Rehabilitation in Spinal Cord Injuries: An Introduction

Surgery does a limited job for the overall management of patients with spinal cord injuries. The fact that needs to be emphasized here is that it is the rehabilitation that sustains the patients for a long-term. Hence, a more pragmatic approach to different resources of rehabilitation should be considered.

Types of Spinal Cord Injuries

Spinal cord injuries could be either traumatic (accidents, falls, violence, diving, etc.) or nontraumatic (tumors, inflammations, vascular, etc.). Whether it is traumatic or nontraumatic, the final result often is the same as far as disability is concerned, and the rehabilitation processes are necessarily the same.

Loss of function

For rehabilitation, it is important to assess what happened at the time of injury and the extent and level of loss of function (Figure 1), whether it is:

- Below the level of injury.
- At the level of injury.
- Temporary loss of function above the level of injury.

This serves as a background to know what functionality to expect from what level and if there is no return of a particular functionality, what is the reason for it (if there is a local injury at that level which also needs to be addressed). This might have to be done through exercises or surgically in order to integrate different muscles together.

Expected levels of function

It is important to know the expected levels of function. For example, a person with tetraplegia with injury above the level of C5 is dependent upon others for activities such as feeding, dressing and bathing. He requires the availability of an attendant at all times. However, a powered wheelchair offers such a person independence in mobility in an accessible environment and independence in weight-shifting.

Similarly, when a patient has an injury at the C5–C6 level, a different kind of perception and expectation is observed in terms of functions. These persons have increased functional capacity, but still require physical assistance for activities such as dressing, bathing and transfers. A person with an injury at C7 level may be independent with the proper equipment in all of the above-discussed areas, requiring only some assistance with bowel management. Paraplegia is compatible with total independence at a wheelchair level. However, even these individuals may require the assistance of a homemaker.

Recovery

A majority of patients have some neurological recovery in the form of sensation and motor activity, but this often does not get converted to functional recovery and this does not have any useful functional outcome. Why the neurological recovery occurs and why it does not go on to become functional is something to ponder about? If ways and means can be developed to translate this neurological recovery into a functional recovery, then perhaps there would be an answer to effective rehabilitation programs also.

Recovery mechanisms following complete transections

The recovery mechanisms following complete transections begin from the recovery of the roots apart from the level of injury, and then the gray matter shows changes at the level of injury. There occurs reorganization of spinal circuits, which is a very important step.

This reorganization is always an attempt of nature to define some rules for exciting circuits and thus try to overcome and circumvent the damages that have occurred. Some axonal regeneration always happens over a few segments but this regeneration does not translate into proper circuitry being generated. One has to form or reteach these circuits to perform functions, and this is where rehabilitation has got a major role to play.

Completeness of injury

The completeness of injury is generally based on the American
Spinal Injury Association (ASIA) guideline. According to this guideline, total transection means complete absence of motor and sensory activity at levels below the injury including S2–S4 segments. Any activity below the injury, especially S2–S4, means incomplete lesion. The S2–S4 segment is generally not examined too closely. Any sensation at this level means that the patient has got some integrity and has all chances of recovering if properly rehabilitated.

**Importance of rehabilitation in SCI patients**

In case of SCI, rehabilitation is an aspect to deliberate about, to think about and to really work hard on. It has been misunderstood that rehabilitation often includes bladder and bowel training and managing bed sores. The role of surgeons does not end with surgery; rather, they have to ensure that the patient is provided with adequate rehabilitation.

Most patients with severe spinal injuries do not recover. They require support and assistance. They have to be integrated into the society and the role of the surgeon with regard to rehabilitation of these patients will be discussed here.

Rehabilitation has been defined by the World Health Organization as a progressive, dynamic, goal-oriented and often time-limited process, which enables an individual with impairment to identify and reach his/her optimal mental, physical, cognitive and social functional level.

### Table 1: Role of multiple specialties in the rehabilitation of SCI patients

- Nursing
- Physical therapy
- Occupational therapy
- Respiratory management
- Medical management
- Recreation and leisure psychology
- Vocational counseling
- Driver training
- Nutritional services
- Speech pathology
- Social worker
- Sexual health counseling
- Assistive device prescription
- Pharmaceutical service

Physical interventions (exercises or electrical) or pharmacological stimulations, which can help in enhancing neuroplasticity, are now being recognized. Further research in this area can be a stepping stone towards innovative ways of rehabilitation.

### Goals of Rehabilitation

The goals of rehabilitation are as follows:

- Rehabilitation continues with planning for discharge back to community and finally reintegration into the former or new roles and activities within the community.
- Family and peers have important roles throughout the rehabilitation process and must be initiated and integrated into this process planning.

### Types of rehabilitation

Rehabilitation can be classified into early or intermediate based on the timing.

**Early rehabilitation**

The rehabilitation does not have to wait for the person to be discharged home. It has to begin very early. A predischarge home visit for modification and community inclusion would definitely benefit the patients. Patients with viable phrenic nerves and adequate diaphragm and lung function can be freed from mechanical ventilation by the use of phrenic nerve pacers.

**Intermediate rehabilitation**

As part of intermediate rehabilitation, it is necessary to prevent life-threatening complications. For example, it is difficult to ascertain if anticoagulants should be given in case of thromboembolism in patients with spinal cord injury. These patients fail to express pain or tenderness and the breathlessness is often attributed to respiratory compromise. Pneumatic stockings, heparin, physical examination and weekly Dopplers might ensure that these life-threatening complications do not happen.

**Rehabilitation and recovery**

Does rehabilitation actually influence neurologic and functional recovery? Neuroplasticity is indeed influenced by neuronal inputs even if they come from areas that are supposedly denervated, that is below the level of injury.

Karl Lashley’s experiment: Rats were taught to negotiate a maze and then the cerebrum was removed in pieces until 90% was gone. The maze was still negotiated by the rats but for slight fall in the speed and accuracy.

From this, it can be hypothesized that every cell of the brain can store data of the whole brain while at the same time exposing a specific task.

It is important to evaluate if it is possible for spinal neurons to learn those tasks and to perform those tasks if a proper stimulus is provided, in accordance with the above-discussed hypothesis. This can be done when a pattern-generating spinal circuitry is developed. Certain study papers refer to a particular stimulus given to a particular part of the spinal cord and gives specific responses, e.g. lifting a finger. There are certain circuits which can be preprogrammed and a simple command to those circuits will produce specific actions. For example, slight electrical stimulation or stepping movement by a paraplegic on a treadmill might start an ambulatory or a stepping movement. If we can find out these circuitries and generators and tend to facilitate and stimulate them, rehabilitation processes will become much easier and efficacious.
Role of counseling

Psychological adjustment and life satisfaction are also important aspects, which have to be addressed. Psychological and psychiatric support and the use of antidepressants as and when required must be initiated without fail. The significance of counseling is that it can prevent depression and reduce the risk of death due to suicide. Peer counseling is also extremely important in this regard.

Education and employment

Persons with spinal cord injuries in many instances have to be educated and allowed to find suitable employment. Surprisingly, the average education level at 5 years following injury is below that of the general population, but by 10 and 15 years, it exceeds that average.

Different components of rehabilitation

Nutrition

Necessarily, nutrition has to be started very early. Early endoscopic gastrostomy has to be initiated to drive in nutrition as these patients tend to waste away rapidly and as a result it tends to become difficult to rehabilitate them. The nutritional requirements are definitely less than that of an ambulatory person. The requirements are fat <30%, carbohydrates 60% and the rest comprising of proteins. The bottom line is that the weight of the patient has to be preserved, otherwise he/she tends to waste and this would hinder the rehabilitation process.

Autonomic dysfunction

Autonomic dysreflexia has to be taken care of as and when it happens due to the associated problems like autonomic hyperreflexia (bladder/bowel distension), bradycardia with hypotension and asystole with autonomic stimulation like tracheal suction.

Bladder management

Although the patient ends up in self-catheterization or an indwelling catheter, there are certain things which are important in bladder management as discussed below.

- Voiding under low vesical pressures:
  - 40 cm of water.
  - Reflex voiding training.
  - Urethral stenting.
  - Sphincter disabling surgeries.
  - Drugs to reduce voiding pressures.
  - Drugs to reduce reflex intermittent contractions.
  - Bladder management by electrical stimulation.
  - Implanting ureters.
  - Yearly monitoring of the urinary tract.

Neurogenic bowel management

In case of neurogenic bowel management, it has to be assessed whether the patient has a lower motor dysfunction or an upper motor dysfunction and then treated accordingly.

- Lower motor dysfunction: Flaccid paralysis of the sphincter.
- Upper motor dysfunction: Increased sphincteric tone; reflexes allowing defecation may remain functional and can be exploited.

The various management aspects include:

- Diet and fluid management supported with medication to promote once a day or once every alternate day defecation.
- Timing of the defecation after meals to take advantage of gastrocolic reflex.
- Use of the Valsalva maneuver.
- Pulsed irrigation enhanced evacuation device.
- Electrical stimulation, as in the case of the urinary bladder.

Neuropathic pain and its management

Neuropathic pain is another area that needs to be managed. It is most often spontaneous hyperalgesia and may signify underlying unstable spine or a pain-causing organicity like renal stone (especially if the character of the pain changes). The patient needs to be reassured that the pain is neuropathic and does not mean any active disease and that activities need not be curtailed. In fact, increased activity often alleviates the neuropathic pain.

There is a hope for spinal cord injury patients suffering from neuropathic pain. In a first-ever trial on post spinal cord injury, it was established that pregabalin gave significant relief from pain, improvement in sleep disturbance and anxiety.

Spasticity and its reduction

Spasticity has both benefits and pitfalls. Its benefits are that it assists in mobility, especially in those with incomplete injuries. It can improve circulation and may be useful for decreasing the risk of deep vein thrombosis and osteoporosis. The pitfall is that it can interfere with positioning, mobility and hygiene, and spasms can be painful. The bedrock of treatment is the elimination of exacerbating factors and regular muscle stretching. Less invasive methods typically are employed before the more invasive methods. Interventions to reduce spasticity include:

- Prevention and treatment of noxious stimuli, such as pressure ulcers, urinary tract infections or an ingrown toe nail.
- Regular muscle stretching and joint ROM.
- Oral medications.
- Botulinum toxin injection (useful for treatment of problems caused by specific muscle groups).
- Intrathecal baclofen delivered by an implanted pump (involved effective and nondestructive treatment).
- Peripheral procedures, including neurolysis and contracture release.
- Central ablative procedures, such as rhizotomy and myelotomy.

Management of heterotrophic bone formation

Heterotrophic bone formation can severely limit the range of movement. This is very important in rehabilitation since this area is often neglected. This especially occurs in the same joint in a person in bed for prolonged period of time. Although the person would have recovered sufficiently, movement is grossly restricted. This can be combated by the following modes: (1) Use of NSAIDs like indomethacin; (2) Use of drugs like etidronate (20 mg/kg/day PO for 2 weeks, followed by 10 mg/kg/day for at least 10 weeks); (3) Low-dose radiations; (4) In cases with no improvement, surgical correction of motion segment followed by medications or radiations.

Functional neuromuscular stimulation

Axonal sensorimotor neurostimulation is of great interest. Electrical stimulation of intact peripheral nerves can bring about contraction in muscles paralyzed by upper motor neuron injury. This can be done by transcutaneous, percutaneous or implanted electrodes. Such stimulation can be useful for both exercise and...
function. Functional neuromuscular stimulation (FNS) can be used in the upper extremity to provide lateral pinch and palmar grasp to persons with, for example, C5 and C6 tetraplegia. A total implantable system is available with control by the position of the contralateral shoulder. Upper extremity FNS is often combined with tendon transfer surgery. In the lower extremity, patterned lower extremity FNS by external electrodes can allow a stationary bicycle exercise program, with beneficial cardiopulmonary, soft-tissue and psychological effects. As with the general population, benefits are obtained only with the patient’s commitment to the exercise regimen. Functional neuromuscular stimulation combined with lower extremity orthoses and a walker can allow gait. This is controlled by switches placed on the walker. The performance of such a system is not sufficient to substitute for a wheelchair, but it can be useful for specific limited mobility.

*Upper extremity reconstructive surgery*

Tendon transfer surgery offers the opportunity to utilize an innervated but nonessential muscle to rehabilitation for spinal cord injured patients - looking beyond bladder, bowel and bed sores 04 30 provide a lost function. Usually, such surgery is not considered until a year following surgery. A person with a spinal injury level C5 may have a good shoulder control and strong elbow flexion. There will be no active elbow extension, making overhead activity impossible. Such a person may benefit from a transfer procedure to the triceps tendon. One of the muscles available for transfer is the posterior deltoid. A person with an injury level of C6 may lack effective lateral pinch and may benefit from transfer of a muscle (e.g. brachioradialis) to the tendon of the flexor pollicis longus. There are also other procedures available to provide active finger flexion and extension.

*Robotics in rehabilitation*

Robotics plays an important role in rehabilitation. These robots tend to differ from the mechanical or the industrial robots in many ways:

- The payload of the robot will be in the lower range (typically <5 kg).
- The payload/weight ratio must be far higher than the robots that are available to date. This is because lower payload would facilitate swift movement and also facilitate quick set up at new work places.
- Lower accuracy is allowable if the resolution in the motion control is the same as today’s industrial robots.
- Compared to industrial robots, a larger workspace and more flexible configuration will be needed.
- The life duty cycle will be lower for assisting robots than industrial robots.
- Compared to heavy-duty industrial robots, the acceleration and velocity performance can be lower.
- Above all, the design should allow for low-cost production.

Since the payload of the robot will be in a lower range, the payload-weight ratio must be far higher. Lower accuracies are liable if the resolution in the motion control is the same. Live duty cycle will be low for assisting robots than industrial robots. Sensors to guide the robot will increase the performance related to normal tasks, which is an important aspect as far as robotic designs are now concerned. Any task, such as grasping, reading books, turning pages, inserting a CD, all are sensor-based recognition. This is because it is very difficult for a disabled person to maneuver a robot completely.

The Robots for Assisting the Integration of Disabled (RAID) workstation allows the users to perform the following:

- Move books from the book shelf to a reader board and back again.
- Turn single and multiple pages in books.
- Move paper sheets between a printer, the reader board and storage compartments.
- Turn single and multiple pages in a pile of paper sheets.
- Discard documents.
- Staple documents.
- Insert floppy disks.
- Insert CD-ROMs.
- Drink with a straw.

There are a lot of difficulties in designing a rehabilitation robot owing to the end-user operational needs and limitations. A basic goal in rehabilitation robotics is to make the robots perform a single task only once, unlike the industrial robots that are programmed to perform multiple tasks. In contrast to industrial robots, rehabilitation robots should be designed for unskilled operators.

Most of the tasks in rehabilitation robotics are unique in that most of the motions cannot be preprogrammed (such as picking up a newspaper). It is necessary to use sensors to guide the robots and increase their performance in autonomous tasks and interface devices to program and control the robot arm. The reason is that direct control of the robot arm demands a high cognitive load on the uses and physically challenged persons may have difficulties operating joysticks or push buttons in delicate movements. Thus, there is an obvious need for a certain degree of autonomy of the robotic system such as automatic grasping after sensor-based recognition.

The RAID project is one of the first important project as far as rehabilitation robotic designs are concerned. The robotic system is being developed to allow any input devices to connect to the standard set of devices such as keyboard emulation, mouse emulation and serial communication through RS-232/422 interface. Moreover, severely disabled people need individual adaptations.

The joystick used to control the electrical wheelchair is interfaced with the control language of the robot and mouse control function on the PC computer. For most of the users this is a good solution, as most of them can control the wheelchair with the same control device.

**Walky mobile**

The walky mobile is another kind of robotics that can be considered as a part of robotic rehabilitation. The walky mobile can help a person move around. The software for this walky mobile can use with a wireless modem with phonetic devices, which can give commands. Rhythmic movement interactions are devices for a person who has got some functionality left and also these devices help integrate or smoothen off the motion in a person who is otherwise spastic or flaccid.

Different robots and different types were developed by the European consortium. Following intense research and development, the humanoid robot was introduced. Here, a person can be integrated inside this robot and all functionalities can be performed. In fact, it was also suggested that a flail limb (lower limb with limitations) can be amputated and use the humanoid robot for performing various tasks.

However, not everyone would accept this, as there is a lot
hope for rehabilitation and would not want to lose their limb permanently. Robot-assisted arm prototypes are available. Similarly, exercising robots are now available, which can facilitate different types of recoveries.

*Speaking valves*

The speaking valve facilitates communication in a person undergoing permanent tracheostomy. Different types of valves are available, which can again be connected, and enable the person to speak. Ultimately, a tetraplegic can achieve a lot of things. They can communicate verbally, they can write using mouthsticks. They can use computers through mouthsticks or pneumatic switches or even verbal commands. This approach would allow them to integrate themselves with the environment. This is how these patients can be rehabilitated rather than leaving them to their fate with providing any help.

*Sexual functioning*

Sexual functions for men can be facilitated. Reflex erection can be achieved. Oral drugs like phosphodiesterase type 5 inhibitors and viagra can be used. Medicated urethral system erection (MUSE) systems, penile injections, vacuum pumps and permanent prosthesis can be used. However, fertility remains a problem, because anterograde ejaculation with sperms is often a problem.

The common sexual problems identified in females include lack of vaginal sensations, lack of muscular tone, lack vaginal secretions. Also in females, the sexual functions can be facilitated by a number of ways that are now available and as structured programs. Fertility is not a problem. Irrespective of the level of injury or dysfunction, women with spinal cord injuries can have children, share the same parental responsibilities. However, it is up to them to consider their physical, emotional and financial status before considering a pregnancy. If they do not want to get pregnant, then it is up to them to use adequate birth control measures.

*Endocrinology and osteoporosis*

Another important problem that has to be addressed is the endocrinology and osteoporosis right from early stages of rehabilitation. Care has to be taken to prevent bone loss. Supplementation with drugs like alendronate should begin from the 10th day post injury.

**Conclusion**

While research pursues the goals of preventing and reversing neurological deficits, work must continue to remove barriers impeding the return of person with spinal cord injuries to achieve active roles in the community through efficient rehabilitation programs.

**References**