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Factors Affecting Prognosis in Patients with Spinal Injury: A Comprehensive Review

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Abstract **Review Article**

Spinal cord injury (SCI) is a medically complex and life disrupting condition. Advances in emergency medical care/ambulance services have positively impacted outcomes in trauma; however, the situation for SCI still remains a cause of concern. Although there have been advances in achieving spinal stabilization and decompressions of the cord; functional outcomes are a matter of concern. Prognosis in SCI is linked directly to both the severity of the neurologic injury and any associated impairment. A multidisciplinary team work is must along with proper diagnosis for the successful outcome in these patients. Knowing the significant prognostic factors associated with spine injuries would facilitate early, rapid, and better management.

Keywords: Spinal cord Injury, Prognostic factors, neurological deficit, trauma.

INTRODUCTION

Traumatic spinal cord injury (SCI) is a serious debilitating neurological condition that has a profound impact on a patient's psychosocial and physical well-being. Damage to the spinal cord may be traumatic or non-traumatic. More than 90% of SCI cases are traumatic and caused by incidences such as traffic accidents, violence, sports or falls. Non-traumatic SCI, on the other hand, usually involves an underlying pathology – such as infectious disease, tumour, musculoskeletal disease such as osteoarthritis, and congenital problems such as spina bifida, which is a neural tube defect that arises during development of the embryo [1].

SCI is defined [2] as traumatic damage to the spinal cord or nerves at the end of the spinal cord. This affects the conduction of sensory and motor signals across the site of the lesion. There are two types of SCI:

Incomplete Lesions: Not all the nerves are served or the nerves are only partially damaged. Recovery is possible, but never to pre- injury level.

Complete Lesions: The nerves are served and there is no motor or sensory function preserved of this point.

The incidence of traumatic SCI is estimated to be 11 to 53 new cases per million population [3, 4]. The past epidemiological data suggested that SCI mainly affects young adults (mean age 29±3.4 years) but from last two decade, elderly (mean age 45±7.2 years) SCI increased considerably. The male to female ratio of 2:1 has been reported for SCI.

Clinical Anatomy of SCI

The spinal cord is the major pathway through which sensory and motor information travel between brain and body. The spinal cord consisted of longitudinally directed spinal tracts (white matter) surrounding central areas (gray matter) where most spinal neuronal cell bodies are located. The grey matter is organized into segments comprising sensory and motor neurons. Axons from spinal sensory neurons enter and axons from motor neurons leave the spinal cord via segmental nerves or roots. The roots are numbered and named according to the foramina through which they enter/exit the vertebral column. The root receiving sensory information from skin areas are called dermatomes [6]. Similarly, the root that innervates a group of muscles called a myotome. Continuing from the end of the spinal cord, in the spinal canal, is the *cauda equina* (or "horse's tail"). The spinal cord itself has neurological segmental levels that correspond to the nerve roots which exit the spinal column between each of the vertebrae [7]. The spinal column consisted of

four regions: Cervical (7 vertebrae), thoracic (12 vertebrae), lumbar (5 vertebrae) and sacral (5 vertebrae) (Figure-1).

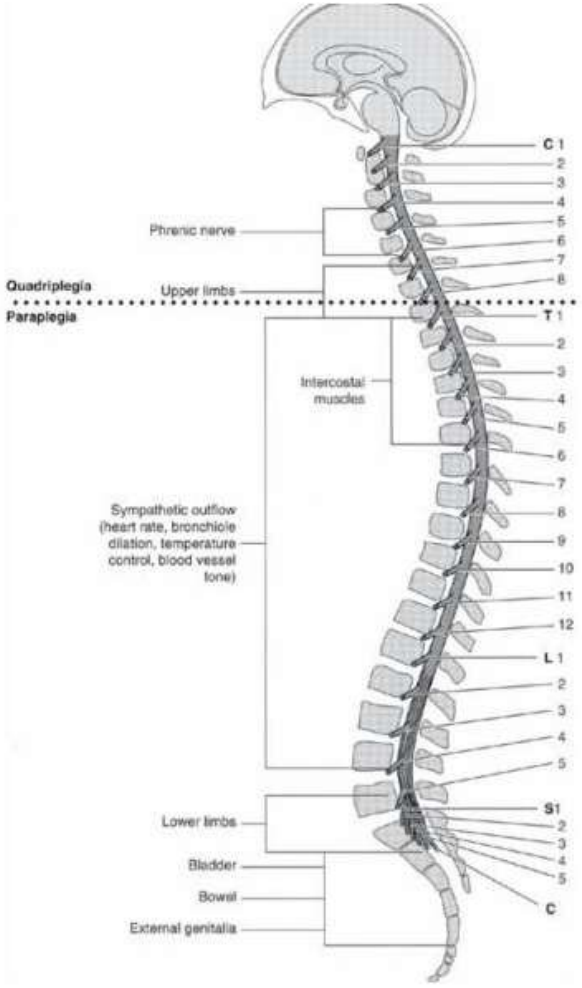

Fig-1: Clinical anatomy of Human Spinal cord

SCI symptoms depends on the extent of injury or non-traumatic cause, but they can include loss of motor or sensory control of the trunk, lower limbs and the upper limbs, as well as loss of autonomic body regulation. This can affect breathing, heart rate, blood pressure, temperature control, bowel and bladder control, and sexual function [8]. In general, the higher up the spinal cord the lesion occurs the more extensive the range of impairments will be. Cervical SCI commonly causes sensory and motor loss (paralysis) in the legs, body and arms, a condition known as *tetraplegia* (the other term *quadriplegia* is less used now a days). Patients with C4 or higher lesions may require a ventilator to breathe because the lesion directly interferes with autonomic control. SCI of thoracic region commonly causes sensory and/or motor loss in the trunk and legs, a condition called *paraplegia*. Lumbar SCI typically causes sensory and motor loss in the legs and hips [9]. All forms of SCI may also result in chronic pain. For all ages, SCI patients with incomplete tetraplegia (29.6%) made up the highest number, followed by complete paraplegia (24.7%), complete tetraplegia (21.5%), and incomplete paraplegia (17.8%) [10].

The Neurological Examination in SCI

The initial neurological examination is the most important instrument for the assessment of the severity and level of the injury.

A 5-point severity scale, (Frankel scale) has commonly been used to determine the severity of the SC (Table-1) [11]. Patients are classified as complete (Grade A), sensory only (Grade B), motor useless (Grade C), motor useful (Grade D), or no neurological deficit/complete recovery (Grade E). This scale provided a simple, though nonspecific, scheme for the categorization of SCI. Two major limitations of this scale have been identified: (1) the injury level is not incorporated into the classification and (2) the inherent subjectivity of scale in judging what constitutes "useful" motor strength. Moreover, the Frankel scale has limited responsiveness to small neurological improvements during recovery [12].

Table-1*:* Frankel Scale for Spinal Cord Injury

A	Complete	No motor or sensory function below the level of lesion
B	Sensory Only	No motor function, but some sensation below level of lesion
C	Motor useless	Some motor function without practical application
D	Motor useful	Useful motor function below level of lesion
E	Recovery	Normal motor and sensory function, may have reflex abnormalities.

The extent and severity of sensory, motor and autonomic loss from SCI depends not only on the level of injury to the spinal cord, but also on whether the lesion is "complete" or "incomplete." According to the International Standards for Neurological Classification of SCI, with the American Spinal Injury Association (ASIA) Impairment Scale (AIS) [13], an SCI is considered complete if there is no sensory and motor function at S4−S5. While some sensory and or motor function is preserved below the level of injury in incomplete SCI, including the lowest sacral segments S4-S5, it is no less serious and can still result in severe impairments (Table-2).

Table-2: ASIA Impairment Scale

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

Among adult patients with SCI, the intrarater and interrater correlation coefficients for the ASIA motor score assessment have been reported as high as 0.98 and 0.97, respectively [14]. The intrarater and interrater correlation coefficients for the ASIA sensory scores varied from 0.76 to 0.98 and 0.88 to 0.96, respectively. Furlan *et al*., [14] demonstrated that the neurological classification on the whole has a good responsiveness to change.

Sensory examination comprises testing of what are known as key points in each of the 28 dermatomes on both the left and right sides of the body (Figure-2) [15]. The key points correspond with a defined area of skin in each dermatome where overlapping innervation to adjacent dermatomes is at a minimum, thereby making these areas most suitable for testing the function of each specific dermatome. The dermatomes extend from level C2 to S5, where S4 and S5 are considered as one dermatome. Each key point, including the anal and perianal region, is tested for light touch (with a cotton tip applicator or similar object) and pain (using a pin or similar object). Sensory function is graded as follows: normal = 2; impaired/ distorted = 1; absent = 0; not testable = NT. The latter may be due to a local injury, amputation, or a cast covering the area.

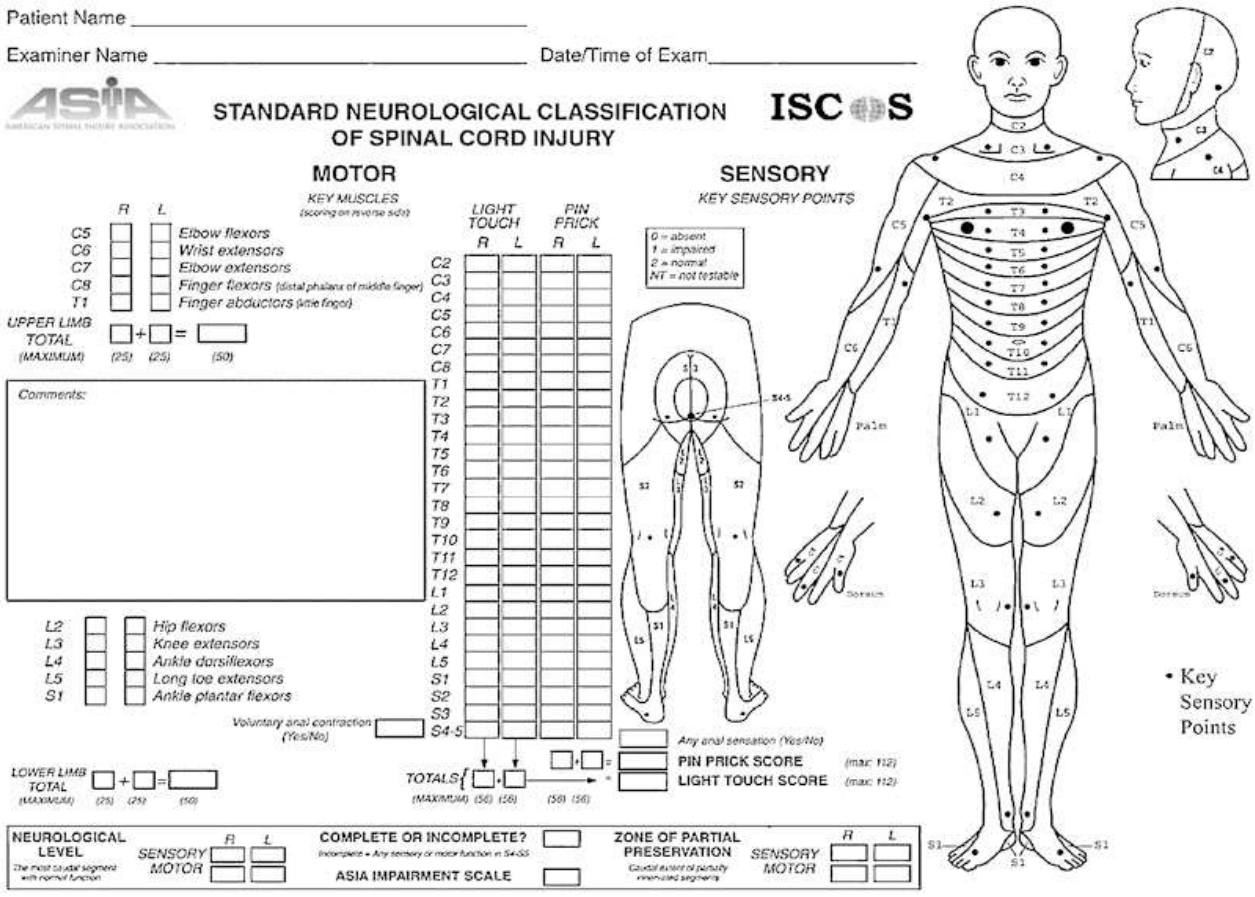

Fig-2: Scoring form of the *International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients*, available on the following Web site: http://www.asia-spinalinjury.org/publications/59544_Sc_Exam_Sheet_r4.pdf

MRI in SCI

Magnetic resonance imaging (MRI) is the best imaging modality for spinal cord. The SCI lesion look spindle shaped, containing an epicenter of hemorrhage surrounded by a halo of edema on MRI; the latter has a greater rostral-caudal extent than the central hemorrhage. [16] Although clearly specified indications have not been postulated yet, many authors advise that

patients with a suspected spinal cord injury should undergo an MRI examination as soon as possible [17, 18]. In currently available evidence, however, MRI does not provide additional *prognostic* information on neurological outcomes in a fully cooperative patient with SCI with a stable neurological condition and an uncomplicated injury of the spinal column [19, 20].

Electrophysiological Examination

The integrity and function of axons in the spinal cord can also be measured with us electrophysiological recordings such as somatosensory evoked potentials and motor evoked potentials. These instruments are particularly valuable in patients who cannot participate in a reliable physical examination. Based on the amplitude of the evoked response and latency, estimation can be made on the severity and prognosis of the SCI [21, 22]. Although it has been demonstrated that somatosensory evoked potentials are strongly related to ambulation outcomes, this technique does not offer additional prognostic accuracy over that provided by the clinical neurological examination. It is for this reason that electrophysiological examinations of the limbs are currently not indicated in the evaluation of cooperative patients with SCI. Electrophysiologic tests can also be helpful prognostically. As might be expected, motor-evoked potentials (MEPs) are more predictive of ambulatory potential than sensory-evoked potentials (SSEPs) given that they can better detect motor tract. One group found that all patients with initial MEPs present recovered at least antigravity strength in the muscles tested [23].

Prognosis in SCI

Goodwin-Wilson *et al.*, recently introduced the use of "evidence-based process maps" for SCI rehabilitation [24]. In these process maps, the range of daily activities of patients with a specified severity (AIS) and injury level are presented for every week post injury. Using this method, physicians are able to provide patients with a framework for expected short-, intermediate- and long-term outcomes. This approach is not only for the benefit of patients with SCI, it also provides a better insight into the complete rehabilitation process for health care professionals. For optimal applicability of the process maps, it is important to determine the severity and level of the injury accurately prior to the start of the rehabilitation program.

The diagnostic and prognostic value of new imaging techniques in the field of SCI is also being investigated. Diffusion-weighted imaging and diffusion tensor imaging are also good techniques that may provide a more detailed visualization the injury than conventional MRI [25, 26]. A relatively new approach for evaluating the extent of the spinal cord damage is the assessment of biomarker concentrations in the cerebrospinal fluid [27]. Kwon *et al.*, [28] showed many biomarkers which are significantly correlated to the severity of neurological deficits as measured with the International Standards in patients with SCI. Moreover, the authors stated that the biomarker concentrations have a stronger relation to neurological outcomes when compared with the initial AIS scores.

CONCLUSION

Despite the availability of promising prognostic advances, the initial neurological examination according to the International Standards will most likely remain the reference standard for the prognosis of SCI for the next decade. Based on prognostic factors from the International Standards, Neurosurgeons and Physicians are able to inform patients about the predicted long-term outcomes, including the ability to walk, with high accuracy. Nonetheless, new imaging techniques and biomarkers do have the potential to become incorporated into the standard diagnostic workup for patients with SCI who are unable to participate in a reliable neurological examination.

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