injury. The goal is that both the measurement technique and the use of the resulting data, clinically and in research, should be consistent across practitioners. It is modified from Frankel (1960) scale. The basic premise of the ASIA standards is that the level of injury is the lowest level in which functional motor power and sensation remain intact after spinal cord injury. Functional motor power is described as a manual muscle test score of 3/5 or greater, when 3/5 is equivalent to the ability to accomplish full range of motion against gravity, but without resistance.
The American Spinal Injury Association classification of spinal cord injury form is composed of several sections. The initial portion grades five muscle groups in the upper and five muscle groups in the lower extremities on a score of 1 to 5. A composite motor score is then obtained. The next section grades light touch and pinprick. The final section on the first page specifies the level of injury. Finally, an impairment scale is specified from A to E and a clinical spinal syndrome is identified, if present. It is helpful in further understanding the patient’s incomplete neurological status.

G. Clinical effects of traumatic spinal cord injury

The immediate effects of complete spinal cord injury include a total loss of motor and sensory function below the level of injury to the spinal cord. Other symptoms that should be recognized include:

- Neurological (spinal) shock evidence by marked hypotension, bradycardia, and loss of reflexes.
- Flaccid paralysis of the bladder with urinary retention.
- Flaccid paralysis of the bowel with paralytic ileus.
- Loss of perspiration below the level of injury.

Traumatic spinal cord injury has profound lasting effects on virtually every system of the body. Prediction of functional abilities after a SCI generally follows the degree of motor function. The expected level of functioning after SCI at different level is generally as follows:

<table>
<thead>
<tr>
<th>Motor level</th>
<th>Functional Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occ – C3</td>
<td>Ventilator dependen; mouth-head controlled wheelchair</td>
</tr>
<tr>
<td>C4</td>
<td>Initially ventilator dependent; improved accessory muscle use of variable</td>
</tr>
</tbody>
</table>

### Table 6.19 Expected level of functioning


<table>
<thead>
<tr>
<th>Level</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Deltoid function ± biceps allows for independent activity with adaptive equipment; electric wheelchair with arm control</td>
</tr>
<tr>
<td>C6</td>
<td>Biceps and wrist extensors allows for increased hand function with adaptive equipment, may use manual wheelchair or electric with hand control</td>
</tr>
<tr>
<td>C7</td>
<td>Triceps, wrist flexion, and finger extension allow increased upper extremity weight-bearing in transfers; operation of manual wheelchair</td>
</tr>
<tr>
<td>C8</td>
<td>Intrinsic and finger flexor function added to independence of ADLs; fine dexterity</td>
</tr>
<tr>
<td>T1-T10</td>
<td>High paraplegia; independent in manual chair; exercise ambulation with knee-ankle-foot orthosis (KAFO)</td>
</tr>
<tr>
<td>T11-T12</td>
<td>Improved ambulation and standing with long-leg KAFOs; assistive device</td>
</tr>
<tr>
<td>L1-L2</td>
<td>Iliopsoas aids in household ambulation with KAFOs and assistive device</td>
</tr>
<tr>
<td>L3-L4</td>
<td>Quadriceps control allows for coordinated ambulation in community with KAFOs</td>
</tr>
<tr>
<td>L4-L5</td>
<td>No longer requires KAFO. Ambulation with ankle-foot orthoses and assistive device</td>
</tr>
<tr>
<td>L5-S1</td>
<td>Community ambulation with or without orthoses ± bowel or bladder dysfunction</td>
</tr>
</tbody>
</table>

**Part IV Physical Examination in Spinal Trauma**

**A. Neurological evaluation**

The basic components of the neurological evaluation are a determination of the level of motor and sensory function preserved and whether there is preservation below the level of injury. A detailed neurological examination should be performed and carefully documented, as follow:
B. Sensory evaluation

- Evaluation of sensation begins with the cervical region and proceeds distally with evaluation of specific dermatomal regions.

- The perineum is innervated by sacral nerves S2 through S5 and the presence or absence of sensory function in the perineal area should be ascertained to determine whether there is “sacral sparing” that is indicative of an incomplete SCI. It also becomes important as a
prognostic indicator of functional recovery in those patients with a SCI.

- Reflex function like the bowel and bladder reflex, biceps reflex, triceps reflex, spasticity and other tactile sensation are to be tested.

<table>
<thead>
<tr>
<th>Level</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4</td>
<td>Clavicle</td>
</tr>
<tr>
<td>C5</td>
<td>Deltoid region</td>
</tr>
<tr>
<td>C6</td>
<td>Radial forearm and thumb</td>
</tr>
<tr>
<td>C7</td>
<td>Middle finger</td>
</tr>
<tr>
<td>C8</td>
<td>Fifth finger</td>
</tr>
<tr>
<td>T1</td>
<td>Medial, proximal arm</td>
</tr>
<tr>
<td>T5</td>
<td>Nipples</td>
</tr>
<tr>
<td>T7</td>
<td>Costal margins</td>
</tr>
<tr>
<td>T10</td>
<td>Umbilicus</td>
</tr>
<tr>
<td>T12</td>
<td>Inguinal ligament</td>
</tr>
<tr>
<td>L3</td>
<td>Anterior thigh</td>
</tr>
<tr>
<td>L4</td>
<td>Medial aspect of knee</td>
</tr>
<tr>
<td>L5</td>
<td>Lateral calf, dorsum of foot, big toe</td>
</tr>
<tr>
<td>S1</td>
<td>Lateral foot, fifth toe</td>
</tr>
<tr>
<td>S2</td>
<td>Posterior thighs</td>
</tr>
<tr>
<td>S3 - 4</td>
<td>Lateral foot, fifth toe</td>
</tr>
<tr>
<td></td>
<td>Buttocks, perianal region</td>
</tr>
</tbody>
</table>

Fig. 6.22 Major sensory level
(Levine et al, (1998) Spine Trauma, Philadelphia: W.B. Saunders, p. 21)

C. Motor evaluation

- Muscles are evaluated and recorded regarding functional strength.
- The evaluation reflects the level of lesion of the spinal cord.
- The ASIA Motor Index Score provides even further descriptive information of patient’s injury.
- Motor evaluation may not be accurate at acute stage because of general swelling of spinal cord after insult.

<table>
<thead>
<tr>
<th>Grade on Right</th>
<th>Muscle</th>
<th>Grade on Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>C5—Biceps</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>C6—Ext. Carpi. Radialis</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>C7—Triceps</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>C8—Ext. Ind. Prop.</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>T1—Opponens Pollicis</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>L2—iliopsoas</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>L3—Quadriceps</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>L4—Ant. Tibialis</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>L5—Ext. Hallicus Longus</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>S1—Gastrocnomius</td>
<td>5</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6.23 ASIA American Spinal Injury Association Motor Index Score
### Complications and Problems

#### A. Pulmonary complications

- Pulmonary conditions are the leading cause of mortality for both tetraplegia and paraplegia.
- Complications include aspiration, atelectasis, pneumonia and ventilatory failure.

1. **Aspiration:**
   - Aspiration of oral or gastric contents leading to pulmonary complications requiring treatment.
   - Older age groups show higher incidence of aspiration.

2. **Atelectasis:**
   - Atelectasis is a term used to describe partial or complete collapse of the lung, usually due to an obstruction of a bronchus.
   - Those with complete injuries had a significantly higher incidence of atelectasis.

3. **Pneumonia:**
The leading cause of death among tetraplegics and SCI patients who are at least 55 years of age is pneumonia.

The higher and more complete the injury, the greater number of persons who developed pneumonia.

Occur because of diminished vital capacity and decreased movement of diaphragm and the intercostals muscles.

4. **Ventilatory failure:**
   - Necessity for partial or total ventilatory support for a period of at least seven consecutive days.
   - Older age groups show higher incidence rate.
   - Individuals with complete tetraplegia are at greatest risk to have ventilatory failure.
   - Patients with C1 to C3 requires mechanical ventilator.
   - Patients above T1 may require temporary assistance because of lost innervation to intercostals muscles.
   - Caused by diminished vital capacity and decreased movement of diaphragm.

**B. Cardiovascular complications**

- Cardiovascular conditions during the acute and chronic phases of SCI are major causes of morbidity and mortality.
- Bradycardia and hypotension are features of neurogenic shock from disruption of sympathetic innervation.
- Examples are deep venous thrombosis, pulmonary embolism, autonomic dysreflexia, myocardial infarction and cardiopulmonary arrest.

1. **Deep venous thrombosis:**
   - A major cardiovascular complication of SCI, occurred when the venous system of the lower extremities is occluded by blood formation.
   - Major contributing factors are decreased or absent muscle function in the legs and loss of sympathetic innervation after SCI that leads to vasodilation and pooling of blood in the venous system.
   - Person with motor complete quadriplegia has the greatest likelihood of developing DVT.
   - Undetected and untreated DVT may lead to pulmonary embolus and sudden death.

2. **Pulmonary embolism:**
Condition resulting when a pulmonary artery becomes acutely obstructed by a clot formed upstream from the pulmonary arterial vascular tree.

Most often found in those 60 to 75 years of age.

Pulmonary embolism occurs very rarely in those with minimal neurological deficit, but with almost equal frequency in persons with paraplegia and tetraplegia, both in those who have incomplete and complete lesions.

3. **Autonomic dysreflexia:**
   - Autonomic dysreflexia is the sympathetic response to stimulation below the level of injury that requires any intervention. Response is marked by symptoms such as hypertension, sweating above the lesion level, ‘goose lumps’, nasal stuffiness and / or headache.
   - Most common causes are distended bladder, fecal impaction, pressure sores, ingrown toenails, any infectious process, catherization, or enemas.
   - Usually seen in patients with lesions at T6 and above, more often in males than in females and more common in those with complete neurologic lesions.
   - Can result in death if not treated immediately.

4. **Myocardial infarction:**
   - Coronary artery insufficiently producing necrosis of the myocardium, confirmed by ECG and / or enzyme changes.
   - Myocardial infarction following SCI is generally considered to be a rare event.
   - Occurred most frequently in those over the age of 60 and found to occur with almost the same frequency in females and in males.
   - Occur more commonly in persons with tetraplegia, both in those with complete and incomplete lesions, compared to those with paraplegia.

5. **Cardiopulmonary arrest:**
   - It is the cessation of respiration and / or heartbeat requiring resuscitation but not resulting in death.
   - Incidence rises with increasing age.
   - More commonly in persons with tetraplegia than in those with paraplegia, especially in those with tetraplegia and complete neurological lesion.

C. **Bladder and bowel problems**
1. **Bladder problems:**
   - SCI can affect any part of urination, depending on the location and completeness of the injury.
Immediately after injury for the 3-6 weeks post-injury, the bladder is usually flaccid. Urinary retention results.

Overflow incontinence occurs when the amount of urine exceeds the bladder’s capacity to contain it.

An injury to the spinal cord that results in an intact sacral arc (S2-4) is called an upper motor neuron injury. This type of bladder is called ‘reflex bladder’ or ‘upper motor neuron bladder’.

Any injury to the peripheral nerves with the sacral arc not intact is called a lower motor neuron injury. This type of bladder is called ‘areflexic bladder’ or ‘lower motor neuron bladder’.

Other complications:
- Urinary tract infection which is the most common complications.
- This can be results of many factors, including frequently over distention of the bladder, poor fluid intake, incorrect catheterization technique, and dehydration.

2. **Bowel problems:**
- SCI affects only the ability to empty the rectum once the initial effects of the injury have passed.
- An injury to the spinal cord that results in an intact sacral arc (S2-4) is called an upper motor neuron injury. This type of bowel is called ‘reflex bowel’ or ‘upper motor neuron bowel’.
- Any injury to the peripheral nerves with the sacral arc not intact is called a lower motor neuron injury. This type of bladder is called ‘areflexic bowel’ or ‘lower motor neuron bowel’.
- Other complications:
  - Diarrhea: usually caused by (1) liquid stool being pushed past an impaction; (2) food or medication irritant; or (3) a virus.
  - Impaction: occurs when the bowel becomes impacted. Signs and symptoms of impaction are nausea, vomiting, loss of appetite, feeling bloated, distended abdomen, etc.

D. **Formation of pressure sores**

Pressure sores, commonly known as decubitus ulcers, are one of the most frequent problems following SCI and one of the major causes of hospital readmission. Pressure sores are may affect both the patient and his / her family members. They cause disruption to the family unit and time away from employment. The morbidity and mortality of pressure sores are clearly significant, and prevention is the primary goal. Prevention, however, depends on a thorough understanding of the etiology of pressure sores.

1. **Aetiology:**
- Pressure may be defined as the force per unit area.
If the forces on an area of the body are great enough for a long enough duration, capillary blood flow is obstructed, blocking cellular metabolism and leading to tissue necrosis as circulation to the muscles or skins and the blood pressure is reduced.

Pressure sores may also be caused by the shearing forces when the skin slides over another, e.g. poor turning and transfer techniques and sliding rather than lifting.

Maceration, resulting from prolonged contact with urine, feces, sweat or the combination of those substances, is related to the development of skin breakdown.

Loss of afferent pathways with no senses on discomfort and pressure leads to inability of the patient to feel the discomfort resulting from pressure on an area and therefore is unaware of the need for a position change.

Loss of muscle layer but increased obesity over buttock impairs and individual’s ability to perform pressure-relief techniques. Moreover, equipments like the wheelchair or braces no longer fit the patient who has gained excessive weight, and skin breakdown may develop in high-pressure areas.

2. Classification:

Pressure sores are classified as Grad I, II, III and IV according to the system developed by the National Spinal Cord Injury Data Collection System.

a. Grade I:
   - Limited to superficial epidemis and dermal layers.

b. Grade II:
   - Involving the epidermal and dermal layers and extending into the adipose tissue.

![Fig. 6.25 Grade II pressure sore involving the epidermal and dermal layers of the skin](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.105)

c. Grade III:
- Extending through the superficial structures and adipose tissue down to and including muscle.

![Fig. 6.26 Grade III pressure sore extending (and including) to the muscle](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.105)

d. **Grade IV:**
- Destroying all soft tissue structures down to bone, with communication with bone or joint structures or both.

![Fig. 6.27 Grade IV pressure sore extending to the bone (shown by red arrow)](Levine et al, (1998) Spine Trauma, Philadelphia: W.B. Saunders, p. 658)

3. **Key Areas of breakdown:**
- Bony prominences have been identified because they carry the greatest forces on their very small surface areas while the individual is in a supine, prone, sidelying or sitting.
- Key areas of skin breakdown are shown below.

![Fig. 6.28 Key areas of skin breakdown in (top) supine, (middle) prone and (bottom) sidelying positions (Click to enlarge)](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.107)

**Part VI Management for Spinal Cord Injuries**

**A. Acute phase**

In the critical care environment, comprehensive evaluation and treatment should be directed toward medical, neurological, and orthopedic stabilization and the prevention of the life-threatening and long-term debilitation complications of traumatic SCI.

1. **Surgical stabilization:**
   - Neurological spinal surgery is indicated by deteriorating neurological function and evidence of bone, disc, or other matter in the neural canal with compression of the spinal cord in the presence of an incomplete injury.
   - Person with a complete SCI may require neurosurgical intervention at the time of surgical fusion to restore the integrity of the neural canal and to prevent long-term problems with spinal pain and deformity.
   - Examples of surgery:
     - Decompression
     - Fusion
- Open reduction and fixation of the spine fractures or dislocations by screws, hooks, rods or plates

![Fixation of the spine by plate (left) and screws (right)](Levine et al, (1998) Spine Trauma, Philadelphia: W.B. Saunders, p.312, 473)

2. **Medical stabilization:**
   - Continuous monitoring of the patient’s cardiovascular status.
   - To assess the patient for the effects of hypotension, bradycardia, and decreased cardiac output.
   - To monitor the respiratory parameters of the patient and to provide ventilatory support whenever necessary such as the utilization of BiPAP (Bi-level Positive Airway Pressure) or CPAP (Continuous Positive Airway Pressure).

3. **Orthopedic stabilization:**
   - Alternative beds are provided for safe turning and patient care.
     - The STRYKER and the ROTO-REST bed (kinetic treatment table)
Application of a definitive spinal orthosis may precede, follow, or eliminate the need for surgical stabilization.

However, application of forces to immobilize the spine has significant side effects. The most significant complications of spinal orthoses are skin breakdown and loss of reduction of spinal alignment.

Examples of orthoses:
- Halo vest: a self-contained traction device that allows the unstable spine to be immobilized rigidly while permitting the patient to be mobilized.
- SOMI (sterno-occipital-mandibular-immobilizer) brace: utilized when immobilization is needed. SOMI is often used to limit flexion and extension when control of rotation is less of a concern.
- Philadelphia collar: the only immobilization needed preoperatively when internal fixation has been accomplished. The Philadelphia collar prohibits gross flexion, extension and rotation when it is properly fitted and applied.
- Custom-fitted plastic body jacket: indicated in patients with injuries to the vertebral column below the cervical and upper thoracic levels. It is recommended for use with persons who are at risk of developing skin breakdown.
B. Subacute phase

1. Intervention to complications:
   a. Respiratory problems:
      - Postural drainage after percussion and vibration techniques.
      - Chest physiotherapy.
      - Breathing exercise.
      - Proper sitting posture to facilitate chest excursion and improve vital capacity. Any abnormal posture such as kyphosis or scoliosis which hinders rib and diaphragm movement should be avoided.

   b. Cardiovascular problems:
      - Application of low dose heparin (anti-coagulant) and external compression of the legs with elastic bandages (like pressure stocking) are recommended.
      - Passive ROM to lower limbs to reduce oedema.
      - Promote active mobilization for general strengthening.
      - Posture to rectify postural hypotension.

   c. Bladder problems:
      i. Upper motor neuron bladder:
         - Reflex emptying of the bladder with minimal postvoid residual.
         - Using intermittent catheterization program with regulated fluid intake.
         - Fluid restriction 1800 – 2000 cc per day and catheterization is done every 4 hours.

Fig. 6.31 the Halo vest (left), the SOMI and the Philadelphia collar (middle and right)
- Emptying the bladder by tapping on suprapubic area, stroking the inner thigh, or pulling pubic hair before catheterization.
- If bladder cannot be emptied satisfactorily, indwelling catheter, either urethral or suprapubic can be used.

![Fig. 6.32 Proper taping of an indwelling catheter for (A) male patient and (B) female patient, and (C) proper taping of a suprapubic tube.](Buchanan et al, (1987) Spinal Cord Injury: Concepts and Management Approaches, USA: Williams & Wilkins, p.107)

ii. Lower motor neuron bladder:
- 4 hour intermittent catheterization program.
- Prevention overdistention and promote adequate emptying
- Keep record of each catheterization.
- Even pressure applied over the bladder pubis.
- Catheter to be lubricated and carefully inserted into the bladder.

d. Bowel problems:
   i. Upper motor neuron bowel:
      - Local and digital stimulation.
      - Hard stool is to be removed manually
      - Use a gloved, lubricated finger to gently insert into the rectum and moved in circular, clockwise motion for 30 – 60 sec to stimulate rectal emptying.
      - May need Dulcolax suppository every other day (insertion).

2. Intervention to pressure sores:
- Correct positioning in bed and all bony prominences should be supported in a manner that relieves forces over small surfaces and distributes forces evenly over large surface areas.
- Relief pressure in bed by turning the patient.
- Skin inspection must be done to see if an area of the skin is susceptible to breakdown or if a new activity is initiated that results in new pressure areas or creates shearing forces.
- Use of pressure relief device, e.g. gel cushion, ROHO cushion, etc.
- Effective pressure relief techniques are recommended for wheelchair user which can help in relieving pressure and maintaining strength in the upper extremities, examples are:
  - Wheelchair “push-up”.
  - Lateral weight shift.
  - Forward weight shift.
  - Forward weight shift with support.

C. Rehabilitation phase

1. Physical therapy:
   - Treatment strategy:
     - Maintain range of motion.
     - Relief of spasticity.
     - Increase muscle strength (including electrical stimulation in strength training).
     - Improve endurance.
     - Facilitate ambulation / wheelchair ambulation.

2. Occupational therapy:
   - Treatment strategy:
     - Assessment of residual function.
     - Functional substitution (including upper limb function, ADL and environmental).
     - Self-care training.
     - Splinting, aids and gadgets.
     - Environmental modifications.
     - Wheelchair prescription and training.
     - Work rehabilitation and vocational training.
     - Community integration.
     - Psychosocial adjustment.
     - Sexual function counseling and training.
References:

Websites:
- http://members.tripod.com/~anwarahmad/sci/sciclass.html

Books:

End of Lecture 6