Neurorehabilitation in Neurosurgery

Taslim Uddin and Forhad H. Chowdhury

Abstract: Neurorehabilitation is an important pillar in the management of neurosurgical patients. Neurorehabilitation is an integrated interdisciplinary care program including a set of interventions to help people with disabilities to acquire and maintain optimal functioning in their environment, permitting them to attain maximum independence and social reintegration. This chapter is an abstract of the rehabilitation approach to neurosurgical conditions, including trauma (to the brain, spine, and nerves), stroke, and tumor, and post-surgical care.

Abbreviations

ADLs	activities of daily living	ASIA	American Spinal Injury Association
CIMT	constraint-induced movement therapy	EMG	Electromyography
FES	functional electric stimulation	ICH	intracranial hematoma
ICF	International Classification of Functioning, Disability, And Health	ICU	intensive care unit
MS	multiple sclerosis	MRI	magnetic resonance imaging
NMES	neuromuscular electric stimulation	OT	occupational therapy
OPD	outpatient department	PET	positron emitting tomography
PMR	physical medicine and rehabilitation	PT	Physiotherapist
SAH	subarachnoid hemorrhage	SCI	spinal cord injury
SDH	subdural hematoma	SLT	speech and language therapist
tPA	tissue plasminogen activator	TBI	traumatic brain injury
WHO	World Health Organization		

1. Introduction and Concepts

Neurorehabilitation is the provision of an integrated interdisciplinary care program that includes a set of interventions to help people with disabilities to acquire and maintain optimal functioning in their environment, allowing them to attain maximum independence and social reintegration (Australian Rehabilitation Alliance 2011). This chapter is dedicated to the rehabilitation approach to neurosurgical conditions, include trauma (to the brain, spine, and nerves), stroke, and tumor, and post-surgical care.

The International Classification of Functioning, Disability, and Health (ICF) is a framework for categorizing and organizing data on functioning and disability developed by the World Health Organization (WHO). It set up a common vocabulary and conceptual structure for defining and measuring disability and health. The purpose of a neurosurgical rehabilitation program is to assist each patient in regaining the best level of independence, function, and quality of life possible. Body structures, body function, activities, and participation are all referred to as "functioning". It refers to the positive or negative features of the relationship between a person's health condition(s) and their surrounding circumstances (environmental and personal factors). Activity limits, impairments, and participation restrictions all fall under the umbrella term "disability". It refers to the unpleasant features of the interaction between a person's health condition(s) and their surrounding circumstances (environmental and personal factors) (www.wcpt.org).

Modern rehabilitation exercises are founded on the concepts of disability, impairment, and handicap, as mentioned by the WHO, which have recently been redefined as "impairment", "activity" and "participation". Rehabilitation is a functional method that consists of four fundamental components: (1) lowering disability; (2) learning new abilities and applying them to reduce the impact of impairment; (3) acquiring new skills and applying them to reduce the impact of disability; and (4) changing the environment surrounding physical and socioeconomic circumstances so that people with disabilities can participate as much as possible.

Symptoms such as muscular weakness, paralysis, poor coordination, and lack of feeling, as well as seizures, disorientation, pain, and altered degrees of consciousness (Sandberg et al. 2009), can be caused by biochemical, structural, or electrical irregularities in the spinal cord, brain, or nerves leading to or from them. Stroke, intracranial hemorrhage (ICH), subdural hematoma (SDH), brain tumor, aneurysm, Parkinson's disease, multiple sclerosis

(MS), spinal cord injury (SCI), traumatic brain injury (TBI), and other neurological conditions such as spinal disc herniation and peripheral nerve injuries can all benefit from neurorehabilitation (Kaldis and Desai 2015).

Many of the neurological and neurosurgical patients may have short-term or long-term functional disability in relation to activities of daily living (ADLs). Rehabilitation interventions proved beneficial in a number of studies including low-income resource settings and patients with stroke, SCI, TBI, brain tumor, spinal disc prolapse, or peripheral nerve injuries (Uddin et al. 2019b; Al Hasan et al. 2009; Lee et al. 2019; Uddin et al. 2019a).

The usual approach involves a multidisciplinary rehabilitation team guided by a physical medicine rehabilitation physician (also commonly known as physiatrist), a neurosurgeon, and a number of rehab professionals. Box 1 explains the rehabilitation team for neurosurgical conditions; however, this number is not limited and other members—like a pressure ulcer dressing specialist, recreation therapist, or vocational therapist— may need to be included as per requirements in special cases, depending on the nature and length of the rehabilitation process.

Box 1. Rehabilitation Modalities. Source: Box by authors.

Rehabilitation modalities include the following:

(a) Pathological basis of diagnosis and evaluation of disability for rehabilitation;
(b) Mobility, pain, spasticity, cognitive function improving medications, and physical modalities;
(c) Nutrition;
(d) Proper positioning at bed and at mobility;
(e) Heat and cold modalities;
(f) Neuromuscular electric stimulation (NMES);
(g) Assistive technology (AT);
(h) Mobility aids and assistive devices;
(i) Functional electric stimulation (FES), e.g., breathing pacemaker;
(j) EMG biofeedback;
(k) Behavioral, cognitive, and communication therapy.

In a recent review paper on emerging therapies, the following principles were used to produce an enhanced functional state: redistribution of leftover control, augmentation using artificial control, and regeneration. Peripheral nervous system "rewiring"; neuromodulation via spinal epidural excitation and brain stimulation (DBS); external robotics to substitute for a deficiency in motor control; brain–computer interfaces to promote control, when very little remaining control persists; and biological therapies involving stem cells, aiding in the recovery of previously unrecoverable injuries, are examples of such interventions (Iaccarino et al. 2015; Wilson et al. 2013). Patients with spinal cord damage, stroke, cerebral palsy, traumatic brain injury (TBI), brachial plexus injury, severe dystonia, spina bifida, and a variety of other disorders and injuries may benefit from such therapies. This chapter emphasizes several operations, processes, and therapies that represent major modalities of restorative functional and reconstructive neurosurgery, as well as contemporary technology breakthroughs, discoveries, and implementations. Rehabilitation techniques vary and are provided depending on a case-by-case disability assessment, as determined during a patient-centered rehabilitation team meeting.

Providing a detailed description and case-based analysis of disability assessment and rehabilitation protocols is beyond the scope of this current topic; however, an attempt will be made to briefly describe the rehabilitation perspectives of some common neurosurgery-related problems. Readers may refer to physical medicine rehabilitation (PMR) text books for further knowledge (Frontera et al. 2019).

2. Spinal Cord Injury (SCI)

Trauma, malignancies, vascular abnormalities, viral diseases, and developmental disorders are all causes of SCI. SCI is linked to a wide range of functional impairments, with motor deficits being a typical and persistent presenting feature that has an impact on a variety of health-related difficulties, as well as other functional issues and ADLs. Tetraparesis (47.2%) is the commonest neurologic condition, followed by paraparesis (20.4%), total paraplegia (20.2%), and total tetraplegia (11.5%) (Frontera et al. 2019).

The International Standards for Neurological and Functional Classification of Spinal Cord Injury is a widely recognized system for describing the extent and level of injury based on a thorough sensory and motor examination of neurological function (Hakkinen et al. 2005; Johansson et al. 2009; American Spinal Injury Association 1992). The word "tetraplegia" has replaced "quadriplegia" to describe spinal cord injury to the cervical area. The American Spinal Injury Association (ASIA) Impairment Scale in Table 1 describes the severity of an injury. It is a variation of the Frankel Classification that does not utilize the phrases "paraparesis" or "quadraparesis". This scale assigns a letter grade to individuals ranging from "A" for complete recovery to "E" for full recovery (Frontera et al. 2019).

Table 1. American Spinal Injury Association (ASIA) Impairment Scale.

ASIA Scale	Description
A	Complete: no motor or sensory function is preserved in the sacral segments S4–S5.
B	Incomplete: sensory but not motor function is preserved below the neurologic level and extends through the sacral segments S4–S5.
C	Incomplete: motor function is intact below the neurologic level, and most of the key muscles below the neurologic level have a muscle power grade less than 3.
D	Incomplete: motor function is intact below the neurologic level, and the majority of key muscles below the neurologic level have a muscle power grade greater than or equal to 3.
E	Normal: motor and sensory function is normal.

Source: Authors' compilation based on data from American Spinal Injury American Spinal Injury Association (1992).

The definition of incomplete and complete SCI is now dependent on the sacral-sparing definition.

Muscles are graded on a scale of 0–5. A grade 3/5 muscle is considered to have intact innervation if the next most rostral muscle has 4/5 strength. Key muscles are considered for C5 through T1, as well as L2 through S1, in Box 2.

Box 2. Key muscles for SCI patients. Source: Box by authors.

C5: Flexors of elbow (brachialis and biceps)
C6: Extensors of wrist (extensor carpi radialis brevis and longus)
C7: Extensors of elbow (triceps)
C8: Flexors of finger (flexor digitorum profundus) to the middle finger
T1: Abductors of small finger (abductor digiti minimi)
L2: Flexors of hip (iliopsoas)
L3: Extensors of knee (quadriceps)
L4: Dorsi flexors of ankle (tibialis anterior)
L5: Long toe extensors (extensor hallucis longus)
S1: Ankle plantar flexors (gastrocnemius, soleus)

The objectives of care for a patient with SCI include a comprehensive continuum of care from the point of injury to the acute care hospital, resuscitation and specialist rehabilitation medical and surgical care (depending on the case), multidisciplinary inpatient rehabilitation care, and step-down and pre-home care to community and vocational care services.

'Time is Spine,' as shown in Figure 1, is a crucial idea that emphasizes the relationship between the time period of damage and pathophysiological changes, as well as the significance of targeted therapies during the acute injury phase to improve long-term results. While there is no cure for the neurological sequelae of SCI, numerous novel therapies are now being tried in clinical trials and have shown promise in improving long-term functional recovery.

Model rehabilitation care has been shown to be effective, and people with SCI typically demonstrate considerable spontaneous motor and sensory improvement in the first 3–6 months after injury, although substantial spontaneous improvement beyond the first year is uncommon, and only about 1% of people with SCI have full neurologic healing at discharge from the hospital.

Concerns over sexual and bowel–bladder functions are also prevalent in SCI patients requiring continuous monitoring by the caring rehabilitation team either during the hospital stay or when back in the community.

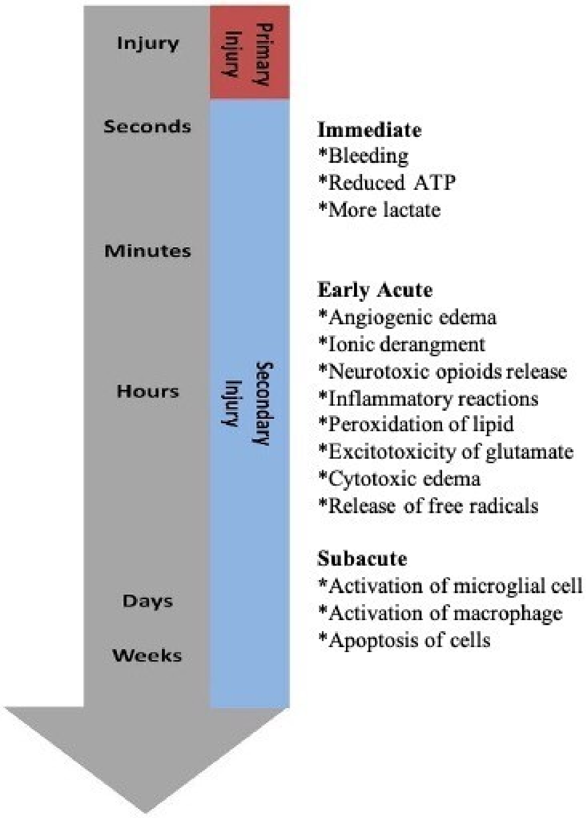

Figure 1. Time is Spine. There are two types of spinal cord injuries: primary and secondary. The first physical injury sets off a chain reaction of subsequent biochemical damage that lasts during the immediate, early acute, and subacute stage. Source: Authors' compilation based on data from Wilson et al. (2013).

3. Spinal Canal Stenosis and Disc Surgery

Low back pain has a high lifetime incidence, and it limits functional activities, resulting in increased health-care consumption and leading to disability and job loss. With the surge in surgical procedures for these disorders, diagnoses of spinal stenosis and disc prolapse are on the rise. Discectomy for intervertebral disc prolapse has greater success rates, ranging from 65–90%, but residual back and leg discomfort, as well as recurrent herniation, remain the most common postoperative problems in lumbar disc surgery, necessitating the attention of a rehabilitation physician. Only 35% of operating surgeons gave written postoperative instructions; referral to rehabilitation therapy was minimal, and 18% of operating surgeons recommended the utilization of a lumbar corset after surgery, with others prohibiting sitting or promoting bed rest. According to research, an intensive postoperative exercise program consisting of stretching and stabilizing exercises, graded behavioral activities, and neuromuscular training with thermotherapy modalities resulted in a faster return to work (Hakkinen et al. 2005).

There are differences in the intensity and type of rehabilitation prescribed for disc surgery patients, including in difficult cases such as failed back surgery syndrome. A graded exercise regime with supporting education given to patients in the postoperative period has proven effective (Johansson et al. 2009).

4. Traumatic Brain Injury (TBI)

TBI is a prominent cause of seizure disorders, disability, and mortality around the world; however, rehabilitation facilities are in short supply. TBI has a wide range of severities, ranging from concussion to a permanent vegetative states, with mild, moderate, and severe classifications. Acute care rehabilitation concentrates on coma emergence and recovery prognosis, with rehabilitation therapy beginning from the first day after trauma and ranging from the ICU through community care. A description of the comprehensive multidisciplinary rehabilitation team involved in a TBI patient's care for assessment of post-traumatic amnesia and pain management is provided in Box 3.

Box 3. Comprehensive multidisciplinary rehabilitation team involved in TBI patient's care. Source: Authors' compilation based on data from Lee et al. (2019).

1. The patient and family members/care giver;
2. Physical medicine rehabilitation physician;
3. Other medical specialties: neurosurgery, orthopedic surgery, and urology;
4. Allied health care professionals and skilled personals: rehabilitation nurse (RN), physiotherapist (PT), occupational therapists (OT), prosthetics and orthotics (P&O), medical social worker, nutritionist, clinical psychologist, speech and language therapist (SLT), and rehab case manager.

Therapeutic modalities are described in Box 1. Exercise, including pharmacologic therapy, can target long-term cognitive and motor effects. Individualized specific rehabilitation protocols prescribed by the physical medicine rehabilitation physician for these patients are discussed in Box 4. They are instituted at three levels of treatment: (a) inpatient, (b) OPD, and (c) home- and community-based facilities. Heterotopic ossification, dystonia, agitation, and spasticity are some of the functionally limiting and therapy-impeding complications of severe TBI.

Box 4. Prescription of rehabilitation protocols in TBI patients. Source: Authors' compilation based on data from Lee et al. (2019).

- Health education and training of the caregiver for pressure ulcer prevention, understanding of the complications, and time-demanding rehabilitation protocols;
- Prescription of neuropharmacological medications and agents;
- Nutritional attainment;
- Cognitive rehabilitation therapy;
- Pain management;
- Management of contractures: serial casting, splinting, and orthotic prescription;
- Cognitive rehabilitation therapy;
- Bowel and bladder management;
- Spasticity management: phenol blocks, botulinum toxin, baclofen pump, and use of pharmacological and non-pharmacological agents;
- Comprehensive dysphagia and communication management;
- Brain stimulation therapy;
- Rehabilitation robotic therapy.

Most patients recover swiftly from mild TBI; however, education about recurrent exposure is crucial, as the sequelae of many injuries can be devastating. Moreover, sleep disturbances, migraines, visuospatial impairments, and cognitive dysfunction are all dealt with throughout therapy (Lee et al. 2019).

5. Rehabilitation of Stroke Patients

Stroke is the absence of neurological function due to an abrupt interruption of relatively constant blood supply to the brain. It is the world's second major cause of death. Ischemic and hemorrhagic strokes are the two main types of strokes. Ischemic strokes are produced by a disruption in the brain's blood flow, whereas hemorrhagic strokes are caused by a blood vessel rupture or an aberrant vascular structure. Acute ischemic strokes constitute 87% of strokes and subarachnoid hemorrhages (SAHs) account for 3%, which is important information in neurosurgery (Kicielinski and Ogilvy 2019). The need for integrated stroke care grows as the load of stroke pathology grows and treatment choices develop.

In medically neglected, lower-income areas around the world, the rates of mortality and disability from stroke are at least 10 times higher than in the most industrialized nations. When compared to Primary Stroke Centers, Comprehensive Stroke Centers showed faster tPA administration and a higher rate of mechanical thrombectomy.

Acute stroke care is quickly changing, and rehabilitation physicians and neurosurgeons are still vital members of the care team.

The rehabilitation team, led by the rehabilitation medicine physician, assess the functional disability status, socioeconomic backgrounds, and comorbidities (usually in association with the neurophysician or neurosurgeon) from the first day of hospital care. A large team, comprising the patient and their family and friends, rehabilitation physicians, other caregivers, occupational and physical therapists, speech–language pathologists, nurses, psychologists, recreation therapists, nutritionists, social workers, and others, is required for stroke rehabilitation. The team set the goal of care either as an intensive phase of inpatient care or OPD/day care. The traditional model of rehabilitation still remains the gold standard of care and includes proper bed positioning, nutritional aspects including dysphagia management, bowel–bladder care, chest–limbs physiotherapy, spasticity, speech therapy, and mobility. Constraint-induced movement therapy (CIMT) and robotics are two potentially useful therapeutic approaches for arm motor rehabilitation. High-intensity therapy, fitness training, and repetitive-task training are all promising strategies for improving the components of gait. The prescription of proper assistive devices for mobility, transcranial magnetic stimulation, programs for cognitive therapy, and functional electrical stimulation are the other rehabilitation programs offered to stroke patients (Dionísio et al. 2018).

The Lokomat robotic assistive device offers novel gait training options in stroke therapy while removing the physical therapist's need to perform long, repetitive movements in an unnatural position. Repeated assessments of the stroke patient, as well as communication and coordination among team members, are critical to improve the efficiency and effectiveness of stroke rehabilitation.

6. Rehabilitation of Patients with Brain Tumor

Brain tumors can be classified into two general groups: primary and secondary. The most common primary brain tumors are gliomas, which include astrocytoma, oligodendroglioma, and ependymoma. Some other mostly benign types are also described, e.g., meningiomas, schwannomas, craniopharyngiomas, etc. Secondary brain tumors are usually metastatic. Magnetic resonance imaging (MRI), intraoperative MRI, computed tomography (CT), magnetic resonance spectroscopy, and positron emission tomography (PET) are some of the advanced imaging techniques used in diagnosis. Surgery, radiation, and/or chemotherapy are commonly used to treat brain tumors, whether they are metastatic or primary, benign or malignant (AANS 2024).

The goal of the operating neurosurgeon is to remove as much tumor as feasible while avoiding damaging brain tissue that is critical to the patient's neurological function (such as the capability to walk and speak; cognitive function; etc.). Common surgical complications include prolong hospital stays, pneumonia, and venous thrombosis, giving rise to deconditioning of the musculoskeletal and cardiorespiratory system, requiring attention from the physical medicine rehabilitation physician and rehabilitation team assessment as a long-term patient (De la Garza-Ramos et al. 2016). The rehabilitation approach is focused on the identification of a specific problem and the prescription of an individualized institute- or home-based rehabilitation protocol. The basic guidelines are discussed above in **??** 2–4. Interested readers may consult physical medicine rehabilitation text books and advanced webpages for further information (Frontera et al. 2019; John Hopkins Medicine n.d.).

7. Conclusions

Ultimately, the outcome of a neurosurgical patient depends on many factors and neurorehabilitation is one of the most important factors. Any patient with neurosurgical intervention needs proper postoperative neurorehabilitative care, otherwise it may not produce any benefit to the patient.

Author Contributions: Conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, T.U.; writing—review and editing, visualization, supervision, F.H.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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