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A review of physical modalities and the potential to expand the treatment of patients with traumatic brain injury

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Abstract

Traumatic brain injuries (TBIs) and hemiplegia often involve alterations in cortical function that are often widespread and may not be confined to the peri-infarct regions. Rehabilitation of these injuries may therefore require extensive and innovative physical modalities and exercise activities that enhance mobility. Disuse in limbs can occur in any brain injury derived from different etiologies and advances in rehabilitation indicate that neuromuscular stimulation of both the nerve supply and muscle groups involved impacts plasticity and prepares the limbs for stronger muscle responses during functional activities. Combined therapies are apparently more productive than monotherapies and this may include electroacupuncture and functional electrical stimulation to expedite recovery. The combination of mixed physiotherapeutic interventions also encourages biokinetics, hydrotherapy and robotic rehabilitation over a prolonged period to enable the patient to achieve functional goals. Recovery may not be achieved within a period of 6 months post injury as has previously been accepted and may even require lifelong participation.

Keywords

electroacupuncture, functional electrical stimulation, hemiplegia, nerve stimulation, traumatic brain injury

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Background

Current knowledge regarding the pathophysiology of cerebral ischemia and brain trauma indicates that similar mechanisms contribute to the loss of cellular integrity and tissue destruction.[1] It may be assumed therefore that these conditions can present with similar symptoms of spasticity, flaccidity or lack of use.[2]

Rehabilitation of traumatic brain injury (TBI) embraces both physical and electrical modalities. Two research fields have fostered a new evidence-based paradigm in neurobiology and rehabilitation thanks to, first, neuroscience studies from the 1980s (in animals) demonstrating the functional plasticity of the cerebral cortex[3] and, second, an abundance of neuroimaging data from human stroke populations, providing evidence that the animal results could be generalized to humans. These concepts fostered the generation of specific hypotheses regarding potential treatment approaches.[3] Chronic alterations in cortical function that take place after stroke are likely to be widespread and not confined to the peri-infarct regions,[3] and this has provided scientists and clinicians with the evidence to consider the development of new treatment strategies that may be initiated long after stroke or TBI has occurred.

Recent studies of brain injury indicate that both the functional and structural changes that take place in the cerebral cortex can be modified by new rehabilitative interventions—both physiotherapeutic and pharmocotherapeutic.[4,5] During the learning of new skills, cortical regions associated with sensorimotor function of the body parts most used for skilled tasks become represented over larger cortical territories. Cortical function, sensorimotor learning and cortical injury interact and the undamaged parts of the brain are remodeled during recovery, shaped by the sensorimotor experiences of the individual.[6] The period of partial to advanced recovery seems indeterminate and new rehabilitative interventions

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may have benefit via modulation of neuroplastic mechanisms that are likely to be widespread and not necessarily confined to the original areas of damage.

Methods

There is a paucity of research on the subject of TBI. A focused search of PubMed, ScienceDirect, PEDRO and Google Scholar was used to identify TBI-related articles from the 1980s to 2018. The search included the terms traumatic brain injury AND rehabilitation, combined therapies, acupuncture and functional electrical stimulation (FES). The findings are summarized in the following narrative review of the rehabilitative processes involved in TBI and/or stroke recovery.

Findings

There are limited recommendations for physical modalities in TBI or stroke rehabilitation and the modalities that are currently considered effective are as follows: exercise, including constraint therapy;[7] transcutaneous electrical nerve stimulation (TENS); acupuncture; electroacupuncture (EA); neuromuscular electrical stimulation (NMES); and a combination of these depending on the ability of the patient to participate therein. The following review of these rehabilitative processes also exposes the difficulties that may arise in executing these activities.

Exercise

The rehabilitation setting following TBI involves multimodal therapeutic interventions. Exercise has demonstrated facilitation of the release of molecules that support neuroplasticity and offers protection from brain damage.[8] However, exercise in the acute phase of TBI may impede neuroplasticity and similarly exercise that is associated with the release of stress hormones can inhibit the expression of brain-derived neurotrophic factor.[8] The exercise variables that are available in the post-acute rehabilitation phase play a valuable role when utilized as a therapeutic intervention and the goal is to ensure that physical exercise programs promote adaptive neuroplasticity.

It appears that interventions that encourage neurophysiological, motor learning, orthopedic or mixed interventions demonstrate the most consistent evidence for physical recovery following stroke according to a Cochrane Library editorial report.[9] A more recent systematic review of preclinical studies on the effect of combined therapies on recovery after acquired brain injury indicates that combined treatments continue to provide hope for enhanced recovery, although consistent combined effects on motor, cognitive or cerebral recovery do not indicate uniformity among patients.[10] This review included 29 studies of enriched environment, exercise or task-specific training with other monotherapies to determine if the degree of recovery could be enhanced. Although there was an indication of inconsistency, this research is in its infancy, possibly due to sparse knowledge regarding optimal treatment. However, it seems that combined treatments may hold the most promise regarding treatment of the complex changes induced by TBI combined with the complexity of heterogeneity within this group of patients.

However, different approaches to exercise, being the main mechanism to achieve rehabilitation or functional recovery, albeit partial, are often difficult to achieve in the presence of either flaccidity and/or spasticity in hemiplegic patients. A study on the probability of regaining dexterity in the flaccid upper limb by investigating the impact of severity of paresis and time since onset in acute stroke came to the conclusion, based on the Fugl-Meyer scores of the flaccid arm, that optimal prediction of arm function at 6 months could be made 4 weeks after onset.[11] Lack of voluntary motor control of the leg in the first week with no emergence of arm synergies at 4 weeks is associated with poor outcome at 6 months.[12]

In total, 42 patients were divided into two cohorts with either spasticity or flaccidity at 3 months. The main findings were that those patients with flaccidity had greater motor deficits with a significantly higher prevalence of structural involvement in the lentiform nucleus.[13] Relative perfusion in the lentiform nucleus, thalamus and contralateral cerebellar hemisphere was significantly lower in prolonged muscular flaccidity than in muscular spasticity.

Time until maximum recovery from a stroke or brain damage is variable and often reports/studies have demonstrated that a period of 6 months may be the limit to achieving positive plasticity in rehabilitation. However, this appears to be unpredictable and continuing progress may extend for years or life, depending on factors such as advancement of treatments that encourage progress in neuroplasticity and the patient's ability, aspiration and hope to achieve and continue their rehabilitation process.

The understanding of rehabilitation within the brain is complex. It was discovered that, in 14 stroke patients, transcranial magnetic stimulation (TMS) and transcranial Doppler (TCD) were able to document the capacity for ipsilateral activation during recovery.[14] TMS reveals a specific area in the motor cortex from which ipsilateral motor evoked potentials can be elicited, and both TMS and TCD indicate that the ipsilateral corticospinal tract can be accessible in some adult controls or can be unmasked after cerebral damage.

TENS

TENS and EA are similar in that they both stimulate nerve fibers.[11] Analgesia is achieved by both the facilitation of afferent inhibition, depending on the frequency and intensity of current, and whether they are applied to segmental or non-segmental areas.[12]

TENS can activate nerves 4 cm below the surface and is known to be effective at improving circulation and increasing vasodilatation.[15–17] Acupuncture-like TENS may also activate muscles at higher amplitudes. Therefore, it is possible that TENS could be used advantageously on limbs that are not functioning normally, as in TBI.

Movement retraining and peripheral somatic stimulation, which may include touch, acupuncture and TENS, has an effect on both the central and peripheral nervous systems by re-stimulating and re-educating brain function after any brain trauma and is an essential key to recovery.[18] TBI damages neurons, which may never recover, but if circulation in the brain is improved then the effects of the stimulations alluded to could assist healing and activate undamaged neural circuits adjacent to the original injury and, with remodeling[3] of structure and function, improvement in motor activity could then follow.

Acupuncture

Traditionally, acupuncture has been used for all stages of stroke (preventive, acute and convalescent) and for addressing the sequelae of this condition.[18] Most experimental research has focused on the effects of EA in animals with acute cerebral ischemia, a model for both transient ischemic attacks and ischemic stroke. According to White,[19] on balance the clinical trials do not provide support for the therapeutic value of EA as used in clinical practice for many different conditions. However, this appears to be due to lack of evidence rather than lack of effect due to the heterogeneous nature of the experiments and difficulty comparing the effects of acupuncture against placebo controls.

When inserted into the body, the acupuncture needle creates a local injury and various inflammatory and immune mediators are released that may represent a positive biochemical response.[20] The therapeutic responses at these locations comprise effects at local and systemic levels due to a robust axon reflex and modulation of afferent fiber transmission.

The effects on afferent fiber excitability can be classified as inhibitory and stimulatory. The inhibitory mediators mainly include acetylcholine, noradrenaline (NA), γ-aminobutyric acid (GABA), β-endorphin, substance P, somatostatin, nitric oxide (NO), adenosine triphosphate/cyclic guanosine monophosphate (ATP/cGMP), and adenosine, which suppress afferent fiber excitability. Most cytokines, prostaglandins, bradykinin and other proinflammatory factors are stimulatory mediators that directly or indirectly enhance afferent fiber excitability of the neural unit. Serotonin (or 5-hydroxytryptamine; 5-HT) and histamine can exert either inhibitory or stimulatory effects, depending upon which receptors they act.[20]

The advantages that acupuncture may bring to brain injuries have yet to be shown conclusively due to the methodological issues mentioned in acupuncture research. Studies have shown that the effects of EA on cerebral circulation alter to maintain a degree of physiological balance and it is suggested that this concept may also benefit patients with TBI. A more cautious view would be that acupuncture helps relieve the symptoms of spasticity and twitching, and the sequelae of stroke, such as flaccidity, increased tone, proprioception, as well as movement that requires retraining.

EA

EA can protect the brain following acute cerebral ischemia, demonstrated by measurement of evoked potentials and electroencephalograms and by detection of changes in the levels of neurochemicals such as NO, endothelin, angiotensin and nerve growth factor (NGF). In some conditions, EA has been found to regulate blood vessel diameter to maintain balance.[21] EA may increase peripheral dilatation, which appears to be mediated by 5-HT as well as peptides such as vasoactive intestinal peptide (VIP) and calcitonin gene–related peptide (CGRP), and has the capacity to alter levels of several blood constituents including red blood cell membrane characteristics.[15]

EA may also increase neuronal survival after a lesion and promote regeneration of peripheral nerves. In the immune system, EA may impact both humoral and cellular function with useful biphasic regulatory effects. The release of adrenocorticotropic hormone (ACTH) and segmental reflex mechanisms may also affect central mechanisms.[15]

Changes in blood flow and edema are likely greater with EA than manual acupuncture (MA). Therefore, EA tends to enhance tissue repair including that of nerves. The effects of both MA and EA are evident in studies on brain oxygenation, pituitary enzyme release, muscle function in patients with cerebral ischemia, pain thresholds and analgesia.[15]

Different frequencies of electrical stimulation have been used at traditional acupuncture points, but usually strong stimulation from 1–5 Hz with a TENS unit has been applied to induce electrical acupuncture for the primary symptom of hemiplegia.[15] The frequency of treatments suggested by Maciocia[22] is daily within 3 months of a stroke, or on alternate days if administered after 3 months. A break in treatment can be given every 2 weeks. According to a meta-analysis of Chinese randomized controlled trials (RCTs), the median number of treatments given was 38 over 30 days—the intensity of such treatments compared more favorably to the less intensive Western approaches, with less convincing results. A systematic review of the effectiveness of acupuncture for stroke was evaluated.[23] RCTs that compared any form of needle insertion with any form of non-acupuncture control intervention in the treatment of human stroke patients were eligible. Nine RCTs recruiting a total of 538 patients were included. Of these, six yielded positive results, suggesting that acupuncture is effective, and three reported negative findings, implying that acupuncture is not superior to control treatment. Due to the heterogeneous nature of the stages of stroke among these patients and of the treatments applied, it was considered that further investigations are warranted.

Differences between MA and EA

When pulsed or direct currents from low-voltage devices, including traditional TENS devices, are applied transcutaneously to traditional acupuncture points, trigger points or motor points through a small-diameter metal probe electrode, the current density and the transcutaneous resistance are very high.[15] This same effect, without the surface noxious sensation and sensory paresthesia, can be applied through a needle with the TENS/EA application on both traditional acupuncture points and motor points, and it is postulated that the principle of stimulating these points may improve muscle contraction and thereby strength.

A pilot study of functional magnetic resonance imaging (fMRI) of the brain during MA and EA at LI4 in normal subjects delineated differences in the activation of brain areas. MA produced prominent decreases in fMRI signals of the posterior cingulate, superior central gyrus and the putamen/insula. EA produced an increase in fMRI signals of the precentral gyrus, postcentral gyrus and inferior parietal lobule/putamen.[21]

It should be noted that patients who have experienced brain trauma may not react to MA or EA in the same way as healthy volunteers.

Neuromuscular and functional electrical stimulation

Among the monotherapies, NMES/FES has been used to reduce spasticity and flaccidity and improve range of motion in patients after stroke. However, contradictory results have been reported in clinical trials. A placebo-controlled RCT study indicated that FES improves motor recovery of the lower extremity and walking ability of subjects with a first acute stroke.[24]

A systematic review and meta-analysis of RCTs of electrical stimulation of spastic muscles after stroke evaluated 29 RCTs with 940 subjects.[25] The effect of NMES with and without another therapy on spastic muscles after stroke was compared with placebo or another intervention. It was concluded that NMES combined with other interventional modalities may be considered to represent a treatment option that provides improvements in spasticity and range of motor ability post stroke.

An adjunctive rehabilitation protocol could combine the prior experience of others and reorganization of concepts that may develop innovative and experiential pathways that may ultimately expedite rehabilitation and achieve individuals' goals. The main premise in a program of this nature is to accept that lack of mobility (especially flaccidity) may create disuse over months or years, weakness, and an inability to perform movements even if the motor cortex could activate these pathways.

Summary

Prolonged non-use as in TBI, especially with flaccidity, may produce profound weakness that can eventually even promote fibromuscular changes. Rehabilitation in hemiplegia may be expedited by stimulation of both nerve supply and muscles in the areas affected. It seems incumbent to explore areas of nerve conduction that appear dormant and excite these nerve pathways to enable the patient to improve muscular function. Therefore, stimulation of peripheral nerve pathways could become a necessary concept to improve general rehabilitation. The combined effect of any strengthening program, albeit passive, must also impact upon central circuits, thereby increasing plasticity.

Declaration of conflicting interests

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