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Case Report

Methods of Assessment, Therapeutic Objectives, and the Benefits of Botulinum Toxin Injection in Patients with Stroke at Various Stages of Progression. Series of Case Studies

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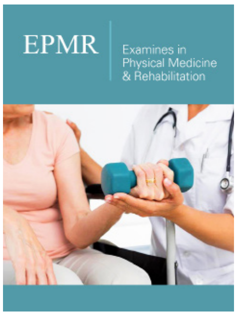

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Abstract

Introduction: Achieving successful control of spasticity can represent a significant therapeutic challenge. The numerous complications need to be anticipated and properly managed through a complex and personalized therapeutic approach.

Objectives: Depending on the degree of spasticity, its duration, and the motor control in the targeted segment, the therapeutic objectives can vary considerably concerning spasticity in the context of stroke (AVC).

Materials and Methods: Four case studies are presented, involving patients with stroke and spasticity ranging from grade 1+ to 4 (measured using the Modified Ashworth Scale-MAS), with varying duration and motor control in the affected segments. These patients underwent a conservative rehabilitation treatment and received botulinum toxin administration. Evaluating spasticity is crucial to determine treatment effectiveness and plan medical applications. It also helps measure and, ultimately, decide the goals of rehabilitation treatment. Therefore, different functional clinical scales are used based on the characteristics of spasticity in each case, allowing for a better dynamic evaluation and quantification of motor impairment, leading to more accurate setting and monitoring of therapeutic objectives and methods.

Result and Discussion: Consistent application of botulinum toxin treatment for high-intensity spasticity led to long-term improvement in pain syndrome in the affected limb and prevented further damage to periarticular tissues. For cases of low-intensity spasticity in a limb with mild motor deficits, restoring functionality to almost normal levels required the use of different functional scales, and botulinum toxin administration was needed at intervals longer than three months, with progressively smaller doses.

Conclusion: Considering the variability in the functional status of patients with stroke and spasticity, both functional evaluation and rehabilitation treatment objectives differ significantly. Therefore, the injection of botulinum toxin calls for a personalized approach based on the patient, regarding dosage and administration intervals.

Keywords: Botulinum toxin injection; Patients; Stroke; Therapeutic challenge; Treatment effectiveness; Self-Esteem

Introduction

The clinical-functional status of patients with spasticity in the context of stroke exhibits extensive variability, and both functional assessment and rehabilitation treatment objectives differ greatly. The existence of multiple standardized functional scales for assessing patients with stroke makes it even more important to choose the most relevant ones based on each patient's clinical picture. Consequently, it is necessary for the medical team to have a detailed understanding of these clinical tools, as well as their feasibility and relevance, in order to evaluate and monitor the patient's progress in line with established therapeutic objectives. Spasticity is defined as the increased muscle tone resulting from hyperexcitability of the stretch reflex, as a component of the Upper Motor Neuron Syndrome (UMNS), following injuries at the cerebral or spinal level [1]. It is a sensorimotor disorder that occurs due to a Central Nervous System (CNS) lesion, characterized by intermittent or sustained involuntary muscle contractions [2]. Spasticity has a significant impact on a person's ability to use the affected limb for its active function (such as tasks and activities) or passive function (proper care of the affected limb). It is a source of stress and pain and can lead to costly disabilities. The secondary complications of spasticity include impaired mobility and motor function, difficulty in self-care and maintaining proper hygiene, decreased self-esteem, pain, and pressure ulcers [3]. It is challenging to manage for patients, caregivers, and healthcare professionals. It can interfere with the rehabilitation program, increase its costs, and prolong long-term care. The evaluation of spasticity is aimed at setting variable therapeutic objectives. The management of spasticity involves rehabilitation and medical treatment, including the use of Botulinum Toxin (BTX).

Materials and Methods

Botulinum toxin

Botulinum toxin, a potent neurotoxin, has demonstrated its efficacy in the management of various medical conditions [4-6]. Specifically, it plays a crucial role in the treatment of focal spasticity [4,6] in patients who have experienced a stroke. Botulinum toxin exerts its therapeutic effects by inhibiting the release of acetylcholine from cholinergic nerve terminals at the neuromuscular junction [7,8]. This blockade prevents the transmission of nerve impulses to the muscles, resulting in reversible and dose-dependent muscle relaxation. In the context of stroke, spasticity refers to the increased muscle tone and involuntary muscle contractions that can occur as a result of the central nervous system damage. Focal spasticity commonly affects specific muscle groups, leading to functional impairments and limitations. By administering botulinum toxin injections directly into the affected muscles, healthcare professionals can selectively target the spasticity and reduce muscle overactivity. This localized treatment approach allows for precise and targeted intervention. The use of botulinum toxin in the treatment of focal spasticity following a stroke has been well-established [4-6,8]. It offers several benefits, including improved motor function, increased range of motion and reduced pain and discomfort associated with spasticity. Furthermore, the effects of botulinum toxin are reversible, allowing for adjustments in dosage and treatment as the patient's needs evolve [5,6]. This adaptability ensures that the treatment can be tailored to each individual's specific requirements, maximizing its therapeutic potential. It is important to note that the administration of botulinum toxin for focal spasticity in stroke patients should be part of a comprehensive rehabilitation program. This program typically includes other therapeutic interventions, such as physical therapy and occupational therapy, to optimize functional outcomes and improve overall quality of life [9].

Modified Ashworth scale

The Modified Ashworth Scale is a tool used to assess muscle tone by evaluating the perceived resistance experienced during passive movement. It categorizes muscle tone into five grades of intensity [10]. Grade 0 indicates no increase in muscle tone, while Grade 1 represents a slight increase with resistance observed in half of the Range of Motion (ROM). Grade 1+ signifies a slight increase in muscle tone but with minimal resistance throughout the entire ROM. Grade 2 reflects a more pronounced increase in tone, although it can be easily overcome with slight flexion of the limb. Grade 3 indicates a considerable increase in tone, making passive movement difficult. Finally, Grade 4 signifies that the limb is rigid and fixed either in flexion or extension.

Barthel index

The Barthel Index, on the other hand, is a measure of functional independence in performing basic daily activities. It includes tasks such as feeding, bathing, grooming and personal hygiene, dressing, bowel and bladder control, transfers, walking, and stair climbing [11]. The index is commonly used to assess patients with stroke [12,13], as well as those with other neuromuscular or musculoskeletal conditions, and even oncology patients [14]. Scoring on the Barthel Index ranges from 0 to 100 points, with intervals of 5 or 10 points. It provides a comprehensive assessment of an individual's ability to carry out essential activities of daily living, offering insights into their functional independence and level of assistance required [11].

Action Research Arm Test (ARAT)

Action Research Arm Test (ARAT) [15] is an observational measurement of upper limb capacity in terms of functionality, coordination, and dexterity standardized for stroke [16], multiple sclerosis [17], Parkinson's disease [18] and brachial plexus conditions. It consists of 4 subcategories that assess grasp, grip, pinch, and gross movement, arranged in descending order of difficulty, with the most challenging task examined first, followed by the least challenging and each task is scored from 1 (poor) to 3 (normal), with 0 indicating the inability to perform the task. The potential prognostic value is predicting functional recovery of the upper limb during rehabilitation after a stroke, with scores categorized as follows: <10 points - poor, 10-56 points - moderate, 57 points and above – good [16,19].

Berg Balance Score (BBS)

The Berg Balance Score (BBS) is a measurement tool for assessing balance which consists of 14 items (scored from 0 to 4), with a total possible score of 56 points [20,21]. The score is inversely proportional to the risk of falling and it evaluates the ability to maintain increasingly difficult static positions by reducing the base of support and progressing to dynamic activities of varying difficulty.

Chedoke-McMaster Stroke Assessment (CMSA)

The Chedoke-McMaster Stroke Assessment (CMSA) is a screening instrument for assessing functional impairment after stroke which is structured as following: deficiency inventory - includes 6 domains (shoulder pain and stages of postural control recovery, arm, hand, leg, and foot) (scored from 1 to 7) , activity inventory - evaluates gross motor function (10 items assessing rolling, sitting balance, transfer, and standing) and walking (5 items) ->15 items (scored from 1 to 7) [22].

Fugl-Meyer Assessment (FMA)

The Fugl-Meyer Assessment (FMA) is specific to stroke and measures the patient's ability to perform certain actions [23,24]. It is applicable in both clinical settings and research and it assesses the severity of the disease, while being used for planning and evaluating rehabilitation treatment. The scale consists of five domains focusing on: motor function (upper and lower extremities), sensory function (assesses light touch on two surfaces of the arm and leg, as well as joint position sense for 8 joints, balance (includes 7 tests, 3 in sitting and 4 in standing), range of joint motion (8 joints) and joint pain [19,25].

Reintegration to Normal Living Index (RNLI)

The Reintegration to Normal Living Index (RNLI) is a quantitative assessment that measures the reintegration into normal social activities (e.g., recreation, community engagement, socio-familial interaction) following a traumatic or disabling condition. It also assesses the „reorganization of an individual's physical, psychological, and social characteristics into a harmonious whole, enabling them to resume a well-adapted life after a disabling illness or trauma." It consists of a questionnaire-based assessment with 11 items, scored from 1 to 10 points [26,27].

General guidelines for the application of functional assessment instruments:

a) Safety considerations: Ensure a safe environment during the assessment to prevent any potential risks or accidents.

b) Exclusion criteria: Take into account factors such as low Mini-Mental State Examination (MMSE) scores, sensory aphasia, low compliance, or underlying pathologies that may pose risks during the evaluation.

c) Inclusion criteria: Consider the underlying pathology or condition that necessitates the functional assessment.

d) Patient training: Provide appropriate instructions and training to the patient regarding the tasks or activities involved in the assessment to ensure understanding and cooperation.

e) Encouragement: Offer encouragement to the patient in case of frustration or difficulty in completing the tasks, promoting motivation and a positive mindset.

f) Suitable setting and materials: Ensure that the assessment is conducted in an appropriate setting with the necessary materials and equipment available for accurate evaluation.

It is important to tailor the application of functional assessment instruments to the individual needs and abilities of the patient while adhering to standardized protocols and guidelines.

The following clinical cases consist of patients with confirmed stroke through CT or MRI, in different stages of evolution, with associated spasticity and variable clinical presentation, evolution, and prognosis. They were monitored during 2 or 3 hospitalizations in the clinic and received specific medical rehabilitation treatment for 15 days during each hospitalization (physical therapy, physiotherapy, adjunctive methods, specific orthoses for posturing/ambulation of the spastic limbs). Final evaluation was conducted 21 days after the second injection of botulinum toxin type A (BoNT-A). Every BoNT-A injection was undertaken with ultrasonographic guidance.

Case Report

Case 1

In this case 1, the patient is a 66-year-old male who experienced a hemorrhagic stroke affecting the right capsulo-lenticular region. As a result, he developed chronic spasticity in the left hemiparesis. The stroke occurred in June 2019, indicating a considerable time has passed since the initial event. The patient's condition has reached a chronic stage, suggesting long-term rehabilitation and management of his spasticity. Further evaluation and treatment will be necessary to assess the functional improvements and overall progress of the patient's condition.

The functional and paraclinical evaluation in december 2021 yielded the following: Upper limb motor control: proximal to intermediate region: grade 2/5 on the Medical Research Council (MRC) scale, distal region: grade 1/5 on the MRC scale; spasticity: grade 2 MAS in the major pectoral muscle, grade 3 MAS in the flexor muscles of the elbow, wrist, and fingers; mechanical and neuropathic pain also present; lower limb motor control: proximal to intermediate region: grade 3/5 on the MRC scale, distal region: grade 1/5 on the MRC scale; tendon retraction in the Achilles tendon. Ultrasound-visible tendinopathy and periarticular calcifications are present in the shoulder, elbow, and ankle. Fixed orthosis for wrist-finger posture and fixed orthosis for ankle-foot during walking are utilized.

First BoNT-A (Dysport) injection (December 2021) Upper limb:150 units in the major pectoral, brachial, brachioradialis, and superficial and deep flexor muscles of the fingers, 200 units in the radial flexor of the wrist and pronator teres, 300 units in the biceps brachii. Lower limb: 150 units in the medial and lateral gastrocnemius, and posterior tibial muscles, 200 units in the soleus muscle. Despite the injections, the patient continues to experience neuropathic pain without improvement in spasticity or motor control. This suggests a non-responder to the treatment. Second injection (April 2022) - similar results. Third injection (July 2022): upper limb: 100 units in the brachialis, deep finger flexors, and radial flexor of the wrist, 150 units in the superficial finger flexors and pronator teres, 200 units in the biceps brachii; lower limb: 100 units in the medial and lateral gastrocnemius, soleus, and posterior tibial muscles. There was an improvement in pain after the third injection.

Functional scores were as followed: Barthel Index: 65/100 - 75/100, Berg Balance Score: 14/56 => 24/56 (reaching a plateau), Action Research Arm Test (ARAT): 0, Fugl-Meyer Assessment for Upper Extremity (FE-UE): 11/66 => 15/66 (improvement in volitional movement component within synergies, passive joint movement, pain, minimal hand grasp component), Reintegration to Normal Living Index (RNLI): 45-59/110 (reaching a plateau).

The functional progression has reached a plateau with partial improvements observed after the comprehensive rehabilitation treatment. Regular intervals of rehabilitation therapy are necessary to maintain functionality and symptom control, particularly in managing pain symptoms. There has been improvement in the volitional movement component within synergies, passive joint movement, pain, and minimal hand grasp component. However, the patient's social reintegration and potential for engaging in household and recreational activities remain limited.

Case 2

In the case 2, we analyze a chronic patient, 56-year-old female, with post-ruptured Anterior Communicating Artery (ACA) aneurysm hemiparesis (2011), and expressive aphasia, regular rehabilitation treatments have been conducted, along with continued home-based physical therapy exercises. A fixed wrist-hand orthosis has been used for posturing, while a fixed ankle-foot orthosis has been employed for walking. There has been no prior administration of botulinum toxin injection before the onset of the stroke.

Clinical examination: right upper limb: motor control: 4/5 Medical Research Council (MRC) proximo-intermediate 3/5 MRC distal; spasticity: grade 1+ MAS in pectoralis major muscle, grade 2 MAS in elbow flexors, wrist, and finger flexors, no tendon retractions or pain; right lower limb: motor control: 5/5 proximo-intermediate 3/5 distal; spasticity: grade 1 MAS in adductor muscles, grade 1+ MAS in quadriceps muscle, grade 2 MAS in gastrocnemius, soleus, and tibialis posterior muscles; no tendon retractions or pain.

The first BoNT-A injection was administered as follows: In the right upper limb, 50 units were injected into the brachioradialis, deep finger flexors, long and short thumb flexors, while 100 units were injected into the pectoralis major, biceps brachii, brachialis, pronator teres, and radial wrist flexor. Additionally, 150 units were injected into the superficial finger flexors. In the right lower limb, 50 units were injected into the tibialis posterior, and 100 units were injected into the medial and lateral gastrocnemius, as well as the soleus. The second injection, performed after a 4-month interval, targeted the following muscles: In the right upper limb, 50 units were injected into the pectoralis major, biceps brachii, pronator teres, and superficial finger flexors. In the right lower limb, 50 units were injected into the gastrocnemius, medial gastrocnemius, and tibialis posterior.

Functional evolution and prognosis were as followed: Barthel Index: Improved from 85/100 to 95/100, indicating increased functional independence in daily activities. ARAT test: Progressed from 35/57 to 45/57, particularly in the grasping component, reflecting improved upper extremity function. RNLI: Showed improvement from 76/110 to 82/100, suggesting enhanced reintegration into normal social activities. Berg Balance Scale: Increased from 45/56 to 49/56, indicating improved balance and stability. Fugl-Meyer Assessment for Upper Extremity: Showed significant improvement from 33/66 to 48/66, indicating enhanced motor function in the affected limb. Reduction of spasticity resulting in improved abilities, mobility, and coordination as quantified by functional scales. Enhancement of walking pattern and gait. Improvement in static and dynamic balance scores, leading to minimal risk of falling during walking without the need for assistive devices such as ankle-foot orthosis and single-point cane. Increased engagement and participation in recreational activities and social-family reintegration. Improvement in components of spontaneous speech and naming within expressive aphasia. There has been an improvement in voluntary movement of the upper limb, both in the presence and absence of synergy, as well as in coordination, speed, and hand and grip abilities.

Case 3

In case 3, we have a 56-year-old male in the acute stage of his condition. He is diagnosed with spastic left-sided hemiparesis following a right Sylvian ischemic stroke that occurred in August 2020. As part of his management, he uses a fixed wrist-hand orthosis to support his posture. Additionally, he experiences a secondary depressive mood due to the stroke and the resulting functional limitations. Clinical examination revealed good motor control in the left upper limb with a 4/5 Medical Research Council (MRC) rating in the proximal-intermediate muscles and a 3/5 MRC rating in the distal muscles. However, there is moderate to severe spasticity in the flexor muscles of the elbow, wrist, and fingers. In the left lower limb, there is good motor control throughout, with a 4/5 MRC rating in the proximal, intermediate, and distal muscles. There is mild spasticity observed in the plantar flexor muscles. There were no tendon retractions or pain reported in either limb.

First BoNT-A injection (25 days post-stroke): 50 units of BoNT-A were injected into the brachioradialis muscle and the flexor carpi radialis muscle, 100 units of BoNT-A were injected into the biceps brachii muscle, flexor digitorum superficialis muscle, and pronator teres muscle. During the second BoNT-A injection (5 months later) there were used: 50 units of BoNT-A were injected into the pronator teres muscle, 70 units of BoNT-A were injected into the flexor digitorum superficialis muscle, 100 units of BoNT-A were injected into the biceps brachii muscle and the pectoralis major muscle.

The functional evaluation yielded: The Chedoke-McMaster stroke assessment showed significant improvements in various areas: the Gross Movement Index achieved a perfect score of 7 out of 7, the Walking Index improved from 92/100 to 96/100, indicating enhanced walking abilities, the stage of arm function improved from 5/7 to 6/7, showcasing progress in upper limb control, the stage of hand function improved from 3/7 to 5/7, indicating improved hand dexterity, the stage of leg function reached the highest score of 7/7, showcasing restored leg control, the stage of foot function improved from 5/7 to 6/7, indicating enhanced foot movements. There has been remarkable progress in the functional assessment scores: the Barthel Index improved significantly from 80/100 to a perfect score of 100/100, indicating a high level of independence in activities of daily living, the Berg Balance Score showed notable improvement, increasing from 46/56 to 54/56, indicating enhanced balance and stability, the Chedoke-McMaster Stroke Assessment (CMMSA) demonstrated progress in arm function, with the ARAT score improving from 42/57 to 51/57. Notably, the pinch section achieved a near-perfect score, the Reintegration to Normal Living Index (RNLI) showed substantial improvement, with the score increasing from 74/110 to 102/110, indicating a greater level of social reintegration and participation in daily activities. The patient has shown positive evolution and a promising prognosis.

There has been a noticeable reduction in spasticity, leading to improved mobility, ability, and coordination of the left upper limb. Additionally, the patient's gait pattern has improved, indicating enhanced walking ability. The scores for both static and dynamic balance have reached a level where the risk of falling during walking without an assistive device is minimal, even in conditions of fatigue or uneven terrain. It is worth noting that the patient has successfully resumed their professional activity as a photographer and actively participates in recreational activities, outings, and excursions. Their social and familial reintegration is complete, indicating a high level of functional recovery and a successful return to daily life. Furthermore, there has been an improvement in the patient's psychosocial and emotional well-being, which contributes to their overall rehabilitation progress. These positive outcomes suggest that the patient's rehabilitation interventions and treatments have been effective in improving their functional abilities, independence, and overall quality of life.

Case 4

Subacute stage: Gender: Female Age: 37 years Diagnosis: Left-sided spastic hemiparesis following a hemorrhagic stroke (June 2021). In August 2021, the patient required assistance for transfers and was unable to walk independently. However, by February 2022, there was significant progress in her condition. She became independent in transfers and was able to walk with the support of a tripod cane and a fixed ankle-foot orthosis on the left side. This improvement during the subacute stage demonstrates the positive effects of treatment and rehabilitation interventions. It indicates that the patient has responded well to therapy, resulting in partial restoration of functionality and improved mobility. However, it is important to continue with therapy and medical support to further enhance motor abilities and walking capabilities, aiming for a more complete recovery.

At clinical examination, in the left upper limb, the patient exhibits motor control impairment with 3/5 MRC strength in proximal muscles, 2/5 MRC strength in intermediate muscles, and 1/5 MRC strength in distal muscles. There is also spasticity present, particularly in the triceps brachii muscle (grade 2-3 MAS) and the flexor muscles of the elbow, wrist, and fingers (grade 2 MAS). Additionally, the patient experiences neuropathic pain. In the left lower limb, there is relatively better motor control, with 4/5 MRC strength observed in both proximal, intermediate, and distal muscles. However, there is still some spasticity noted in the plantar flexor muscles (grade 1+ MAS). Fortunately, no tendon retractions have been observed in either limb.

The patient received two injections of botulinum toxin-A (BoNT-A) for the left upper limb, which was affected by spasticity following the stroke. The first injection was administered 2 months after the stroke and targeted several muscles, including the brachialis, radial wrist flexors, ulnar wrist flexors, pronator teres, biceps brachii, deep finger flexors, triceps, and superficial finger flexors. The dosages varied between 35 U and 150 U depending on the muscle. After a gap of 5 months, the second injection was given, focusing on the pronator teres, superficial finger flexors, biceps brachii, and triceps muscles. The dosages were adjusted accordingly to provide the optimal effect.

The patient's functional status showed significant improvement over time. According to the Barthel Index, their level of independence in activities of daily living increased from 55/100 to 95/100, indicating a substantial enhancement in their ability to perform self-care tasks. The Berg Balance Scale, which assesses balance and mobility, also demonstrated notable progress, with the score improving from 7/56 to 50/57. Additionally, the Chedoke-McMaster Assessment Score, specifically the Recovery of Upper Extremity (UE) component (RNLI), showed remarkable improvement, progressing from 40/100 to 84/100. This indicates enhanced motor recovery and functional abilities in the affected upper limb. The patient has shown positive evolution in their functional status and prognosis. There has been a reduction in spasticity, improvement in mobility and ability, and enhancement of walking pattern and balance. These improvements indicate positive outcomes in their overall motor function and coordination. Furthermore, the patient experienced significant pain relief, with the pain syndrome completely resolving within three months after the initial injection of BoNT-A.

Discussion

For severe spasticity botulinum toxin injections play a crucial role in maintaining the functional status of individuals with severe spasticity. They help prevent the development of contractures through muscle stretching and postural interventions. Additionally, these injections aid in preventing the formation of heterotopic ossification, which is abnormal bone growth around joints. The stretching exercises associated with botulinum toxin injections contribute to proprioception and facilitate neuroplasticity, which is the brain's ability to reorganize and adapt to new neural pathways. Based on the patient's current stage of evolution and level of spasticity, it is important to select appropriate functional assessment scales to effectively evaluate their functionality. In cases where there is minimal spasticity and good motor control, scales such as Chedoke McMaster Stroke Assessment (CMMSA), Fugl-Meyer Assessment, and Action Research Arm Test (ARAT) are suitable. These scales provide detailed testing levels that can assess various aspects of motor function and coordination. For patients with higher levels of spasticity and impaired motor control, the CMMSA and Fugl-Meyer Upper Extremity (FM-UE) scales are particularly useful. These scales allow for dynamic monitoring of functional evolution as they analyze not only motor components but also sensory, proprioceptive, passive mobility, and pain aspects. By selecting the appropriate functional assessment scales based on the patient's specific stage of evolution and level of spasticity, healthcare professionals can obtain valuable insights into their functional abilities and design tailored rehabilitation interventions accordingly.

The role of botulinum toxin in neuropathic pain

Botulinum toxin has shown initial analgesic effects attributed to the reduction of muscle spasms. After peripheral injection of botulinum toxin type A (BTX-A), the heavy chain of the toxin undergoes retrograde transport. It is internalized by motor neurons in the spinal cord through endocytosis and rapid retrograde axonal transport [28]. Post-stroke central pain occurs as a result of cerebral infarction, affecting the brainstem, thalamus, and cerebral cortex. It is characterized by neuropathic pain and sensory abnormalities. This condition is known as central post-stroke pain (CPSP), which is a form of central neuropathic pain [29,30]. A double-blind observational clinical study conducted by Yelnik et al. [31] involved 40 patients who received 500 units of botulinum toxin type A in the affected upper limb. The study reported a significant decrease in Visual Analog Scale (VAS) scores compared to the control group, with a downward trend in VAS scores even 6 months later. These findings suggest that botulinum toxin injections may have a considerable impact on reducing neuropathic pain in post-stroke patients [29,30]. However, further research and clinical studies are necessary to validate these observations and understand the precise mechanisms by which botulinum toxin exerts its analgesic effects in neuropathic pain conditions.

The role of botulinum toxin in neuroplasticity

Neuroplasticity plays a crucial role in the management of spasticity. Spasticity is characterized by abnormal patterns of muscle contractions and impaired motor control, often resulting from the hyperexcitability of the reticulospinal tract. The injection of Botulinum Toxin (BoNT) induces synaptic plasticity in neuromuscular afferents and leads to synaptic reorganization in spinal motor neurons and interneuronal systems. This neuroplasticity induced by BoNT therapy has both beneficial effects and maladaptive effects. On one hand, it promotes beneficial neuroplastic changes such as neuronal plasticity and motor re-education [32,33]. By reducing the hyperexcitability of the reticulospinal tract, it helps restore more normal patterns of muscle activation and control. This is particularly important in chronic stages of spasticity, where motor recovery tends to reach a plateau.

On the other hand, BoNT therapy also reduces maladaptive plasticity, such as the involuntary activation of spastic muscles. By modulating the neural circuits involved in motor control [34,30], BoNT helps prevent the development of abnormal synergistic movements and allows for more efficient motor function. Moreover, BoNT therapy has been found to increase brain activation in areas associated with motor control [34] and sensory integration. This suggests that the neuroplastic effects of BoNT may extend beyond the local muscle level to involve changes in the central nervous system. These changes can contribute to improved motor control and functional recovery. Overall, the use of botulinum toxin in the management of spasticity offers the benefits of promoting beneficial neuroplasticity while reducing maladaptive plasticity. By targeting the underlying mechanisms of spasticity, BoNT therapy facilitates motor relearning, enhances motor control, and improves overall motor function in individuals with spasticity.

The role of botulinum toxin in aphasia

The study „Associations between Upper Extremity Motor Function and Aphasia after Stroke: A Multicenter Cross-Sectional Study" conducted by Shuo Xu et al. [35] in 2021 in China aimed to investigate the correlation between linguistic function and motor status of the upper extremity in patients with left hemisphere stroke and aphasia. The study involved assessing four dimensions of linguistic function, including spontaneous speech, comprehension, repetition and naming, along with the motor status of the upper extremity. The assessment tools used in the study included the Upper Extremity subscale of the Fugl-Meyer Assessment (FM-UE), the Action Research Arm Test (ARAT), the Functional Independence Measure (FIM), the Aphasia Quotient of the Western Aphasia Battery-Revised (WAB-AQ) [36] and the Boston Diagnostic Aphasia Examination (BDAE) [37,38]. By examining these measures, the researchers aimed to determine the association between the linguistic abilities and motor function of the upper extremity in individuals with left hemisphere stroke and aphasia. The results of the study provided valuable insights into how aphasia and motor control are interrelated and how deficits in linguistic function may be linked to impairments in upper extremity motor function [35].

Understanding the relationship between aphasia and motor control can have important implications for stroke rehabilitation. By identifying these associations, healthcare professionals can develop more comprehensive treatment plans that address both the linguistic and motor aspects of recovery. This study contributes to the growing body of research exploring the complex relationship between language and motor function after stroke. Stroke is a complex condition with a high incidence and significant clinical variability, requiring a comprehensive and interdisciplinary therapeutic approach. It involves multiple factors and requires consideration of the various complications associated with this condition. Among these complications, spasticity, aphasia, hemineglect syndrome, neuropathic pain, and ongoing tendon retractions pose challenges in the rehabilitation of stroke patients. However, there is promising evidence and studies that demonstrate the interconnectedness of successful recovery from these complications. Managing spasticity [39], which involves the abnormal increase in muscle tone and involuntary muscle contractions, is crucial for optimizing motor function and overall rehabilitation outcomes. Various therapeutic interventions, including the use of botulinum toxin injections, physical therapy, and occupational therapy, have shown effectiveness in reducing spasticity and improving functional abilities. Aphasia, a language impairment resulting from stroke, can significantly impact communication and daily functioning. Speech and language therapy, augmented with assistive communication devices, can aid in the recovery and improvement of language skills.

Hemineglect syndrome, characterized by a lack of awareness or attention to one side of the body or space, requires specific rehabilitation strategies focused on visual and spatial awareness training. Neuropathic pain, a common complication after stroke, can be challenging to manage. Multimodal approaches, including pharmacological interventions, physical therapy, and psychological support, are often employed to address this issue and improve the patient's quality of life. Tendon retractions, which can lead to joint deformities and functional limitations, may require stretching exercises, orthotic devices, and surgical interventions to prevent or manage contractures. The successful rehabilitation of stroke patients relies on a multidimensional approach that addresses not only the primary impairments but also the associated complications. Interdisciplinary collaboration between healthcare professionals, including neurologists, physiatrists, speech therapists, occupational therapists, physical therapists, and psychologists, is crucial in designing and implementing individualized treatment plans. Through the integration of evidence-based practices and ongoing research, the rehabilitation field continues to advance, offering hope for improved outcomes and quality of life for stroke survivors.

Conclusion

The benefits of botulinum toxin injection in different stages of stroke can be summarized as follows: In the acute and subacute stages, botulinum toxin injection offers the best long-term prognosis due to its overall beneficial effects on neuroplasticity. It helps promote motor control by reducing spasticity and preventing the development of tendon contractures. Lower doses of the toxin are typically used for patients with mild to moderate spasticity. Additionally, the gradual reduction of toxin doses is recommended as the intervention is performed closer to the time of the stroke event.

For mild to moderate spasticity: In the acute stages, botulinum toxin injection provides the best functional prognosis for motor recovery and long-term reduction of spasticity. It helps improve motor control and facilitates long-term rehabilitation outcomes.

In the chronic stage, botulinum toxin injections help maintain mobility, ability, fine motor movements, and coordination. They contribute to the preservation of functional abilities and support ongoing rehabilitation efforts. Also, the central action of botulinum toxin facilitates neuroplasticity. For patients with poor motor control, it helps prevent tendon contractures and heterotopic ossification. In cases where motor control is already good, the use of botulinum toxin helps maintain the existing ability. Overall, botulinum toxin injections provide benefits regardless of the severity of spasticity. They have a positive impact on functional recovery, spasticity reduction, and maintenance of functional abilities. The specific treatment approach should be tailored to each individual's spasticity level and overall rehabilitation goals.

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