World Journal of Orthopedics

Online Submissions: http://www.wjgnet.com/esps/
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
DOI: 10.5312/wjo.v6.i1.8

World J Orthop 2015 January 18; 6(1): 8-16
ISSN 2218-5836 (online)

TOPIC HIGHLIGHT

Kemal Nas, MD, Professor, *Series Editor*

Rehabilitation of spinal cord injuries

Kemal Nas, Levent Yazmalar, Volkan Şah, Abdulkadir Aydın, Kadriye Öneş

Kemal Nas, Department of Physical Medicine and Rehabilitation, School of Medicine, Sakarya University, Korucuk, Sakarya, 54290 Turkey
Levent Yazmalar, Department of Physical Medicine and Rehabilitation, School of Medicine, Dicle University, 21280 Diyarbakir, Turkey
Volkan Şah, Department of Phsyical Treatment and Rehabilitation, Erzincan University Mengucek Gazi Training and Research Hospital, 24100 Erzincan, Turkey
Abdulkadir Aydın, Orthes and Prothes Center, Dicle University, 21280 Diyarbakır,Turkey
Kadriye Öneş, Istanbul Physical Medicine and Rehabilitation Research and Training Hospital Physical Therapy and Rehabilitation Clinic, 34718 Istanbul, Turkey
Author contributions: Nas K, Yazmalar L and Öneş K contributed to the concept and design; Şah V contributed to the interpretation; Aydın A contributed to the literature review.

Correspondence to: Kemal Nas, MD, Professor, Department of Physical Medicine and Rehabilitation, School of Medicine, Sakarya University, Korucuk, Sakarya, 54290 Turkey. kemalnas@yahoo.com
Telephone: +90-264-2759192
Fax: +90-264-2759192
Received: February 14, 2014
Peer-review started: February 14, 2014
First decision: April 4, 2014
Revised: May 24, 2014
Accepted: June 14, 2014
Article in press: June 16, 2014
Published online: January 18, 2015

Abstract

Spinal cord injury (SCI) is the injury of the spinal cord from the foramen magnum to the cauda equina which occurs as a result of compulsion, incision or contusion. The most common causes of SCI in the world are traffic accidents, gunshot injuries, knife injuries, falls and sports injuries. There is a strong relationship between functional status and whether the injury is complete or not complete, as well as the level of the injury. The results of SCI bring not only damage to independence and physical function, but also include many complications from the injury. Neurogenic bladder and bowel, urinary tract infections, pressure ulcers, orthostatic hypotension, fractures, deep vein thrombosis, spasticity, autonomic dysreflexia, pulmonary and cardiovascular problems, and depressive disorders are frequent complications after SCI. SCI leads to serious disability in the patient resulting in the loss of work, which brings psychosocial and economic problems. The treatment and rehabilitation period is long, expensive and exhausting in SCI. Whether complete or incomplete, SCI rehabilitation is a long process that requires patience and motivation of the patient and relatives. Early rehabilitation is important to prevent joint contractures and the loss of muscle strength, conservation of bone density, and to ensure normal functioning of the respiratory and digestive system. An interdisciplinary approach is essential in rehabilitation in SCI, as in the other types of rehabilitation. The team is led by a physiatrist and consists of the patients' family, physiotherapist, occupational therapist, dietician, psychologist, speech therapist, social worker and other consultant specialists as necessary.

Key words: Spinal cord; Injury; Tetraplegia; Paraplegia; Rehabilitation

Core tip: Spinal cord injury (SCI) leads to serious disability and complications. The treatment and rehabilitation process of SCI is long, expensive and requires a multidisciplinary approach. Early rehabilitation is important to prevent disability and complications.

Nas K, Yazmalar L, Şah V, Aydın A, Öneş K. Rehabilitation of spinal cord injuries. *World J Orthop* 2015; 6(1): 8-16 Available from: URL: http://www.wjgnet.com/2218-5836/full/v6/i1/8.htm DOI: http://dx.doi.org/10.5312/wjo.v6.i1.8

INTRODUCTION

Spinal cord injury (SCI) is the injury of the spinal cord from the foramen magnum to the cauda equina which occurs as a result of compulsion, incision or contusion. As a result of the injury, the functions performed by the spinal cord are interrupted at the distal level of the injury. SCI causes serious disability among patients[1]. Every year, about 40 million people worldwide suffer from SCI. Most of them are young men, typically aged from 20 to 35, although 1% of this population are children[2]. In children, motor vehicle accidents are the most common mechanism of injury. Sports-related injuries are responsible for the largest number of spinal injuries after children begin school and start participating in organized sports. Among all sports, football causes the greatest number of injuries[3]. Sixty to eighty percent of spinal injuries in children occur in the cervical region. The remaining 20%-40% are evenly split between the thoracic and lumbar region. Boys are more likely to experience spinal trauma than girls[4]. The most common causes of SCI in the world are traffic accidents, gunshot injuries, knife injuries, falls and sports injuries. Diving was reported to be the most common sport inury. Injury is usually caused by flexion, compression, hyperextension or flexion-rotation mechanisms. This is called "primary damage" that occurs as a result of these mechanisms. The responses of the body in order to overcome the primary damage, such as hemorrhage, inflammation and the release of various chemicals, are described as secondary damage[5].

Spinal cord injuries are classified by the American Spinal Injury Association (ASIA) by considering the motor and sensory functions. The last revision of the ASIA Disorder Scale was made in 2011. The term of "deep anal sense" is replaced by "deep anal pressure". The term skeleton level was not included in the latest "International Standards for Neurological Classification of Spinal Cord Injury (ISNCSC)" contents as it is not always present in spinal cord lesions[6]. The ASIA scale is listed in Table 1.

There is a strong relationship between functional status and whether the injury is complete or not complete, as well as level of the injury. A complete injury means full loss of motor and sensory functions at the distal level of injury[7]. Incomplete injury defines partial preserving of sensory and motor functions below the neurological level and in the lower sacral segments. With this lesion, deep anal sensation and/or anal mucocutaneous superficial sense is expected to be preserved. The status of the lesion could be unclear until the end of the spinal shock period. Although the signs indicating the end of this period are disputed, an increase in reflex activity is known to be a positive indicator.

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 typically in the trunk, legs and pelvic organs, *i.e.,* including the four extremities. It does not include brachial plexus lesions or injury to peripheral nerves outside the neural canal.

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 the trunk, legs and pelvic organs may be involved depending on the level of injury. The term is used in referring to cauda equina and conus medullaris injuries, but not to lumbosacral plexus lesions or injury to peripheral nerves outside the neural canal.

Tetraparesis and paraparesis

Use of these terms is discouraged as they describe incomplete lesions imprecisely and incorrectly imply that tetraplegia and paraplegia should only be used for neurologically complete injuries. Instead, the ASIA Impairment Scale (AIS) provides a more precise approach to description of severity (*i.e.*, completeness) of the SCI[6].

In that case, also called quadriplegia, all extremities and trunk are affected by neurological damage. Tetraplegia occurs in cases of injury at C1-C8 segments. Injuries of the brachial plexus and the nerves outside the neural canal are not included in the definition of tetraplegia. The previous definition of tetraplegia is no longer used and incomplete tetraplegia is preferred instead. The term paraplegia indicates the paralysis of lower extremities and part of the trunk resulting from injury of thoracic, lumbar and sacral segments. This concept encompasses lesions of the cauda equina and conus medullaris but it does not include peripheral nerve and lumbosacral plexus lesions outside the neural canal. Paraplegia is sometimes called diplegia. The body and/or extremities may not be affected depending on the level of the lesion. In many cases of paraplegia, sensory loss and urinary and anal sphincter dysfunction would be detected in the distal levels of injury, in addition to loss of motor function[8].

The most common form of spinal cord injury in the neck is the posterior ligament rupture and dislocation that causes severe neurological pathologies, especially as it is related to damage and ischemia of the gray part in the cord. Ischemia occurs due to direct injury of the circulatory system or neurogenic shock caused by vasospasm. Results of the SCI vary according to the size and localization of the injury[9].

The results of SCI bring not only damage to independence and physical function, but also cause many

Table 1 American Spinal Injury Association scale for spinal cord injury

ASIA-A	Complete. There is no sensory or motor function preserved in the sacral segments of S4-S5
ASIA-B	Sensory incomplete. Motor deficit without sensory loss below the neurological level, including the sacral segments of S4-S5 (light touch, pin sensation or deep anal pressure at S4-S5), and there is no protected motor function from three levels below the motor level at each half of the body
ASIA-C	Motor incomplete. Motor function is preserved below the neurological level[1] and more than half of the muscles below this level have strength lower than 3/5 (0, 1 or 2)
ASIA-D	Motor incomplete. Motor function is preserved below the neurological level[1] and at least half of the muscles (half or more) below this level have strength higher than 3/5
ASIA-E	Normal. Sensory and motor function as assessed by ISNCSC in all segments are normal and in patients with pre-existing deficits there is "E" degree of ASIA. Initially one without a spinal cord injury does not have an ASIA degree

[1]To have a degree of American Spinal Injury Association (ASIA) C or D so to be motor incomplete, the patient must have voluntary contraction of the anal sphincter or protection of motor function at more than three levels below motor level on the same side of the the body with sacral sensory protection. These standards permit the use of muscle function except the key muscles more than three levels below the motor level in discrimination of ASIA B and C. Motor levels in both sides are used to distinguish between ASIA B and C. Single neurological level is used to distinguish between ASIA C and D.

complications. Neurogenic bladder and bowel, urinary tract infections, pressure ulcers, orthostatic hypotension, fractures, deep vein thrombosis (DVT), spasticity, heterotrophic ossification, contractures, autonomic dysreflexia, pulmonary and cardiovascular problems, and depressive disorders are frequent complications after SCI. These complications are directly related to the patient's life expectancy and quality of life. Bladder infections, pressure ulcers and autonomic dysreflexia especially isolate the patient from society[10,11]. Negative changes occur in the patient's perception of health due to complications resulting from SCI. Pressure ulcers, spasticity, contractures, bladder and bowel problems especially cause delay of integration with society and psychosocial distress for patients. SCI patients are hospitalized for a long period of time and experience a variety of limitations in daily living activities due to these complications. Low self-esteem can also occur as a result of the decrease in sexual dysfunction, negatively affecting the patient's body image[12].

During the growth period, diabetes and metabolic diseases are potentially serious diseases in patients who have suffered spinal cord injury in childhood. Spasticity, insulin resistance, dyslipidemia, reduced glucose transfer and obesity are common childhood complications. Passive, active-assisted, active and resistive exercises, cycling and water exercises have to be compatible with the level of SCI and the complications. These exercises will reduce muscle atrophy, decubitus ulcers, inactivity, obesity and bone fractures[13].

The treatment and rehabilitation process for trauma caused by SCI is long, expensive and exhausting, which brings biophysical, psychosocial and economic problems[14]. Treatment of patients with spinal cord injury treatment is an ongoing process for many years and starts shortly after the injury with acute care and early surgical interventions; thereafter, sensory, motor and autonomic dysfunction treatment in the chronic phase and finally, life long treatment in the home environment. Therefore, it is difficult to calculate the cost of treatment in spinal cord injury for many reasons, such as not recording the treatment regularly and not calculating the total cost of the patient as a whole. DeVivo *et al*[15] reported that overall mean first year costs were $222,087 and that mean annual cost after 1 year were $68815 (2009 US $). Mean initial acute care costs of $76711 and mean rehabilitation costs of $68543 (2009 US $) have been reported. Munce *et al*[16] reported that both the average per patient and total direct costs of health care utilization for traumatic SCI increased between 2003 and 2005. The average patient cost rose from $102900 in 2003/04 to $123674 in 2005/06.

The treatment and rehabilitation process of SCI is long, expensive and requires a multidisciplinary approach. Therapeutic strategies and results of clinical studies related to the rehabilitation of patients with spinal cord injury are summarized in Table 2.

Functional goals

Short and long term functional targets are determined by the calculation of the patients' ASIA scale, taking into consideration medical and social status and the individualized rehabilitation plan. Expected functions of motor complete injury patients at the end of the first year according to the level of the injury are given below[28-30].

C1-C4 levels

Patients with C3 and higher level injuries need ventilator support. C4 level patients can manage spontaneous respiration. The patients in this level are completely dependent. Mouth bars can be used for some activities such as page turning and writing. Wheelchairs must have high back supports and a safety belt which is able to stabilize the body and is available for a reclining or tilting position. Battery powered wheelchairs must have a head, tongue, breath or jaw control. Elbow flexion and deltoid muscles are moderately powerful in C4 level patients and thus they can use balanced forearm orthosis in personal care. Static wrist orthosis can be used to maintain the normal position of the hand and wrist and reduce the risk of contractures and deformities.

C5 level

There is enough elbow flexion muscle strength at this level. Range of motion (ROM) and stretching exercises are important in the acute stage to prevent elbow flexion and supination contractures. Static positioning of the hand orthosis preserves the wrist extensors against overstretching.

Table 2 Therapeutic strategies and results of clinical studies related to the rehabilitation of patients with spinal cord injury

Ref.	Therapeutic strategy	Results
Mehrholz *et al*[17]	Locomotor training for walking after spinal cord injury	There is insufficient evidence from RCTs to conclude that any one locomotor training strategy improves walking function more than another for the patients with SCI. The effects of robotic-assisted locomotor training are not clear, therefore research in the form of large RCTs, particularly for robotic training, is needed. Specific questions about which type of locomotor training might be most effective in improving walking function for the patients with SCI need to be explored
Berlowitz *et al*[18]	Respiratory muscle training for cervical spinal cord injury	Inspite of the relatively small number of studies included in this review, meta-analysis of the pooled data indicates that RMT is effective for increasing respiratory muscle strength and perhaps also lung volumes for people with cervical SCI. Further research is needed on functional outcomes following RMT, such as dyspnea, cough efficacy, respiratory complications, hospital admissions, and quality of life. In addition, longer-term studies are needed to ascertain optimal dosage and determine any over effects of RMT on respiratory function, quality of life, respiratory morbidity and mortality
Domingo *et al*[19]	A systematic review of the effects of pharmacological agents on walking function in people with spinal cord injury	There is limited evidence that pharmacological agents tested so far would facilitate the recovery of walking after SCI. More studies are needed to better understand the effects of drugs combined with gait training on walking outcomes in people with SCI
Wessels *et al*[20]	Body weight-supported gait training for restoration of walking in people with an incomplete spinal cord injury: a systematic review	Subjects with subacute motor incomplete spinal cord injury reached a higher level of independent walking after over ground training, compared with body weight-supported treadmill training. More randomized controlled trials are needed to clarify the effectiveness of body weight-supported gait training on walking, activities of daily living and quality of life for subgroups of persons with an incomplete spinal cord injury
Taricco *et al*[21]	Pharmacological interventions for spasticity following spinal cord injury	There is insufficient evidence to assist clinicians in a rational approach to antispastic treatment for SCI. Further research is urgently needed to improve the scientific basis of patient care
Hitzig *et al*[22]	Randomized trial of functional electrical stimulation therapy for walking in incomplete spinal cord injury: effects on quality of life and community participation	The present study provides insight into the perceived benefits acquired by participating in an RCT comparing exercises to FES therapy and serves as a model for pinpointing domains of well-being that could be targeted for assessment in future SCI trials
Astorino *et al*[23]	Effect of chronic activity-based therapy on bone mineral density and bone turnover in persons with spinal cord injury	Chronic activity-based therapy did not reverse bone loss typically observed soon after injury, yet reductions in BMD were less than the expected magnitude of decline in lower extremity BMD in persons with recent SCI
Sadowsky *et al*[24]	Lower extremity functional electrical stimulation cycling promotes physical and functional recovery in chronic spinal cord injury	FES during cycling in chronic SCI may provide substantial physical integrity benefits, including enhanced neurological and functional performance, increased muscle size and force-generation potential, reduced spasticity, and improved quality of life
Gorgey *et al*[25]	Neuromuscular electrical stimulation attenuates high skeletal muscles atrophy but not trunk muscles after spinal cord injury	NMES can delay the process of progressive skeletal muscle atrophy after chronic SCI However, the effects are localized to the trained high muscles and do not extend to the proximal trunk muscles
Karimi *et al*[26]	Robotic rehabilitation of spinal cord injury individual	Although various types of orthotic systems have been developed for paraplegic subjects for walking and rehabilitation, there is not enough research in this regard. It is not easy to determine the therapeutic influence of robotic orthosis on the health status of paraplegic subjects There is a huge gap for a randomized clinical trial research to determine the effect of robotic system on the health status of the SCI subjects
Karimi *et al*[27]	Functional walking ability of paraplegic patients: comparison of functional electrical stimulation *vs* mechanical orthoses	FES and hybrid orthoses offer considerable potential for restoring standing and walking abilities in persons with SCI. However, improvements in their designs and operation with subsequent objective evaluations are required to demonstrate that the systems enable users to improve their performance over that currently possible with passive, mechanical orthoses

SCI: Spinal cord injury; FES: Functional Electrical Stimulation; RCTs: Randomized controlled studies.

Patients can use a battery powered wheelchair with a joystick modification and can push a manual wheelchair with special gloves. Transferability is completely dependent. Most of these patients need assistance for daily living activities although they may eat with a special splint.

C6 level

Active wrist extension is possible and hand grip can be achieved with a tenodesis effect. These patients are usually independent in activities like nutrition, care and hygiene and dressing the upper body. A dynamic triceps-driven orthosis is helpful for reading books, eating, teeth and hair care activities in the cases of weak proximal muscles and strong distal muscles. The driven hand/wrist brace can be used for the function of the hand grip. Transfers are achieved by the assistance of transfer board. A manual wheelchair can be used by adding a knob to the circle but a battery powered wheel chair is needed for long distances. While men are independent in bladder care with some modifications such as clean intermittent catheterization,

women often need help.

C7-C8 levels

The elbow extension in C7 level and finger flexor muscle strength in C8 level is sufficient. Patients are independent in most daily living activities and transfers. They may need some help in lower extremity dressing. A manual wheelchair is accessible and wheelchair transfer is successful. Specially equipped cars can be used.

T11-T12 levels

Patients are independent in daily living activities, bowel-bladder care, using a manual wheelchair and transferring. The target is therapeutic ambulation in upper thoracic injury patients. They can not socially ambulate. Body control is present in lower thoracic injury patients and they may be ambulant at home with lower extremity orthoses and a walker.

L1-L2 levels

They are fully independent in activities of daily living and personal care. They may be ambulatory with long leg walking device for short distances but they need a wheelchair for a long distance.

L3-L4 levels

Patients can lock the knee fully and dorsiflexion of the ankle can be partly made. Patients can ambulate socially with elbow crutches and ankle foot orthoses. They are independent in bowel and bladder care.

L5 and lower

They are independent in all activities.

ACUTE AND SUBACUTE REHABILITATION IN THE SCI

This period begins with admission to hospital and stabilization of the patient's neurological state and is a 6-12 wk bed period. The aim of rehabilitation in this period is to prevent complications that may occur long term. Passive exercises should be done intensively to resolve contractures, muscle atrophy and pain during the acute period of hospitalization in patients with complete injury. Positioning of the joints is important in order to protect the articulary structure and maintain the optimal muscle tonus. Sand bags and pillows can be useful in positioning. If the pillows and sandbags are not able to provide positioning, it can be achieved with plaster splints or more rigid orthotics. Ankle foot orthosis, knee-ankle foot orthosis or static ankle foot orthosis, *etc*. are mainly used for this purpose[31].

The most common and important complication is the development of joint contractures and stiffness during this period. At least one joint contracture (43% shoulder, 33% elbow, 41% forearm and wrist, 32% hip, 11% knee, 40% foot and ankle) has been reported in about 66% of patients within 1 year. If the patient is paraplegic or tetraplegic, intensive passive ROM exercises must maintain the lower extremities to be compatible with the level of the injury. ROM exercises prevent contractures and maintain functional capacity. These exercises should be done in a flaccid period at least once a day and at least 2-3 times a day in the presence of spasticity. Damage level, awareness and cooperation with the state determine the places that must be protected by passive EHA. Shoulder ROM exercises are important to prevent pain in all levels of damage. Passive ROM exercises should be done for both upper extremities in C1-C4 level tetraplegia. In injuries of C5 and C6 levels, ROM exercises should be done to prevent the development of contractures, especially contractures of elbow flexion and supination[32].

Stretching should be done to protect the tenodesis effect in patients without active wrist extension and fingers that are not fully stretched. Muscles are flaccid during the spinal shock period. Exercises can be done more easily with flaccid muscles. Flaccidity is replaced with spasticity after the period of spinal shock. Despite the positive effects of spasticity, it has negative effects on mobility, daily living activities and transferring. The severity and type of the other complications of SCI affects spasticity and the precipitating factors should be eliminated for the treatment of spasticity. Isometric, active or active-assisted truncal exercises should be done in the patient's bed if partial movements are present, depending on the injury level. Recent studies have shown that early mobilization plays an important role in prevention of pulmonary function decline and in the development of muscle strength. Breathing exercises should be carried out and taught and its importance should be explained to complete or incomplete paraplegic and tetraplegic patients during the acute phase in order to protect lung capacity. During this period, the number of exercises should be kept at the maximum level depending on the patient's tolerance. If the physiotherapist or allied health staff in the clinic are not present or are not sufficient, the patient's family should be included in the rehabilitation team from the initial days and the importance and necessity of the rehabilitation must be shared with patients and their relatives[33].

The most important point is strengthening of the upper extremities to the maximal level in the acute period of rehabilitation in patients with complete paraplegia. Enpowering exercises for shoulder rotation are proposed for using crutches, swimming, electric bicycles and walking[34]. At the end of the acute phase, strong upper extremities are needed for the independent transfer from bed. For this purpose, active and resistance exercises to strengthen the muscles of the upper extremity should be initiated at the earliest possible period. Weight and resistance exercises can be applied with dumbbells in bed depending on the patient's muscle strength. Electrical stimulation may be a useful alternative if extreme fatigue occurs while strengthening the muscles. Shoulder exercises performed with elastic bandages were found to be effective to reduce shoulder pain[35].

In order to prevent decubitus ulcers, the patient's position should be changed every 2-3 h. Decubitus ulcers

occur most frequently on the sacrum, ischium, trochanter and superior aspect of the heel. Flexion contractures of the hip may develop due to continuous lying on the side and sitting in the wheelchair. Flexor muscle tension can be reduced with a prone position at regular intervals and ROM exercises in all directions. The ankle ROM exercises are useful to prevent contractures of the foot as well as the proper positioning of the foot while sitting in a wheelchair. Patients should be asked to change position and actively participate. In addition, attention should be paid to keeping the skin clean and preventing the formation of decubitus ulcers[36].

Corsets are used for fixation and supporting the spine while moving on to a sitting position after the end of the bed interval. Hyperextension corsets or plaster plastic body jackets are used in treatment of thoracic and upper lumbar region fractures. A knight-type corset would be more appropriate to support the fractures at the lower of L2 vertebrae. Knight-Taylor type corsets restrict flexion and extension of the trunk but have no restriction on rotation. Plaster or plastic body jacket corsets should be used to restrict movements in all directions[37].

Orthostatic hypotension is likely to be found in patients with a long period of lying in bed. Syncope can be seen in these patients while sitting and being lifted up due to low blood pressure. A tilt table may be useful for patients with this condition, starting from 45 degrees for 30 min a day. The degree is increased according to the patient's complaints or state. Standing upright stimulates the blood pressure reflexly to a sufficient and persistent limit. The patients adapt to sit and stand and are prepared to transfer and balance. When the patient comes to the upright position with a tilt table, the patient should be in a sitting position on the edge of the bed 3-4 times a day and balance exercises should be done to maintain this position. Independent sitting on the edge of the bed is very important for wheelchair use, enabling wheelchair transfer. The purpose of this rehabilitation period should focus on stability and strength education for sitting and transportation. Functional goals must prepare the patient for movements such sitting up in bed or a wheelchair, dressing and transfers. Initially, the goal is for successful bed movements. ROM and stretching exercises are used for functional activities. Exercises for sitting, balance and strengthening of the upper extremities should be done at the beginning. Patients who can tolerate sitting can begin to push up, with static and dynamic balance training to transfer to the wheelchair[38].

Wheelchairs, walkers and crutches are used for out of bed transferring of patients. The wheelchair is the most important tool for SCI patients to be mobile and participate in social life. Ideally, wheelchairs must allow for optimal mobility, protect skin integrity and maintain the normal anatomical posture. A battery assisted wheelchair is appropriate for injuries at the upper segments, whereas a manual wheelchair is preferred at lower levels. Wheelchair dimensions such as the height, pelvic width, seat length, backrest, seat and arm support should be specifically prescribed for each patient[39].

The success of splints or other attempts for functional ambulation depends on whether the injury is complete or incomplete and the injury level. An incomplete SCI patient has the potential to walk, irrespective of level. The beginning of functional ambulation level is considered to be T12. Truncal and pelvic stabilization must be provided to stand and mobilize in the parallel bars. Mobilization in the parallel bars, standing and balance training exercises should be started and the patient could be supported by a posterior shell in the parallel bars during this period. A long and locked knee joint walking device is utilized, ensuring the integrity and stability of the lower extremity joints in patients after the upright standing with a posterior shell. The benefits of standing are a reduction in spasticity and the risk of DVT, bowel and bladder function recovery, prevention of pressure ulcers and osteoporosis, and reduction in depression[40]. Functional neuromuscular stimulation (FNS) is based on innervating nerve fibers of intact muscles. If the muscles are denervated, FNS stimulates the muscle fibers. A study suggests that suitable activation to specific muscles of the trunk and lower extremity can enable patients with SCI to alter their standing postures with minimal upper body effort and subsequently increase the muscle volume[41].

CHRONIC REHABILITATION PERIOD OF SCI

The most important goal is realization of the independent mobilization for both complete and incomplete paraplegic patients during the chronic period. Ambulation can be social, domestic and aimed at exercise. The patient must be able to walk 50 m unaided or with assistive devices for social ambulation. Those who ambulate domestically can walk independently or with partial assistance and need a little help or can be independent at home. Those who ambulate for exercise need advanced help for walking or transferring. Factors such as injury level, age, weight, general health status, motivation and spasticity affect the ambulation potential. Generally, patients with an injury of T10 and above can be ambulated for exercise. Patients with T11-L2 injuries can ambulate in the home (domestic) and the patients of more distal injuries can ambulate socially[42].

Walkers, crutches and orthoses are important to provide chronic stage ambulation. Patients with pelvic control can walk with an orthosis or crutches outside the parallel bars. If the muscle strength of quadriceps femoris is normal, patients can walk with elbow crutches and orthosis without needing a wheelchair. In patients with complete injury of C8-T12, ambulation can be achieved by a parawalker (hip guidance orthosis), both in the house and outside. Walking devices used in spinal cord injury are becoming more and more lightweight and easy to move. However, the devices with advanced technological features are also more expensive. Oxygen consumption, energy expenditure and walking speed can vary significantly depending on the shape, type and weight of material of

devices used by the patients. One of them is the RGO (Reciprocating Gait orthosis)[43]. For effective use, patient's excess weight reduction and increased aerobic capacity must be maintained and muscle mass must be increased. RGO has been further developed and is more complicated and more expensive than ARGO[44]. ARGO also leads to an excessive waste of energy like RGO[45]. Hybrid walking devices were created by adding Functional Electrical Stimulation to orthosis. Walking is becoming better within the hybrid devices[46]. Robotic training is a new approach and is developing day by day. A case report showed that upper extremity function has been improved by robotic assistance over four weeks. After training, manual muscle test scores of wrist extensor, finger flexor and finger abductor are significantly increased[47]. Another study demonstrated that the robotic-assisted gait training using the locomat system improved the functional outcome of subacute SCI patients[48].

The most important expectations in the chronic phase or phase to return home are ensuring the maximum independence related to the level of the patient's injury, integration of the patient to society and teaching the importance of the family's role.

In addition, house modifications are important for patients with SCI in order to have independent activities of daily living. Door width should be 81.5 cm for manual wheelchair access and 86.5 cm for battery assisted wheelchairs. The height of electric switches should be 91.5 cm. Adequate insulation and heat must be provided at home. Door handles must be the "leverage shaped" type and the height of the door sills should not impede the passage of a wheelchair for tetraplegic patients. Carpets should be removed and the surface should be hard in order to maneuver the wheelchair. Bath tubs should be mounted on the wall and must have handles. The height of kitchen apparatuses should be accessible to the patient[49]. There must be a ramp at the entrance to the house[50].

One of the important features of this period is restoring the patient's psychological and emotional state again because of the high incidence of depression in patients (the incidence is about 1/3 in the first six months). Depression is not a natural process experienced after SCI but is a complication that needs to be treated. Suicide is the most common cause of death after SCI among patients under the age of 55. Frequency of posttraumatic stress disorder is 17% and usually occurs in the first 5 years. Consultation with a psychiatrist is needed if there is psychotic behavior and depression[51]. Occupational therapy and finding the patient's role in society are most important factors in restoring the psychological state. Social and psychological problems in the absence of daily activities have been reported. Suicide attempts have been reported due to a lack of daily activity, depression, alcohol dependence and emotional distress. Occupational therapy allows SCI patients to be more social, to use their own functions for creative jobs and to deal with psychological problems like depression[52].

Occupational therapy is an important part of the rehabilitation process. In developed countries, occupational therapy is carried out by the occupational therapist in the rehabilitation team. Occupational therapists assess the patient's limitations and plan the occupational activities. Occupational therapy is planned and implemented depending on the social and cultural characteristics of individuals, level of education, personality traits, interests, values, attitudes and behaviors before and after the injury. Pictures, music, crafts, ceramic work and a variety of activities (for example, sports) and entertainment are implemented and planned to focus on the purpose in the occupational treatment[53].

REFERENCES

1 **Yıldırım K**, Şengel K. Spinal kord yaralanmaları ve rehabilitasyonu (Spinal cord injury and rehabilitation). *Klnk Akt Tıp Derg* 2004; **(4)**: 26-38

2 **Yip PK**, Malaspina A. Spinal cord trauma and the molecular point of no return. *Mol Neurodegener* 2012; **7**: 6 [PMID: 22315999 DOI: 10.1186/1750-1326-7-6]

3 **Cantu RC**, Li YM, Abdulhamid M, Chin LS. Return to play after cervical spine injury in sports. *Curr Sports Med Rep* 2013; **12**: 14-17 [PMID: 23314078 DOI: 10.1249/JSR.0b013e31827dc1fb]

4 **Mahan ST**, Mooney DP, Karlin LI, Hresko MT. Multiple level injuries in pediatric spinal trauma. *J Trauma* 2009; **67**: 537-542 [PMID: 19741397 DOI: 10.1097/TA.0b013e3181ad8fc9]

5 **Sipski ML**, Richards JS. Spinal cord injury rehabilitation: state of the science. *Am J Phys Med Rehabil* 2006; **85**: 310-342 [PMID: 16554684]

6 **Kirshblum SC**, Burns SP, Biering-Sorensen F, Donovan W, Graves DE, Jha A, Johansen M, Jones L, Krassioukov A, Mulcahey MJ, Schmidt-Read M, Waring W. International standards for neurological classification of spinal cord injury (revised 2011). *J Spinal Cord Med* 2011; **34**: 535-546 [PMID: 22330108 DOI: 10.1179/204577211X13207446293695]

7 **Gibson KL**. Caring for a patient who lives with a spinal cord injury. *Nursing* 2003; **33**: 36-41; quiz 42 [PMID: 12851498]

8 **Fries JM**. Critical rehabilitation of the patient with spinal cord injury. *Crit Care Nurs Q* 2005; **28**: 179-187 [PMID: 15875447]

9 **Barbin JM**, Ninot G. Outcomes of a skiing program on level and stability of self-esteem and physical self in adults with spinal cord injury. *Int J Rehabil Res* 2008; **31**: 59-64 [PMID: 18277205 DOI: 10.1097/MRR.0b013e3282f28e8a]

10 **Paker N**, Soy D, Kesiktaş N, Nur Bardak A, Erbil M, Ersoy S, Ylmaz H. Reasons for rehospitalization in patients with spinal cord injury: 5 years' experience. *Int J Rehabil Res* 2006; **29**: 71-76 [PMID: 16432393]

11 **Hitzig SL**, Tonack M, Campbell KA, McGillivray CF, Boschen KA, Richards K, Craven BC. Secondary health complications in an aging Canadian spinal cord injury sample. *Am J Phys Med Rehabil* 2008; **87**: 545-555 [PMID: 18574346 DOI: 10.1097/PHM.0b013e31817c16d6]

12 **Yuen HK**, Hanson C. Body image and exercise in people with and without acquired mobility disability. *Disabil Rehabil* 2002; **24**: 289-296 [PMID: 12017462]

13 **Chen SC**, Lai CH, Chan WP, Huang MH, Tsai HW, Chen JJ. Increases in bone mineral density after functional electrical stimulation cycling exercises in spinal cord injured patients. *Disabil Rehabil* 2005; **27**: 1337-1341 [PMID: 16321917]

14 **Pickett GE**, Campos-Benitez M, Keller JL, Duggal N. Epidemiology of traumatic spinal cord injury in Canada. *Spine* (Phila Pa 1976) 2006; **31**: 799-805 [PMID: 16582854]

15 **DeVivo MJ**, Chen Y, Mennemeyer ST, Deutsch A. Costs of care following spinal cord injury. *Top Spinal Cord Inj Rehabil* 2011; **16**: 1-9 [DOI: 10.1310/sci1604-1]

16 **Munce SE**, Wodchis WP, Guilcher SJ, Couris CM, Verrier M,

Fung K, Craven BC, Jaglal SB. Direct costs of adult traumatic spinal cord injury in Ontario. *Spinal Cord* 2013; **51**: 64-69 [PMID: 22801189 DOI: 10.1038/sc.2012.81]
17 **Mehrholz J**, Elsner B, Werner C, Kugler J, Pohl M. Electromechanical-assisted training for walking after stroke. *Cochrane Database Syst Rev* 2013; **7**: CD006185 [PMID: 23888479 DOI: 10.1002/14651858]
18 **Berlowitz DJ**, Tamplin J. Respiratory muscle training for cervical spinal cord injury. *Cochrane Database Syst Rev* 2013; **7**: CD008507 [PMID: 23881660]
19 **Domingo A**, Al-Yahya AA, Asiri Y, Eng JJ, Lam T. A systematic review of the effects of pharmacological agents on walking function in people with spinal cord injury. *J Neurotrauma* 2012; **29**: 865-879 [PMID: 22142289 DOI: 10.1089/neu.2011.2052]
20 **Wessels M**, Lucas C, Eriks I, de Groot S. Body weight-supported gait training for restoration of walking in people with an incomplete spinal cord injury: a systematic review. *J Rehabil Med* 2010; **42**: 513-519 [PMID: 20549154 DOI: 10.2340/16501977-0525]
21 **Taricco M**, Adone R, Pagliacci C, Telaro E. Pharmacological interventions for spasticity following spinal cord injury. *Cochrane Database Syst Rev* 2000; **28:** CD001131 [PMID: 10796750]
22 **Hitzig SL**, Craven BC, Panjwani A, Kapadia N, Giangregorio LM, Richards K, Masani K, Popovic MR. Randomized trial of functional electrical stimulation therapy for walking in incomplete spinal cord injury: effects on quality of life and community participation. *Top Spinal Cord Inj Rehabil* 2013; **19**: 245-258 [PMID: 24244090 DOI: 10.1310/sci1904-245]
23 **Astorino TA**, Harness ET, Witzke KA. Effect of chronic activity-based therapy on bone mineral density and bone turnover in persons with spinal cord injury. *Eur J Appl Physiol* 2013; **113**: 3027-3037 [PMID: 24097172 DOI: 10.1007/s00421-013-2738-0]
24 **Sadowsky CL**, Hammond ER, Strohl AB, Commean PK, Eby SA, Damiano DL, Wingert JR, Bae KT, McDonald JW. Lower extremity functional electrical stimulation cycling promotes physical and functional recovery in chronic spinal cord injury. *J Spinal Cord Med* 2013; **36**: 623-631 [PMID: 24094120 DOI: 10.1179/2045772313Y]
25 **Gorgey AS**, Dolbow DR, Cifu DX, Gater DR. Neuromuscular electrical stimulation attenuates thigh skeletal muscles atrophy but not trunk muscles after spinal cord injury. *J Electromyogr Kinesiol* 2013; **23**: 977-984 [PMID: 23683374 DOI: 10.1016/j.jelekin.2013.04.007]
26 **Karimi MT**. Robotic rehabilitation of spinal cord injury individual. *Ortop Traumatol Rehabil* 2013; **15**: 1-7 [PMID: 23510817 DOI: 10.5604/15093492]
27 **Karimi MT**. Functional walking ability of paraplegic patients: comparison of functional electrical stimulation versus mechanical orthoses. *Eur J Orthop Surg Traumatol* 2013; **23**: 631-638 [PMID: 23412182 DOI: 10.1007/s00590-012-1049-1]
28 **Savaş F**, Üstünel S. Omurilik yaralanması sonrası rehabilitasyon prensipleri (Principles of rehabilitation after spinal cord injury). In: Hancı M, Erhan B (eds): omurga ve omurilik yaralanmaları (spine and spinal cord injuries). İntertıp, 2013: 585-588
29 **Tander B**. Nörolojik hasarlı hastanın rehabilitasyonu (Neurological injured patients of rehabilitation). In: Şenel A, Çaylı S, Dalbayrak S, Temiz C, Arslantaş A(eds): Omurga travmalarında tedavi prensipleri (Principles of rehabilitation after spinal cord injury). Türk nöroşirürji derneği, 2011: 297-308
30 **Şahin E**. Omurilik yaralanmaları ve üst ekstremite ortezleri (Spinal cord injuries and upper extremity orthoses). In: Hancı M, Erhan B (eds): omurga ve omurilik yaralanmaları (spine and spinal cord injuries). İntertıp, 2013: 603-615
31 **Chi JH**. Combination therapy improves walking in spinal cord transaction. *Neurosurgery* 2009; **65**: N10-N11 [PMID: 19934949 DOI: 10.1227/01.NEU.0000345340.19534.7A]
32 **Diong J**, Harvey LA, Kwah LK, Eyles J, Ling MJ, Ben M, Herbert RD. Incidence and predictors of contracture after spinal cord injury--a prospective cohort study. *Spinal Cord* 2012; **50**: 579-584 [PMID: 22450888 DOI: 10.1038/sc.2012.25]
33 **Jia X**, Kowalski RG, Sciubba DM, Geocadin RG. Critical care of traumatic spinal cord injury. *J Intensive Care Med* 2013; **28**: 12-23 [PMID: 21482574 DOI: 10.1177/0885066611403270]
34 **Jacobs PL**, Nash MS. Exercise recommendations for individuals with spinal cord injury. *Sports Med* 2004; **34**: 727-751 [PMID: 15456347]
35 **Curtis KA**, Tyner TM, Zachary L, Lentell G, Brink D, Didyk T, Gean K, Hall J, Hooper M, Klos J, Lesina S, Pacillas B. Effect of a standard exercise protocol on shoulder pain in long-term wheelchair users. *Spinal Cord* 1999; **37**: 421-429 [PMID: 10432262]
36 **Kruger EA**, Pires M, Ngann Y, Sterling M, Rubayi S. Comprehensive management of pressure ulcers in spinal cord injury: current concepts and future trends. *J Spinal Cord Med* 2013; **36**: 572-585 [PMID: 24090179 DOI: 10.1179/2045772313Y.0000000093]
37 **Patwardhan AG**, Li SP, Gavin T, Lorenz M, Meade KP, Zindrick M. Orthotic stabilization of thoracolumbar injuries. A biomechanical analysis of the Jewett hyperextension orthosis. *Spine* (Phila Pa 1976) 1990; **15**: 654-661 [PMID: 2218711]
38 **Mehrholz J**, Kugler J, Pohl M. Locomotor training for walking after spinal cord injury. *Spine* (Phila Pa 1976) 2008; **33**: E768-E777 [PMID: 18827681 DOI: 10.1097/BRS.0b013e3181849747]
39 **Hastings JD**. Seating assessment and planning. *Phys Med Rehabil Clin N Am* 2000; **11**: 183-207, x [PMID: 10680165]
40 **Guest RS**, Klose KJ, Needham-Shropshire BM, Jacobs PL. Evaluation of a training program for persons with SCI paraplegia using the Parastep 1 ambulation system: part 4. Effect on physical self-concept and depression. *Arch Phys Med Rehabil* 1997; **78**: 804-807 [PMID: 9344297]
41 **Audu ML**, Nataraj R, Gartman SJ, Triolo RJ. Posture shifting after spinal cord injury using functional neuromuscular stimulation--a computer simulation study. *J Biomech* 2011; **44**: 1639-1645 [PMID: 21536290 DOI: 10.1016/j.jbiomech.2010.12.020]
42 **Kirshblum SC**, rehabilitation of spinal cord injury. In: Physical medicine and rehabilitation, principle and practice. Philadelphia: Lippincott Willams&Wilkins, 2005: 1715-1751
43 **Hawran S**, Biering-Sørensen F. The use of long leg calipers for paraplegic patients: a follow-up study of patients discharged 1973-82. *Spinal Cord* 1996; **34**: 666-668 [PMID: 8918963]
44 **Jaspers P**, Peeraer L, Van Petegem W, Van der Perre G. The use of an advanced reciprocating gait orthosis by paraplegic individuals: a follow-up study. *Spinal Cord* 1997; **35**: 585-589 [PMID: 9300963]
45 **Massucci M**, Brunetti G, Piperno R, Betti L, Franceschini M. Walking with the advanced reciprocating gait orthosis (ARGO) in thoracic paraplegic patients: energy expenditure and cardiorespiratory performance. *Spinal Cord* 1998; **36**: 223-227 [PMID: 9589520]
46 **Kantor C**, Andrews BJ, Marsolais EB, Solomonow M, Lew RD, Ragnarsson KT. Report on a conference on motor prostheses for workplace mobility of paraplegic patients in North America. *Paraplegia* 1993; **31**: 439-456 [PMID: 8371935]
47 **Yozbatiran N**, Berliner J, O'Malley MK, Pehlivan AU, Kadivar Z, Boake C, Francisco GE. Robotic training and clinical assessment of upper extremity movements after spinal cord injury: a single case report. *J Rehabil Med* 2012; **44**: 186-188 [PMID: 22334347 DOI: 10.2340/16501977-0924]
48 **Schwartz I**, Sajina A, Neeb M, Fisher I, Katz-Luerer M, Meiner Z. Locomotor training using a robotic device in patients with subacute spinal cord injury. *Spinal Cord* 2011; **49**: 1062-1067 [PMID: 21625239 DOI: 10.1038/sc.2011.59]
49 **Stiens SA**, Kirshblum SC, Groah SL, McKinley WO, Gittler MS. Spinal cord injury medicine. 4. Optimal participation

in life after spinal cord injury: physical, psychosocial, and economic reintegration into the environment. *Arch Phys Med Rehabil* 2002; **83**: S72-81, S90-8 [PMID: 11973700]

50 **Baslo M**. Omurilik yaralanmalı hasta için konut ve çevre düzenlemeleri 'evrensel tasarım' (Housing and environmental regulations for spinal cord injured patients' universal design'). In: omurga ve omurilik yaralanmaları (spine and spinal cord injuries), editörler; Hancı M, Erhan B. İntertıp, 2013: 645-668

51 **Lee Y**, Mittelstaedt R. Impact of injury level and self-monitoring on free time boredom of people with spinal cord injury. *Disabil Rehabil* 2004; **26**: 1143-1149 [PMID: 15371027]

52 **Loy DP**, Dattilo J, Kleiber DA, Exploring the influence of leisure on adjustment: Development of the leisure and spinal cord injury adjustment model. *Leisure Scie* 2003; **25**: 231-255 [DOI: 10.1080/01490400306565]

53 **Youngstrom MJ**. The Occupational Therapy Practice Framework: the evolution of our professional language. *Am J Occup Ther* 2002; **56**: 607-608 [PMID: 12458854]

P- Reviewer: Zaminy A, Zhang M **S- Editor**: Wen LL
L- Editor: Roemmele A **E- Editor**: Wu HL

Published by **Baishideng Publishing Group Inc**
8226 Regency Drive, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com