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CONTINUING EDUCATION

PRACTICAL MANAGEMENT OF SPINAL CORD INJURY

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Spinal cord injury (SCI) is a major cause of mobility and mortality worldwide. [1, 2] Majority are caused by road traffic accidents. These patients often have other associated injuries such as head injury, chest trauma etc. [3, 4] and 20% of patients with major spinal injury have a second spinal injury at another level. [4, 5] The cervical spine is the most commonly affected segment 42%, followed by thoracic 31%, and lumbar 27%. [5] Mortality is higher with spinal injury in children. Patients with incomplete injury can suffer complete injury during transport or delay in management. Early diagnosis of injury, preservation of spinal cord function, and maintenance or restoration of spinal alignment and stability are the keys to successful management. The introduction of spinal cord rehabilitation centers and the evolution of multidisciplinary trauma teams, have led to marked improvements in the management of patients with spine and spinal cord injuries.

Biomechanics

The different mechanisms of injury include hyperflexion, rotation, heperextension, vertical load, flexion rotation and shearing. [5] Age, as expected affects the mechanism of injury. In developed communities the vast majority of SCIs are caused by road traffic accident (RTA). Fall from height (especially important in less developed countries) and sports injury account for a considerable proportion of SCIs. [2, 4,5] In children, birth injury, whiplash injury and non-accidental trauma (NAT) are also important mechanisms of injury. SCIs due to birth trauma rarely occur in vertex deliveries and are more common in breech deliveries (67%). [6] Importantly, since most spinal birth injuries are not accompanied by radiological abnormalities, peripheral nerve injury must be excluded. [6, 8]

Pathophysiology and pathology

Concussive or compressive force to the spinal cord can lead to immediate death of neural cell bodies in the local central gray matter. Following the initial injury, secondary damage to the spinal cord is initiated by inflammatory response via arachidonic acid cascade. [8, 9] There is release of excitatory amino acids (glutamate and aspartate), and lipid peroxidation of cell membranes by various forms of oxygen free radicals. Oedema and action of various vasoactive inflammatory mediators, result in changes in local blood flow thereby causing cord ischemia. There is initiation of apoptotic change in the neurons and glial cells. [11]

Trauma to the child's spine is more likely to result in ligamentous injury and facet capsule rupture. In the cervical region there could be avulsion and epiphyseal separation of basal synchondrosis of the odontoid process in the body of C2. Fracture of the vertebral bodies and disc herniation are uncommon. There could be a split in the cartilaginous end, particularly the growing zone. [12, 13]

Vertebral artery injury is observed in two-third of tetraplegics who die. Depending on the severity of trauma, contusion, infarction, laceration, transection, dural disruption, vertebral artery injury and total anatomic discontinuity of the cord can occur. [14]

Trauma can cause spinal epidural, intradural, or intramedulary haematoma. Localized demyelination of damaged axons, and transsynaptic degeneration of caudal neurons lead to cord cavitations and formation of posttraumatic cysts.

Classification

Categorization is important for treatment decision and prognosis.

1. *Complete lesion:* patient with no preservation of any motor and sensory function below the level of the injury. The chance of recovery beyond 24hours is very little.
2. *Incomplete lesion:* These are patients with residual sensory or motor function below the level of the injury.
   Types of incomplete lesion include:

- Anterior cord syndrome due to damage to anterior part of the spinal cord.
- Posterior cord syndrome due to posterior cord damage, which is rare.
- Central cord syndrome due to damage around the spinal canal by direct trauma, haematoma, fluid collection or ischemia.
- Brown-sequard syndrome [10] due to hemi-section of the spinal cord.
- Spinal shock is a transient loss of all neurologic function below the level of the lesion leading to flaccid paralysis and a reflexia lasting varying period (usually 1-2 weeks). [4, 15]

Some patients suffer soft tissues injury (whiplash injury) usually following road traffic accident. The patients complain of neck pains with or without minor neurologic symptoms, usually the cervical x-rays are normal. [16, 17]

Some patients suffer spinal cord injury without obvious radiologic abnormality (SCIWORA). This type of injury commonly affects children. [4, 18]

Prehospital management

The goal of management is to prevent further injury and reduce neurological deficits. At the site of trauma the patient is considered to have spinal injury especially if unconscious. The cervical spine is immobilized with sand bags or blocks. Rolled up jacket or other materials can be use to immobilize the spine. A rigid cervical collar can be used if available. The patient is placed in supine position if conscious or in the left lateral position with the neck immobilized if unconscious. The airways should be protected from obstruction and inhalation of vomitus and secretions.

Lateral bending and rotation should be avoided. The patient should be logrolled and carried in one piece. Hard board is used if available for transport to the hospital. The patient is removed from the board soon after radiological evaluation to prevent development of pressure sores.

Hospital management

Resuscitation

The major causes of death in a patient with SCI are aspiration and shock. Hypoventilation and aspiration of gastric content is common especially following high cervical injury. Initial field or emergency room management should always begin with the basics: airway, breathing, and circulation.

Early intubation may be indicated when there is respiratory insufficiency. Intubation is safe when the cervical spine is immobilized. Alternatively fiber optic intubation is preferred when there are associated maxilofacial injuries. In the emergency situation cricothyroidotomy, and gastric aspiration to prevent aspiration may be required. Bradycardia, hypotension and shock can result from venous pooling, and loss of motor and sympathetic vasomotor tone. Volume management is usually adequate. Central catheters to assess pulmonary wedge pressure, cardiac output, and vascular resistance are often needed. Only if effective volume resuscitation cannot correct cardiac output should inotropic agents such as dopamine, or neosynnephrine be used.

Immobilization

The entire spine of the patient suspected of spinal injury should be immobilized. The following are scenarios of suspected spinal cord injury.

Table 1: Scenarios and evidence for suspected SCI

Scenario	Signs
• Major trauma • Ejection from vehicle • Hit and run • Holding head in rigid position • Apnea following trauma • Any neurological deficit e.g. weakness, abdominal breathing, priapism from autonomic dysfunction	• Seatbelt bruises of neck or abdomen • Clothes line injury of the neck with • Subcutaneous emphysema • Crepitance or displacement of spinal process • Vehicle track marks across back • Heart rate of 80% with hypotension, consistent with spinal shock

The spine should be immobilized with cervical collar and radiological evaluation carried out to determine the level and type of spinal injury.

The use of collar is not practical in young children but is the standard for older children. Laying a child younger than 7 years flat causes flexion of the cervical spine because of the relatively large head. The trunk can be raised on folded sheets or a hole cut out for the posterior cranium. In infants the head is best taped to the board. The child should be removed from the board soon after radiological evaluation to avoid pressure necrosis of their delicate skin. [16, - 19]

Evaluation

Adequate history should be taken as soon as possible. Dragging of patient should be avoided. The patient should be moved in one piece by the logrolling and carrying method. If a board was used, the patient is

removed from it after radiological evaluation. [20]

Examination should include motor functions of the major muscle groups as well as rectal examination for sphincteric tone. Initial examination serves as a base line for subsequent examinations.

Neurological assessment

The adult spinal cord ends at the lower level of L1. To determine the spinal segment underline a given vertebra:

- The cervical nerves 1 to 8 exit below the pedicle of their corresponding vertebra.
- For T_2 to T_{10} add 2 to the number of the spinous process.
- T_{11}, T_{12} and L_1 over lie 11 lowest spinal segments (L_1 to coccygeal 1).
- Conus medullaris lies at L_1 (in children at $L_{2/3}$). [16 - 18]

Motor level

The Royal Medical Research Council of Great Britain scale can be used to assess muscle power (Table 2). The American Spinal Injury Association (ASIS) motor scoring system can provide rapid assessment (Table 3). The degree of paralysis can be assessed using the Frankel scale (Table 4) as well as the sensory level (Table 5).

Table 2: Royal Medical Research Council of Great Britain strength grading scale

Grade	Strength
0	No contraction
1	Flicker or trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against resistance • 4^- slight resistance • 4 moderate resistance • 4^+ strong resistance
5	Normal strength

Table 3: ASIA motor scoring system

Right grade	Segment	Muscle	Action to test	Left grade
0-5	C5	Deltoid or biceps	Shoulder abduction or elbow flexion	0-5
0-5	C6	Wrist extensors	Cock up wrist	0-5
0-5	C7	Triceps	Elbow extension	0-5
0-5	C8	Flexor digitorum profundus	Squeeze hand	0-5
0-5	T1	Hand intrinsics	Abduct little finger	0-5
0-5	L2	Iliopsoas	Flex hip	0-5
0-5	L3	Quadriceps	Straighten knee	0-5
0-5	L4	Tibialis anterior	Dorsiflex foot	0-5
0-5	L5	Extensor halllusis longus	Dorsiflex big toe	0-5
0-5	S1	Gastrocnemius	Plantar flex foot	0-5
50		← Total possible points →		50
		Grand total: 100		

Table 4: Frankel scale

Grade	Description
A or 1	Complete motor and sensory paralysis below the lesion
B or 2	Complete motor and sensory paralysis, but some residual sensory perception below the lesion
C or 3	Residual motor function, but of no practical use
D or 4	Useful but subnormal motor function below the lesion
E or 5	Normal

Table 5: Key sensory landmarks

Level	Dermatome
C4	Shoulders
C6	Thumb
C7	Middle finger
C8	Little finger
T4	Nipples
T6	Xiphoid
T10	Umbilicus
L3	Just above patella
L4	Medial malleolus
L5	Great toe
S1	Lateral malleolus
S4 - 5	Peri-anal

Management

- Immobilization is maintained until after radiologic examination.
- The systolic blood pressure is maintained at or above 90mmHg; over hydration should be avoided to prevent pulmonary oedema.
- Oxygenation is maintained.
- N-G tube aspiration to decompress the abdomen, which can interfere with respiration.
- Indwelling urethral catheter to monitor urine output and prevent over distension of the bladder from urinary retention.
- Vaso motor paralysis may lead to loss of temperature control, especially in infants. The child should be covered or exposed depending on the temperature.
- Electrolytes: hypotension (Spinal shock) and hypovoleamia can cause release of aldosterone, which may lead to hypokalemia.

Investigation

Plain X-ray is indicated in all patients with suspected spinal injury. Radiologic evaluation should be done after adequate resuscitation and before removal of immobilization devices.

1. Cervical spine X-ray from cranio-cervical junction to C7/T1 junction. Antero-posterior, lateral, oblique or 'swimmer view' may be necessary to demonstrate lower cervical vertebrae. In a patient with suspected odontoid process fracture open mouth view can be carried out.

Figure 1: Fracture dislocation of C5 over C6

2. Flexion-extension (dynamic) views can be performed under medical supervision, in a patient with no neurologic deficit that had previous normal radiograph but still having neck pains.
3. Thoraco-lumbar spine X-rays: antero-posterior and lateral view to rule out a second injury or demonstrate fracture in cases of suspected thoraco-lumber injury.
4. Computer tomography (CT) scanning and magnetic resonance imaging (MRI) of the fractured segment may demonstrate cord involvement or spinal canal obstruction. CT myelography may demonstrate spinal block, although MRI has largely replaced it.
5. Spinal angiography may demonstrate vascular involvement especially in patients with SCIWORA.

Treatment

After resuscitation, treatment of patients with complete injury is aimed at preventing the three major complications of traumatic paraplegia viz pressure sore, urinary tract infection and, contracture and deformities of the limbs. In those with incomplete injury the aim is stabilization until spontaneous recovery occurs.

High dose corticosteroids (methylprednisolone), which act by limiting secondary injury, have been found to improve functional outcome in spinal cord injuries. However data regarding effectiveness in children is lacking. Methylpredisolone given within 8 hours of injury has been found to have both sensory and motor benefit in patients with complete or incomplete spinal cord injury. The use H_2 receptor antagonist to prevent gastric erosion by the steroid is recommended.

Prophylaxis against deep vain thrombosis (DVT) using low dose heparin and pneumatic compression boots is recommended after the age of 14 years.

Skull traction

Skull traction is aimed at reducing cervical fracture-dislocation, maintaining normal alignment, immobilizing the spine and decompressing the spinal cord and nerve roots. It also facilitates bone healing. It is contraindicated in:

1. Atlanto-occopital dislocation.
2. Type IIA or III hangman's fracture.
3. Skull defect at anticipated pin site.
4. In children ≤ 3 years.

Crutchfild tongs require pre-drilled hole. Gardner-Wells tongs or Halo ring can be used.

The pins are inserted under local anesthesia through a stab incision above the temporalis muscle insertion; 3 to 4 cm above the pinna, for neutral traction in line with the external auditory meatus, 2 to 3 cm posteriorly for flexion traction and 2 to 3 cm anteriorly for extension traction. The traction weight should be increased gradually under radiographic control. Formula for calculating weight:

Weight (lbs) = 3 × cervical vertebral level or 5 lbs per level

- Not more than 10 lbs should be used in children <14 years.

- Over distraction should be avoided.
- Regular neurological examination to detect deterioration should be carried out.

Figure 2: Cranium holder from AESCULAP. Used for skull traction. No drilling is required

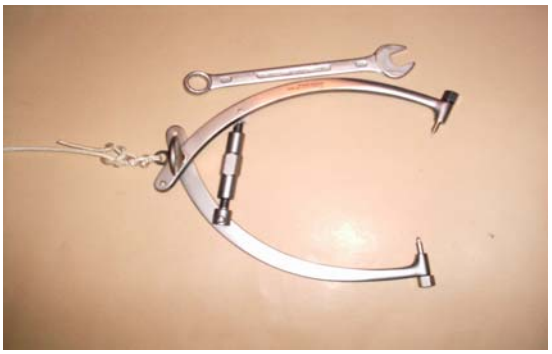
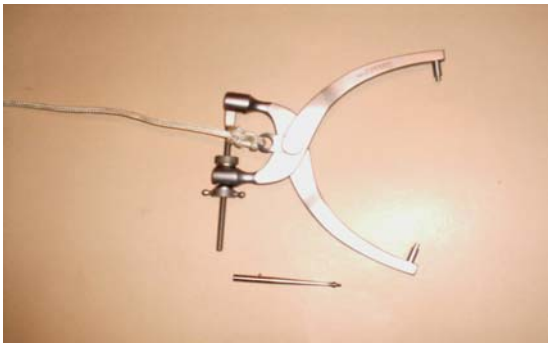


Figure 3: Crutchfield tongs require predrilled hole. The guarded drill bit is by the side



Complication of skull traction include:

- Skull penetration by pins.
- Retropulsion of disc with neurological deterioration (need emergency CT/myelogram or MRI).
- Over distraction.
- Infections such as osteomylitis and subdural empyema.

Surgical management

Emergency laminectomy has been associated with neurologic deterioration. Decompression is usually combined with a stabilization procedure.

Incomplete spinal injury

Patients with incomplete injury and instability or canal compromise that do not improve on conservative management should undergo surgical decompression and stabilization. This may facilitate some return of neurological function.

Emergency surgery is indicated in patients with incomplete lesion, who, following reduction of subluxation show the following:

1. Progressive neurologic deterioration.
2. Complete spinal block on MRI or myelogram.
3. Bone fragment within spinal canal.
4. Cervical nerve root compression.
5. Compound fracture or penetrating spinal trauma.
6. Acute anterior cord syndrome.
7. Non-reducible locked facet causing compression.

Contraindications to emergency operation include:

1. Complete spinal cord injury more than 24 hours.
2. Medically unfit patient.

The operative approach could be anterior, posterior or both, depending on the mechanism of the injury. Instrumentation (wires, cables, plates) can be used to immobilize the area of instability while bony fusion is occurring.

Surgical complication include:

1. Hardware problems.
2. Failure of graft to take.
3. Judgmental errors such as failure to incorporate all unstable levels.
4. Postoperative kyphosis.

Complete spinal injury

The goals of surgical management in a patient with complete spinal lesion include:

1. Spinal stabilization before spontaneous fusion takes place in about 8 to 12 weeks time. This allows the patient to be placed in sitting position, improve pulmonary function and initiate of early rehabilitation.
2. Reduce risk of kyphotic angulation.

Surgery should be delayed for 4 to 5 days until the patient is stabilized.

Bracings

Bracings are mostly used for cervical fracture. Collars are mostly used in older children. Function is mainly to help the patient to reduce neck movement. It immobilizes the neck very little. The Philadelphia collar prevents neck rotation.

Cervicothoracic orthoses (CTO)

CTO incorporate body vest to immobilize the cervical spine. The following have increasing degree of immobilization.

1. Guilford brace: this is a ring brace around the occiput and chin connected by two anterior and posterior thoracic pads.
2. SOMI brace: acronym for sternal occipital mandibular immobilization. Good for bracing against flexion. Allows patient to eat without mandibular support.
3. Yale brace: An extended Philadelphia collar. It is an effective CTO for bracing against flexion-extension and rotation.
4. Poster braces: Differ from CTO by lack of straps under the axilla. Good for preventing flexion at mid-cervical levels.
5. Halo-vest brace: Immobilizes upper or lower cervical spine.

Table 6: Recommended bracing for various cervical spine injuries

Condition	Recommended brace
Cervical strain	Philadelphia collar
Jefferson fracture	Cervicothoracic halo
• stable	
• unstable	
Odontoid fracture	Cervicothoracic halo
• type I	
• types II and III	
Hangman's fracture	SOMI halo
• stable	
• unstable	
Flexion injuries	SOMI, cervicothoracic
• Mid cervical (C3-5)	Halo
• Low cervical (C5-T1)	
Extension injuries	
• Mid cervical (C3-5)	SOMI halo, cervicothoracic halo
• Low cervical (C5-T1)	

Treatment of thoracolumber spine

Table 7: The Denis three-column model has a good predictive value

Column	Structure
Anterior	• Anterior half of disc and vertebral body including anterior annulus fibrosus
	• Anterior longitudinal ligament
Middle	• Posterior half of disc and vertebral body including posterior annulus fibrosus
	• Posterior longitudinal ligaments
Posterior	• Posterior bony complex
	• Interspinous and supraspinous ligament, facet joints and capsule
	• Ligamentum flavum

Damage to more than one column produces an unstable injury.

- Instability of first degree is mainly mechanical.
- Instability of second degree is a danger to neurological deficit.
- In third degree instability there is associated neurologic damage.

Bed rest for 1 – 6 weeks can manage stable injury and first-degree instability. This is followed by ambulation in an orthosis such as thoracolumber sacral orthosis or Jewett's brace for 3 to 5 months.

Second and third degree instability may require thoracolumbar instrumentation. Systems available include:

1. Harrington rods, which provide distraction.
2. Luque rods which are more rigid but do not provide distraction.
3. Cotrel-Dubousset system (CD system).

Complications of spinal cord injury

1. Mortality is 4 to 10%, mostly associated with head injury.
2. Pneumonia is common with upper cervical injury due to aspiration.
3. Urinary tract infection from Foley's catheter or intermittent cauterizations.
4. Ventilator dependence especially in high cervical injury.
5. Gastro intestinal ulceration.
6. Constipation.
7. Posttraumatic syrinx with delayed neurologic deterioration.
8. Progressive scoliosis due to imbalance of muscle innervation and poor posture.
9. Decubitus ulceration.
10. Chronic Pain.
11. Spasticity.

Outcome

- Majority of patient with complete injury make no improvement with or without surgery.
- Majority of patient with incomplete injury will make some improvement with or without, surgery, although some may deteriorate.

New trends in therapy

Acute spinal cord injury

A variety of compounds are now being investigated which could increase spinal cord blood flow, block excitatory amino acid receptors or modulate the immune response. [19, 20] All these effects could improve the success of methylprednisolone. Examples of these compounds include naloxone, aminosteroids, indomethacin and GMI ganglioside. [21, 22]

Chronic spinal cord injury

With chronic spinal injury the aim of therapy is to promote regeneration of functional neural connections between the supra-spinal centers and isolated caudal segment. Several strategies to achieve these effects are being explored. These include the effects of growth factors (bfGF and Hnt3) on cultured neuronal cells, transplantation of fetal nervous tissue at the site of injury and transportation of immature oligodendrocytes. [21, 22]

Another entirely new concept being investigated is that of neuroprosthesis, but this needs further advancements in molecular biology for any meaningful progress. [22]

Conclusion

A systematic and effective practical management of patients with spinal cord injury can improve the over all outcome. A multidisciplinary approach to management can lead to prevention of the chronic complications associated with spinal injury. There is a need for more studies and trials to advance knowledge and outcome of spinal cord injury.

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