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Chapter

Post-Stroke Rehabilitation: A Necessary Step

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Abstract

A stroke is defined by the abrupt and sudden onset of neurological signs and symptoms that occur due to a disorder in cerebral blood circulation. Cerebrovascular diseases are a well-known cause of morbidity and mortality, being the second cause of mortality and disability throughout the world. Stroke treatment has improved substantially in recent years with the implementation of stroke units and revascularization therapies. The role of rehabilitation is to help improve deficits to regain functionality and to define the needs and care in patients with permanent disabilities. Stroke rehabilitation must start early and intensively and it must be carried out by a multidisciplinary team made up of neurologists, rehabilitation doctors, nurses, physiotherapists, occupational therapists, speech therapists, neuropsychologists, neurophysiologists, and social workers. Patients and families should be actively involved with this team, if possible, from the beginning and throughout the rehabilitation process. Functional recovery through comprehensive rehabilitation allows patients to remain in their usual environment, perform their work duties and carry out activities of daily life by themselves, reducing the need for institutionalization in long-term care facilities.

Keywords: stroke, rehabilitation, disability, skills, recovery

1. Introduction

A stroke is defined by the abrupt and sudden onset of neurological signs and symptoms that occur due to a disorder in cerebral blood circulation. It can be due to an excess of blood in the cranial cavity, which is in expansible, called hemorrhagic stroke; or due to insufficient blood supply of oxygen and nutrients to the parenchyma: an ischemic stroke. Strokes usually have symptoms related to a focal brain lesion, an abrupt onset followed by stabilization with a tendency to regress, and predisposing risk factors.

We should suspect it when the following symptoms suddenly appear: weakness or numbness of a half body; difficulty speaking or understanding language; vision difficulty in one or both eyes having ruled out ophthalmological pathology, vertigo, or instability associated with other neurological symptoms or signs.
Cerebrovascular diseases are the second cause of morbidity and mortality in the world [1].

There is an estimated prevalence of about 80 million people with stroke worldwide. In 2016, of the 80.1 million affected, 41.1 were women and 39 were men [1].

The highest risk of stroke is found in populations in East Asia, Central Europe, and Eastern Europe. In terms of race, the incidence per 100,000 inhabitants of ischemic stroke is higher in black than in Hispanic, and higher in Hispanic than in white; being all the etiologies of stroke more frequent in black, except cardioembolic [2, 3].

In the last 30 years, a decrease in the incidence and mortality from stroke has been observed due to the better control of vascular risk factors, health education, and advances in the treatment of the acute phase of stroke. This improvement, unfortunately, is not universal and is highly influenced by the economic situation and the educational background of the population in each geographic area. In recent years, a decrease in the incidence of stroke has been observed in whites, remaining constant in blacks [4].

Hand in hand with the global decrease in incidence and mortality rates is the increase in the prevalence of stroke and its social health impact, due to a longer life expectancy and increased survival rate of patients suffering from cerebrovascular events.

Stroke patients have a high risk of poor prognosis during the first year after the event, including rehospitalization (33%), recurrence (7–13%), dementia (7–23%), mild cognitive disorder (35–47%), depression (30–50%) and fatigue (35–92%), all contributing to affect health-related quality of life [5, 6].

Stroke units and revascularization therapies have changed the stroke prognosis [7]. The role of rehabilitation is to help improve deficits, regain functionality and define the needs and care in patients with permanent disabilities. Disability in stroke varies according to the initial severity, the location of the injury, the patient’s pre-morbid state, the degree of neurological recovery, and the support system that surrounds the patient [7, 8].

It is evidenced that comprehensive rehabilitation after stroke has a prognostic impact that is maintained in the long term, in the form of a better functional situation for the patients who access it. Functional recovery through comprehensive rehabilitation allows patients to remain in their usual environment, perform their work duties and carry out activities of daily life autonomously, reducing the need for institutionalization in long-term care facilities [9].

The recommendations of the King’s College research team, in collaboration with the European Alliance Against Stroke, which presented the document “The impact of stroke in Europe to the European Parliament”, indicate that multidisciplinary evaluations should be carried out in the stroke unit and the rehabilitation should start as soon as the patient is medically stable. People who start rehabilitation within the first week after admission have better long-term results than those who start their rehabilitation later [10].

2. Stroke rehabilitation

2.1 Pathophysiology and principles of neurological rehabilitation

The cells of the nervous system and the endothelial cells are continuously interacting with each other and with the extracellular matrix in order to maintain continuous cerebral homeostasis, forming a functional unit called the neurovascular unit. It is made up of neurons, interneurons, astrocytes, basal lamina lined with smooth
muscle cells and pericytes, endothelial cells, and an extracellular matrix [11]. All these elements, interconnected with each other, constitute a highly efficient system for regulating cerebral blood flow [11]. Cerebrovascular events alter the correct molecular communication between each of the elements of the neurovascular unit, generating a functional dysregulation that leads to the damage of the tissue. In the functional recovery phase after an ischemic stroke, compensatory neurovascular signaling at this level favors the repair mechanisms that involve angiogenesis and neurogenesis, thus intervening in achieving the most complete functional recovery possible [12].

Astrocytes play a fundamental role in cerebrovascular events, both in the establishment of the definitive lesion and in the process of tissue repair. During ischemia, the first morphological change observed is the edema of astrocytes, being one of the responsible factors for the decrease in glutamate reuptake. The edema may be surrounding the lesion up to 8 weeks after the stroke, which may alter the functioning of nearby neurons by blocking neuronal conduction [10].

Glial cells that survive the ischemic episode undergo a process of hypertrophy and proliferation, known as reactive gliosis, which has been related to mechanisms of neuroprotection and repair of ischemic injuries [13].

Recovery after stroke is associated with cortical reorganization [8]. After a cerebrovascular event, the tissue recovery that takes place during weeks, months, or years after the acute event is related to different physiological phenomena: dendritic growth, formation of new synapses (synaptogenesis), functional reorganization in the injured area or participation of other neighboring or homologous areas of the contralateral hemisphere in the process. These phenomena can occur spontaneously and they can be facilitated and directed by rehabilitative therapeutic interventions [13].

In ischemic stroke, the obstruction of a cerebral artery generates local changes in cerebral blood flow (CBF). Under normal conditions, CBF through adult brain tissue is >50 ml/100 g of brain parenchyma/minute. When the CBF is reduced in a certain area of the brain below 10 ml/100 g/min, a severe cerebral dysfunction is produced. This leads to a complete neuronal, structural and functional loss in that location in a short time; it is called the core of the infarction. Between this nucleus of ischemic infarction and the normally perfused brain parenchyma, there is a moderately vascularized region, the extent of which depends on the functioning of the collateral circulation, called the penumbra zone, in which two zones with different prognosis are differentiated: oligohemia zone (22–0 ml/100 g/min) and ischemic penumbra zone (10–22 ml/100 g/min) [14, 15]. The oligohemia zone is a hypoperfused zone that still maintains its functionality, while the ischemic penumbra is a hypoperfused and functionally inactive zone that limits the edges of the infarcted area but is still viable if CBF is recovered early [11]. Current strategies for acute reperfusion in ischemic stroke are aimed at restoring cerebral perfusion in the ischemic penumbra [11]. The therapeutic window in ischemic stroke is the time that elapses between the onset of ischemia and the moment in which the neuron located in the ischemic penumbra loses its ability to survive. After this time, reperfusion of the ischemic zone will be useless [13].

The tissue that survives a cerebrovascular event has the ability to adapt and reorganize itself anatomically and functionally to rebuild or replace synaptic connections that have been injured and reinforce neural networks that have remained after injury. This phenomenon is known as neuroplasticity [15], and neurological rehabilitation therapies play a fundamental role in its enhancement [16]. The key to activating neuronal plasticity is the repetition of the affected function, so all those treatment techniques that favor the performance of a function and its repetition will promote brain plasticity and the recovery of patients [9, 10].
The functional reassignment of the different healthy cortical areas to supply the deficit in the damaged area is called brain remapping [12].

The neuroanatomical, neurochemical, and functional changes that occur during the reorganization by neuroplasticity will facilitate, in some cases, the recovery of the affected functions (adaptive neuroplasticity). On other occasions, as a consequence of this reorganization in favor of some functions, the development of others may be hindered (maladaptive neuroplasticity) [17].

The most important cortical functions are not linked to specific anatomical regions, but rather depend on neural networks made up of neurons of diverse cortical locations interconnected with each other and distributed throughout the cerebral cortex [15, 18].

Although some functions of a neural network are specifically ascribed to a region of the same (e.g.: the execution of language to Broca’s area), the lesion in that specific area may have little clinical translation if the remaining structures that makeup that network take over functional relief and thus compensate for the defect.

If the damage to a functional system is partial, recovery within the system itself is possible. On the other hand, if the damage is complete, replacement by a functionally related system is the only alternative for the functional recovery of the injured area. Each of the mechanisms involved in the post-injury functional recovery process will depend on the magnitude of the brain damage [16].

Although the basic mechanisms of neuroplasticity are common to the entire cerebral cortex, the pattern of cortical reorganization in the functional recovery of the different capacities is not the same, and the peculiarities in these patterns support the different modalities of therapeutic intervention for the different deficits: motor, sensory and cognitive (Table 1) [17, 19].

Motor recovery is a complex process that combines intrinsic or spontaneous neurological recovery and functional recovery. Intrinsic neurological recovery is the recovery of normal movement patterns, being the severity of the initial deficit inversely proportional to the recovery prognosis. It occurs generally within the first 1–3 months after the event. Functional recovery is the regaining of basic tasks or activities of daily life through learned compensatory movements (new movement patterns), which depends on motivation, learning capacity, family support, and the quality and intensity of the rehabilitative therapy [8].

The structures that help restore motor activity and function after a brain injury can be gathered into three groups: intact perilesional areas of the ipsilateral

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Table 1. Mechanisms of neuroplasticity [19].
primary motor cortex, ipsilateral and contralesionally auxiliary motor systems together with the structures responsible for executive control and contralateral motor system [20].

In addition to neuroplasticity phenomena, the post-injury recovery process involves mechanisms of regeneration, differentiation, and maturation of new neurons and support cells that facilitate the creation of new neural networks, thus allowing the replacement of damaged ones [16]. Neurogenesis, gliogenesis, and angiogenesis refer to the development and formation of new neurons, supporting glial cells, and blood vessels respectively [14, 15]. Neurogenesis takes place throughout life, although it is attenuated with age. In adults, it is discrete and basically restricted to two neurogenic areas: the subventricular zone close to the third ventricle and the infragranular area of the dentate gyrus of the hippocampus [15]. Several studies have shown that ischemic lesions of the central nervous system lead to an increase in the proliferation of neural stem cells located in the subventricular zone, which will subsequently differentiate into mature cells that will travel to the damaged brain areas through different biochemical mechanisms and molecular cell signaling. Neuronal death is a strong stimulus for neurogenesis after ischemic stroke, even when it occurs in brain territories that are located at a distance from neurogenic niches. However, the vast majority of these newly generated cells have low survival once they reach the damaged area, a fact that could be favored by detrimental factors in the perilesional environment, lack of neurotrophic support, and molecular signaling which is necessary for proper development [16].

Both in the phenomena of neuroplasticity and cell regeneration, epigenetic regulation through mechanisms that include DNA methylation, histone modification and the action of micro-RNAs (miRNA) play a fundamental role [16].

2.2 Disability measurement scales

2.2.1 Disability of basic activities of daily living

2.2.1.1 Barthel scale

The most widely used and the fastest index of functional independence. Its completion time is 5 min. The maximum score is 100 points (complete functional independence for activities of daily living) and a score below 20 points will show a great dependency level. It rates the level of dependency with feeding, movement, personal grooming, getting on and off the toilet, bathing, walking on a level surface, ascend and descend stairs, dressing and undressing, and bowel and bladder continence [21].

2.2.1.2 Functional Independence Measure (FIM)

Assesses physical and cognitive disability according to the level of assistance required to carry out activities of daily life. Its completion time is 30–40 min. It consists of 18 items that assess 6 areas of function that are summarized in 2 basic domains: physical and cognitive. Each item scores on a scale of 1–7 (1 = total dependence and 7 = total independence), with a maximum score of 126 points. An unfavorable prognostic factor of function is considered a score less than 40 or a score less than 60 in people older than 75 years [9].
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2.2.2 Motor disability

2.2.2.1 Motor index

It is a simple, fast scale: its completion time is 5 min and it is useful to assess voluntary motor activity in three basic movements of the upper limb (shoulder abduction, elbow flexion, and handgrip) and another three in the lower limb (hip flexion, knee extension, and foot dorsiflexion). 0 represents total paralysis and 100 represents normality [9].

2.2.2.2 Fugl-Meyer scale

It is used to assess the function and control of the musculoskeletal system, including balance, sensitivity, and joint pain in patients who have suffered a stroke. It has the disadvantage that it requires training for the evaluators, and its application is very slow, taking about 30–40 min. It consists of 155 items, each of which is scored on a three-point ordinal scale. The maximum motor performance score is 66 points for the upper limb, 34 points for the lower limb, 14 points for balance, 24 points for sensitivity, and 44 points each for passive joint movement and joint pain. A maximum of 266 points can be reached [9, 10].

2.2.3 Cognitive disability

2.2.3.1 Mini Mental State Examination (MMSE)

It is a brief test for the detection and quantitative evaluation of cognitive impairment. Its maximum score is 30 and the threshold value for cognitive impairment is 23. It consists of 11 questions that assess orientation in time and space, fixation, attention and calculation, memory, nomination, repetition, understanding, reading, writing, and replication of a drawing. The test is valid as a screening tool and is sensitive to detect moderate/severe impairment, but not mild impairment [10].

2.2.3.2 Montreal Cognitive Assessment (MoCA)

It is a short test that can be performed in 12 min to detect mild cognitive impairment. It consists of 30 questions, the score ranges from 0 to 30. A score above 26 is considered normal. It evaluates different types of cognitive abilities, including orientation, short-term memory, delayed recovery, executive function, visuospatial ability, language skills, abstraction, object naming, and attention [22].

2.2.4 Disability for communication

2.2.4.1 Boston aphasia test

It requires 1–4 h to do and consists of 16 slides for the diagnosis of aphasia and 60 graphic elements for the vocabulary test. 1 point is awarded for each correct answer, the maximum score being 60. A score above 50 is considered normal [23].
2.2.5 Walking disability

2.2.5.1 Sagunto Hospital Functional Gait Categories

Sagunto Hospital Functional Gait Categories (FACHS) allows a quick, valid, sensitive, and reliable assessment of ambulation, allowing to determine the walking speed of stroke patients. It has 6 self-exclusive and self-explanatory function levels. Level 0: impossible; 1: completely dependent; 2: dependent hand; 3: free; 4: prolonged and 5: normal [10].

2.2.6 Stroke severity

2.2.6.1 Modified Rankin scale

It is a scale to measure functional outcomes in post-stroke patients. Assigns a score of 1–5 based on the level of independence from pre-stroke activities. 0: Asymptomatic; 1: No significant disability, able to carry out all usual duties and activities; 2: Mild disability, unable to carry out all previous activities but able to look after own activities without assistance; 3: Moderate disability, requiring some help, but able to walk without assistance; 4: Moderately severe disability, unable to walk and to attend to own bodily needs without assistance; 5: Severe disability: bedridden, incontinent, and requiring constant nursing care and attention [24].

2.2.6.2 National Institutes of Health Stroke Scale (NIHSS)

It is a measure of somatosensory function used in the acute phase with patients who have suffered a stroke. It is made up of 11 items: level of consciousness, conjugate look, visual fields, facial paresis, paresis of upper extremities, lower extremity paresis, limb ataxia, sensitivity, language, dysarthria, extinction/neglect/inattention. It determines the severity of the stroke: Mild <4, Moderate <16, Severe <25, Very severe ≥25 [10].

2.2.6.3 Canadian Neurological Scale (CNS)

It is also used in the acute phase to assess the neurological status of stroke patients. Ten clinical domains are measured, including mental state: level of consciousness, orientation, language, and motor functions: face, proximal arm, distal arm, leg [10].

2.3 Upper and lower limb motor rehabilitation

Stroke is one of the main causes of disability in adults, and the demand for rehabilitation services after suffering a cerebrovascular event is very high.

Motor deficit is the main cause of physical disability in stroke and the area in which rehabilitation works as a priority. It is usually unilateral, although in more severe patients bilaterally innervated muscle functions, such as trunk control, may be affected [25, 26].

Hemiparesis or hemiplegia is the most prevalent deficit in stroke, being the symptom that is more worrying for the patient and their relatives, and the main indicator of treatment expectations [27]. The rehabilitation program consists of different phases.
2.3.1 Rehabilitation in the acute phase

It covers the first 2 weeks after a stroke and it must be started soon when they are still in the stroke unit [25, 27]. All patients with acute stroke should be evaluated by the rehabilitation physician in the first 24–48 h to assess the deficit and initiate measures to prevent future complications, grade of recommendation A [27].

It is necessary to correctly align the patient in bed, make frequent postural changes, and place the joints in a functional position, with the help of orthoses and pillows. Adduction and internal rotation of the shoulder and flexion of the wrist and hands, which tend to extension and varus should be avoided [27].

The immobilization of the muscles in a shortened position is the initial mechanism for the development of contractures, which are objectified as an increase in resistance to passive movement, a situation that, if maintained, will decrease the joint range [26]. Therefore, once the patient is hemodynamically stable, passive kinesitherapy of the affected hemi body will be started [27], performing passive exercises of the full joint arch on a daily basis in the routes susceptible to muscle shortening. Prolonged muscle stretching is more effective than a brief passive exercise. It is also necessary to stimulate the mobility of the unaffected side since immobility weakens its strength [26].

Likewise, the patient will receive instruction to perform functional tasks, such as getting up in the bed and recovering adequate trunk control, which later allows sitting, self-mobilization, and transfers, as well as standing and walking depending on the degree of involvement [27].

In addition, respiratory physiotherapy treatment and global stimulation of the patient should be started [25].

Early mobilization and immediate rehabilitation appear to be the main variables associated with getting the best results in stroke units, by reducing bed-ridden complications (such as aspiration pneumonia, deep vein thrombosis, and pulmonary embolism as a consequence of immobility, contractures and pressure ulcers, potentially avoidable through frequent postural changes) [26].

Current evidence confirms that the more intensive the stroke rehabilitation treatment after the first 24 h, the better the functional results [27].

2.3.2 Rehabilitation in the subacute phase

From 2 weeks to 4 months after the stroke. Patients should be treated both during their hospital stay and after discharge, by units that are specialized in stroke rehabilitation treatment, recommendation grade A [27].

The objective during this phase is to gain the maximum degree of functionality possible by adapting to the deficits [25]. Recovery of motor activity usually follows a proximal to distal order. In cases of partial motor recovery, synergistic mobility patterns may develop. Proximal muscle contraction may induce distal contraction with the mass movement of the limb. The predominant synergies are antigravity: flexor in the upper limb and extensor in the lower [26].

The patient will learn new motor skills through experience and training for the phenomenon that constitutes brain plasticity. This brain reorganization substrate can be modulated by different rehabilitation therapies [26]. These therapies are very varied, and each physiotherapist applies them according to their knowledge and experience. There is no evidence that any type of physiotherapy shows superior results to the others [25].
2.3.2.1 Compensation techniques

They seek to reeducate residual capacities, especially of the unaffected hemi body, to improve function [26]. They are indicated in severe patients with a poor prognosis or in the stabilization phase [25].

2.3.2.2 Neuromotor techniques or facilitating techniques

Their objective is to improve the quality of movement on the affected side. There are different methods [26, 27]:

Bobath method: inhibition techniques (which reduce spasticity, synergies, and abnormal patterns), facilitation techniques (favor the development of normal posture patterns) are applied and the incorporation of the plegic side in therapeutic activities is promoted [25].

Brunnstrom method: It is based on the stimulation of synergies for the performance of analytical movements that the patient does not perform voluntarily [26].

Proprioceptive neuromuscular facilitation (Kabat): its main objective is to improve muscle weakness. It uses peripheral stimuli of superficial (touch) or deep origin (joint position, stretching) to improve muscle strength and coordination. It is based on movement patterns in which weak muscles are aided by stronger agonists [25].

2.3.2.3 Motor relearning techniques or task-oriented rehabilitation

It aimed at improving the execution of specific tasks that have a practical meaning in the patient's life [27]. Learning requires repetitive and intense training, progressive in its difficulty, with feedback on what is being done and motivation strategies [26].

2.3.2.4 Therapy of movement induced by restraint of the healthy side

It is based on experimental studies carried out by Taub in 1977 with monkeys that had undergone a dorsal rhizotomy, showing that they were able to use the affected limb by immobilizing the healthy side [27].

2.3.2.5 Technology applied to task-oriented rehabilitation programs

For example, functional electrical stimulation (FES) applied to the lower extremity as an alternative to an antiequine orthosis or biofeedback to the patient (FES-EMG). Technology can facilitate the automation of the activity to be trained [26].

In this phase, the assessment and treatment of spasticity are also important, and the prescription of drugs or the application of botulinum toxin on the spastic muscles and/or orthoses that maintain muscle stretching may be necessary [25].

Rehabilitative treatment of the upper extremity: Unlike the lower limb, only a minority of patients achieve satisfactory functional use of the upper limb. The purpose of the rehabilitation treatment will be to reach the maximum possible functionality of the affected upper limb [25]. The specific techniques used for its treatment are [27]:

Assisted passive and active kinesitherapy of the affected upper limb, as well as muscle strengthening.

Mental imagery: Mental practice of movements and activities helps the functional recovery of the affected side.
Induced movement therapy with suppression of the healthy side: The best results with this therapy have been obtained when applied 3–9 months after cerebrovascular disease and it has been shown to be superior to conventional therapies in the motor recovery of the paretic upper limb, improving grip and speed of movement in carrying out activities of daily living.

Mirror therapy: It is effective in the motor recovery of the affected limb as well as in the reduction of pain. Visual feedback is used through a mirror, mobilizing both extremities, but observing the healthy side reflected.

Virtual reality: A simulation of the real environment is produced, generating human-computer feedback, while the patient performs the programmed exercises. Currently, it has been shown to be superior to conventional occupational therapy in improving the disability of the affected limb, also enhancing the effects of the latter.

Functional electrical stimulation and simultaneous performance of task-oriented exercises: The synchronization between the increase in sensory inputs to the CNS and muscle contraction stimulates motor recovery.

Robot-assisted therapy in the upper limb: It is used when the patient lacks sufficient strength. As an adjuvant therapy to physiotherapy, it makes it possible to increase the intensity of treatment, improving motor function in the shoulder, elbow and wrist, although it has not been shown to improve ADL performance.

Transcranial stimulation: It favors neuroplasticity phenomena, interfering with the patient's learning and motor function in a noninvasive and safe way.

Rehabilitative treatment of the lower extremity: It should start in the first days. A good mastery of orthostasis and some motor coordination should be achieved as soon as possible [25]. The main objective is to improve mobility and restore motor control of standing and walking (recommendation grade A) [26], to achieve greater independence and reduce energy costs [25]. In general, patients who are capable of performing transfers and standing safely in the subacute phase recover ambulation, in some cases requiring the use of technical aids such as anti-equine orthoses, canes, or a walker [26].

Normally the following phases are followed: initiation of standing, balance re-education, parallel standing, and walking [25]. The following techniques are used [27]:

Passive, assisted and active kinesitherapy, as well as muscle strength training, being the strength of the quadriceps essential for dynamic stability during the support phase of walking.

Re-education of balance: Affected in patients with stroke due to impaired motor control in the trunk and lower extremity, as well as the sensitivity of the corresponding hemibody and a perception disorder, which makes it difficult for the patient to achieve correct maintenance of balance. Its treatment is essential since it can reduce the risk of falls.

Physical reconditioning: It is necessary to carry out an individualized aerobic training program that involves large muscle groups, to combat fatigue and increase cardiovascular resistance. Monitoring of heart rate and blood pressure is recommended during the performance of the same.

Treadmill gait training with or without body weight offloading: It improves gait parameters, increasing monopodal support on the affected side and step alternation, as well as physiological activation of the spinal erectors [25].

FES of the affected lower limb: It improves strength and deformity, but the effect is not maintained over time [25].

Mental imagery [26].

Virtual reality [26].
2.3.3 Rehabilitation in the chronic phase

Rehabilitation is a time-limited process. Beyond the sixth month after the stroke, there is a stabilization phase in functional recovery. To indicate additional intervention in the chronic phase, it is necessary to set a realistic goal, have a rehabilitation technique with evidence of being effective in achieving that goal, and objectify progress towards the planned goal on a practical scale [26].

There are different studies about motor limb rehabilitation. The AMOBES trial [28] found that additional physical therapy aimed at reducing complications of immobility had similar benefits at a lower dose of physical therapy. Studies performed in the early subacute stage of stroke, treating patients with neuromuscular electrical stimulation, functional stretch training, and task-oriented training, showed similar benefits to routine care for upper extremity functional capacity [29]. The EXPLICIT trial [30] found that restricted movement therapy led to an increase in upper limb capacity in the first 12 weeks after stroke, without maintaining this benefit at 26 weeks.

The VIRTUES [31] and EVREST [32] studies carried out an investigation on the effects of virtual reality and video games on the motor capacity of the upper extremities during the subacute stage of stroke. The RATULS trial [33] investigated the effects of robot-assisted therapy on upper limb motor ability in the chronic stage of stroke. All of these trials illustrate the feasibility of using these technologies on a large scale and report benefits similar to those produced by an equivalent dose of recreational activities or conventional therapies [29].

2.4 Aphasia and apraxia rehabilitation

Aphasia is an alteration of oral (comprehension and/or expression) or written (reading/writing) language as a consequence of a brain injury. 21–38% of stroke patients will present with some type of aphasia. Dysarthria is the alteration that occurs in speech as a consequence of muscular dyscontrol in the buccophonatory organs due to the lesion, affecting its clarity. It is necessary to differentiate it from apraxia, which is the decrease in the ability to voluntarily plan and execute the appropriate movements for the articulation of speech, without affecting the muscles involved in speech [34].

In the subacute and chronic phases, recovery from language and speech disabilities will depend on neuroplasticity processes, so specific assessment by specialized professionals and the start of speech therapy treatment during the subacute phase will be essential [27]. The period of recovery is variable, it is considered that during the first 6 months the speed of recovery is much higher and later it slows down, until almost stabilizing after the first year [26].

The treatment of these patients aims to increase the patient's linguistic capacity, providing them with tools to deal with the situation and make up for the deficit. It should be individualized, early (as soon as the patient is stable, able to cooperate with an acceptable level of care, and not excessively fatigued), and intensive [34]. There is an inverse relationship between the time elapsed from the onset of the deficit to the start of treatment and the magnitude of its effect. The magnitude of the effect is directly related to the frequency and intensity of treatment. The therapies usually offered in our environment, which are usually 2 h/week in the best of cases, have
effects that are barely superior to those of spontaneous recovery [27]. Its efficacy has been demonstrated with RCTs with frequencies of 3 h/week or 5 h/week [26].

The speech therapist can opt for three treatment strategies, not mutually exclusive, and that depends on the severity, the evolutionary moment, and the characteristics of each patient [26]:

2.4.1 Recovery of specific linguistic deficits

Recovering the norm, the function is recovered. For example, in Wernicke’s aphasia, working on phonological discrimination with specific exercises to differentiate phonemes [26].

2.4.2 Reorganization of the function

Starting from the intact skills. It would be applied to the same patient trying to improve oral comprehension by promoting the use of more preserved semantic comprehension. The important thing is that he understands the messages, not that he maintains certain linguistic skills. It is usually the most used and effective strategy, especially in moderate or severe aphasia [26].

2.4.3 Substitution of lost linguistic abilities by any other mechanism that ensures communication

In the same patient, his or her close environment is taught to increase expressiveness and to increase the gestural code used. It is usually necessary for patients with global or very severe aphasia, in addition to technical aids and augmentative or alternative communication [26].

As long as identifiable goals exist and progress persists, the aphasic patient should continue to receive treatment with regular and objective assessment of progress [25].

2.5 Cognitive and perceptual rehabilitation

Cognitive impairment secondary to stroke is a frequent complication, with a prevalence ranging between 20 and 80%. The risk of cognitive impairment is related to demographic factors (age, education, or occupation of the patient) and vascular factors, although it can be stated in general terms that this risk is increased between 5 and 8 times more after suffering a stroke [35, 36]. Its presence is associated with a lower quality of life 12 months after the stroke, an increased risk of dementia (vascular dementia), mortality and institutionalization rates, as well as an augmented burden on the caregiver and bigger health expenses [37]. However, despite being a common and serious complication that carries a poor prognosis in the medium and long term, it is an underdiagnosed entity [38]. Assessment of cognitive functions should always be done routinely in the clinical care of stroke patients prior to discharge home [39]. To reduce cognitive consequences after stroke, the cognitive impairment must be properly characterized, the underlying causes of cognitive decline understood, and the efficacy of different treatment and rehabilitation approaches determined [40].

Cognition is an aggregate of different cognitive domains that are not independent of each other but are interrelated through neural networks. These cognitive
domains could be outlined as follows [40]: attention (focusing, shifting, dividing, or maintaining attention on a particular stimulus or task); executive functions (work planning, organization of thoughts, capacity for inhibition, control, and monitoring of responses, instrumental adaptation); visuospatial skills (visual search, drawing, construction); praxic function and perceptual/recognition skills (gnosis); memory (recall and recognition of visual and verbal information) and language (expressive and receptive, verbal and non-verbal, reading and writing).

A common finding in patients with cognitive impairment secondary to cerebrovascular lesions, and one that appears to be a consistent pattern, is deficits in attention, executive functions, and processing speed [41]. Memory impairment, highly compromised in patients with Alzheimer’s Disease, is not usually the most obvious cognitive deficit after a stroke; only about half of the people with vascular cognitive impairment present amnesic signs, and approximately 30% of patients with vascular cognitive impairment will progress to a phase of dementia [42].

The location of the lesion constitutes a determining factor in the clinic of cognitive deterioration after stroke [43]. Strategic infarcts in specific locations in the brain are capable of causing a postictal cognitive deficit, sometimes of acute/subacute onset. The first evidence in this regard was obtained after observing symptoms of cognitive impairment in the context of acute vascular thalamic lesions.

Some typical locations of strategic infarcts and their most characteristic clinical manifestations are described below ([Table 2] [44]).

<table>
<thead>
<tr>
<th>Internal capsule</th>
<th>Frontal lobe dysfunction: inattention, fluctuating alertness, apathy, abulia and psychomotor retardation, memory impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thalamus</td>
<td>Memory impairment, dysexecutive, speed of attention, and mental processing</td>
</tr>
<tr>
<td>Fornix</td>
<td>Severe anterograde memory impairment</td>
</tr>
<tr>
<td>Caudate Nucleus</td>
<td>Pronounced abulia, disinhibition, and affective disorders</td>
</tr>
<tr>
<td>Corpus Callosum</td>
<td>Pure alexia, visual agnosia, unilateral apraxia</td>
</tr>
</tbody>
</table>

Table 2. Cognitive disorders after strategic strokes.
mechanisms, or establishing new patterns of activity through external compensatory mechanisms such as external aids, environmental structuring, and support [45].

The objectives of cognitive rehabilitation are to reinforce previously learned behavior patterns, establish new patterns of cognitive activity through internal compensatory cognitive mechanisms for impaired neurological systems, establish new patterns of activity through external compensatory mechanisms such as external aid, or structuring and environmental support and to allow people to adapt to their cognitive disability [45].

2.5.1 Rehabilitation in attention, working memory, and processing speed

Rehabilitation in attention, working memory, and processing speed are three cognitive domains that constitute the cognitive triad that must be addressed first for the rehabilitation to be successful. Most exercises are based on the stimulus–response paradigm. The repeated activation and stimulation of the attentional systems facilitate changes in cognitive capacity, progressively increasing the attentional demand. Transcranial magnetic stimulation over the left dorsolateral prefrontal cortex can improve attention [46, 47].

2.5.2 Memory rehabilitation

In mild memory problems, compensatory strategies may be considered [45]. The use of internal strategies (visual images, semantic organization, and spaced practice) is an option for patients with a high degree of functional independence. Non-electronic external strategies (use of notebooks, wall calendars, notes, to-do lists) will be another valid option in patients with preserved executive functions. In more serious deficits, the use of external compensations through assisted technology (e.g., tablets, laptops) is recommended, as well as specific interventions aimed at facilitating the acquisition of specific skills (e.g., error-free learning). Virtual reality games could improve attention and visuospatial memory, while music therapy improves verbal memory.

2.5.3 Rehabilitation of executive functions

Executive dysfunction is the main component of neurobehavioral disorders in these patients [45]. It causes disruptive behaviors that have a great impact on the autonomy, functional independence, and social interaction of the patient. Intervention in groups constitutes a work tool of great value in these cases. It represents an opportunity to observe and work on cognitive and behavioral functioning and interpersonal interaction. The great variety of frontal symptoms (cognitive and behavioral) and the theoretical complexity of the exercises constitute some obstacles to which the designs of executive functional rehabilitation programs are exposed, which is why it is necessary to use different non-exclusive techniques such as modifications of the environment, restoration techniques, compensatory strategies, and educational interventions.

2.5.4 Dual-task training

Dual-task training requires subjects to perform complex cognitive and motor activities simultaneously, improving the coordination of various tasks. Dual tasks are important for different daily activities, such as walking while having a conversation [46].
Pharmacological treatments

Pharmacological treatments (acetylcholinesterase inhibitors, antidepressants, atomoxetine, methylphenidate, and modafinil) have not been shown to improve cognitive impairment in patients with cognitive impairment secondary to stroke, so their use must always be individualized [45].

Rehabilitation of perceptual and constructive abilities

Cortical perceptual abilities are defined as the ability to organize, process and interpret visual, tactile, or kinesthetic afferent information or both, and the capacity to act appropriately on the information received [47]. Some symptoms in relation to the compromise of perceptual activities are unilateral spatial neglect (the lack of information, response, or orientation to sensory stimuli presented on the contralateral side of the lesion, usually related to right parietal lesions. These patients can ignore food on one side of the plate, or attend only to stimuli on one side of the body) [48] and anosognosia (lack of awareness of the loss of an important bodily function, mainly hemiplegia. It is also more common in right parietal lesions) [49]. The left hemisphere is responsible for modulating arousal and attention in the right visual field, while the right hemisphere controls these processes in the left and right visual fields. Rehabilitative interventions must be implemented repeatedly, training the patient to voluntarily compensate for its deficits: seeking adaptation to the external environment with strategies that do not require the patient to be aware of the deficit [49], modifying behavioral conditions to affect the execution of observable tasks, trying to correct hemineglect without the conscious participation of the patient, or with the top-down strategies, in which the voluntary effort of the patient seeks to reduce or compensate the negligent side, following the indications given by the rehabilitator [50].

Behavior and psychological rehabilitation

The psychological and behavioral changes due to stroke are in most cases devastating, causing a marked decline in quality of life, which can be improved with neurorehabilitation. Anxiety is common during the first year after stroke, with one in three experiencing it, and it gets significantly less attention compared to other psychological problems after stroke. Anxiety significantly influences the quality of life and could be a predictor of depression [51]. Post-stroke depression occurs in 1 in 3 stroke patients and more than half of all cases are neither diagnosed nor treated. Symptoms usually occur within the first three months after the event [52]. These patients experience sleep disturbances, vegetative symptoms, and social withdrawal. In some patients, depression can be accompanied by suicidal thoughts or tendencies. Irritability is a very common symptom after stroke and a source of a great deal of distress to patients and caretakers [53]. All these psychological and behavioral problems can be tackled with group rehabilitation, psychological therapy, and drugs such as selective serotonin reuptake inhibitors.

There are other techniques that can help in mental health recovery and psychological rehabilitation after strokes, such as yoga and meditation. Both are known to reduce anxiety, fear, anger, stress, and depression in patients and caregivers, promote cardio-respiratory health, and reduce stroke-related risk factors such as carotid atherosclerosis, dyslipidemia, hypertension, diabetes, and coronary artery disease. Also, it was demonstrated that following practice of yoga and meditation made significant
improvement in muscle power and range of movements in hemiplegic limbs and some positive effects in the Berg Balance Scale, Timed Movement Battery, and quality of life as assessed with the Stroke Impact Scale [54].

2.7 Rehabilitation technologies and remote rehabilitation

Rehabilitation technologies are defined as 'those whose primary purpose is to maintain or improve an individual's functioning and independence, to facilitate participation and to enhance overall well-being' [54]. Such devices are quite helpful in engaging patient's interests and motivation. A wide range of such applications are available:

2.7.1 Robotic devices and virtual reality

Robotic devices are machines capable of carrying out a series of complex actions automatically. Virtual reality consists of machines that produce interactive simulations to allow users to engage in environments that closely resemble the real world. Both techniques use visual and multisensory stimuli and facilitate joint movements, walking, improving muscle strength and motor function. Electromechanically assisted gait training combined with conventional physiotherapy is more effective than training without these devices [54].

To regain motor function after stroke, rehabilitation robots are increasingly integrated into clinics. The devices fall into two main classes: robots developed to train lost motor function after stroke: therapy devices, and robots designed to compensate for lost skills: assistive devices [55].

2.7.2 Electrical stimulation

Electrical stimulation is one of the most widely used therapy and its reported benefits include spasticity reductions, improvements in range of motion, improved sensation, and reduced pain, but its benefit in stroke rehabilitation has not been adequately demonstrated [54].

Remote rehabilitation is very useful after a stroke. Tele-rehabilitation, also known as e-rehabilitation, is the delivery of rehabilitation services over telecommunication networks and the internet, which provides access to rehabilitation services in a remote area using communication technology, minimizing the problem of living far away from these centers where rehabilitation can be offered.

Wearable sensor technology can also address many of these limitations, being able to offer home-based therapies which can be monitored remotely. Brain-computer interface or brain-machine interface is an upcoming technology in stroke rehabilitation, in which brain signals are recorded through a sensor, transmitted to a computer processor to decode it, and formulate a signal for intended actions with a robotic limb or wheelchair [54].

2.8 Predictive factors of recovery

The factors with the greatest weight in the functional prognosis after a stroke are the initial severity, the functionality before the event, the time between the stroke and the
start of rehabilitation, and the cognitive status. The two most important predictors of functional recovery are initial stroke severity and age.

The patients who benefit the most from a rehabilitation program are usually those with better baseline functionality. Classification of patients can be made based on the severity of the stroke [8, 10].

2.8.1 Mild stroke

Mild deficits: FIM score > 80. NIHSS <5. There are no assessable cognitive deficits. Barthel >80.

2.8.2 Moderate stroke


2.8.3 Severe stroke

Severe deficits: FIM < 40 or motor FIM < 37. NIHSS >9. It is usually associated with severe motor deficits, impaired level of consciousness, and/or medical comorbidities. Barthel <60.

2.9 Community reintegration

Hospital discharge should never lead to an interruption in rehabilitation, and it is the responsibility of the healthcare organization and the professionals of the rehabilitation teams to ensure the continuity of the process. Hospital discharge planning should be approached from the initial stages of admission and should involve the professionals, the patients themselves, and their families or caregivers. Knowing possible problems and needs in advance facilitates reintegration into the community [51].

The perception of health among people with stroke sequelae 2 years after the stroke is lower than the general population. The factors that determine a lower quality of life are depression, having to depend on a third person, and the need for social help.

Rehabilitation programs are most effective when carried out at an early stage. Late rehabilitation is the one performed when most of the deficits have stabilized and the objective is to maintain recovered functionality, continue the adaptation process, and improve the performance of basic activities of daily life [51].

In patients undergoing rehabilitation programs, improvements in deficits, social participation, and quality of life can be seen even years after the event that generated the initial injury. It is important to make a selection of the appropriate approach to continue the rehabilitation treatment according to the type of patient [9].

2.9.1 Long term care facilities

Patients who continue to need hospitalization and have a moderate or severe disability in more than two functional areas such as mobility, swallowing, or communication, but whose medical and cognitive conditions do not allow them to participate in therapies of high intensity, and without sufficient social and family support to foresee a return home in the medium term.
2.9.2 Outpatient rehabilitation

If patients have a mild or moderate disability and meet the medical and cognitive conditions that allow them to travel to a rehabilitation center, and have good social and family support, they will continue with high-intensity treatment (1–3 h daily) in outpatient rehabilitation centers or by going to the referral hospital on an outpatient basis.

2.9.3 Home rehabilitation

In those patients who continue with a moderate or severe disability and good cognitive conditions but whose medical or social situation does not allow them to travel to a rehabilitation center. For patients with very severe disabilities in the chronic phase, as long as there are functional objectives to be achieved, home rehabilitation can help to avoid long-term complications, readmissions and moderate the impact of the disability on the quality of life of patients and caregivers.

Regarding social support after the stroke, it will be necessary to report on aspects such as labor reintegration, changes, and strategies to minimize sexual dysfunction, the possibility of driving vehicles again, or the access to adapted transport systems that would make it possible to increase the level of occupational, social and leisure activities, improving the quality of life of the patients. In addition, after a stroke, family training and emotional support are highly important, especially for those who are going to become caregivers [51].

Conflict of interest

The authors declare no conflict of interest.

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