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Effect of Transcranial Direct Current Stimulation on Cortical Excitability in Stroke Patients: Review Article

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ABSTRACT
Background: A primary consequence of stroke is an inhibitory imbalance and asymmetry of cortical excitability between the contralesional and ipsilesional cerebral hemispheres, which can lead to numerous dysfunctions and impede recovery. Despite the fact that rehabilitation techniques have advanced significantly in recent years, motor and functional recovery are still insufficient, necessitating the ongoing development of novel approaches. A non-invasive technique called transcranial direct current stimulation (tDCS) can be used to restore normal excitability following a stroke.
Objective: This review aimed to illustrate the role of tDCS in stroke in terms of modulating the excitability changes.
Methods: We searched Science Direct, Google Scholar, and PubMed for cortical excitability, Stroke and Transcranial direct current stimulation. The authors also reviewed references from pertinent literature, however only the most recent or comprehensive studies from December 2011 to February 2024 were reviewed. Documents in languages other than English were disqualified due to lack of translation-related sources. Papers such as unpublished manuscripts, oral presentations, conference abstracts, and dissertations that were not part of larger scientific studies were excluded.
Conclusion: A review of the current literature concluded that using tDCS can stabilize the excitability changes and consequently enhance stroke motor recovery results, particularly when combined with traditional rehabilitation approaches. Further high quality studies are necessary to support the evidence-based practice of this stimulation approach.
Keywords: Cortical excitability, Stroke, Transcranial direct current stimulation.

INTRODUCTION

A stroke is a type of cerebrovascular illness that is defined as a clinically defined condition of localised neurological impairments that lasts longer than a day and is caused by ischemia or haemorrhage in the central nervous system [1]. The majority of stroke disorders are caused by ischemic stroke, which also causes thrombotic or embolic abnormalities in the brain. In thrombosis, blood clots develop as a result of atherosclerosis-related vascular constriction that impairs blood flow. In an embolic stroke, embolism restricts blood supply to the brain's tissues, leading to severe metabolic stress and the loss of neurons [2].

Less than 20% of strokes are hemorrhagic strokes. It happens when a cerebral artery bursts, most frequently as a result of amyloidosis or hypertension. When a vessel bursts, hematomas develop and the surrounding tissues are mechanically compressed, which can cause secondary injuries such as disruption of the blood-brain barrier, edema enlargement, and neuronal injury [3].

For people over 60, stroke is currently the leading cause of significant long-term impairment. Even while the death rate has decreased recently, over half of stroke patients will experience severe impairments in their mobility, cognitive function, and capacity to carry out everyday tasks [4].

About 6 million people die from strokes each year, making it the second leading cause of mortality globally. In terms of the total number of deaths and disabilities caused, stroke ranks third. About 50% of those who survive a stroke are permanently disabled. Stroke incidence and socioeconomic status have a significant negative relationship, which is most noticeable in low-income nations where there is a severe shortage of hospital resources [2, 5].

Effect of stroke on cortical excitability and performance

An inhibitory imbalance between the affected and non-affected hemispheres following a stroke is commonly detected, and it can result in motor dysfunction following recovery. When it comes to the complaints of these patients, motor function is the primary evaluation factor and the most important issue[6-7]. Performance losses are caused by a stroke's reduced activity in the afflicted hemisphere and unopposed inhibition from the unaffected hemisphere. There is an increase in this inhibitory imbalance when patients prefer to do activities of daily living (ADL) with the unaffected extremity [8]. Reducing excitability in the unaffected hemisphere or increasing it in the afflicted hemisphere later on may facilitate recovery [6, 9, 10].

Enhancing the motor function of stroke victims is essential to improve their quality of life (QoL), lessen their social impact and financial burden, and lower the rate of disability [11]. Neurological therapies tend to focus on the relationship between symptoms and brain tissue damage, whereas rehabilitation interventions tend to focus on the relationship between symptoms and function. In stroke therapy, there is a crucial distinction between motor and functional recovery [12].

Functional recovery is the enhancement of ADL performance (housekeeping, cooking), mobility (transfers, wheelchair usage), or communication. Motor recovery is the alleviation of motor symptoms such as weakness or ataxia. Even in cases where motor

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recovery is completely absent, functional recovery is likely [12].

Rehabilitation therapies are essential in the treatment of stroke and are frequently used to retrain motor function. Neuroplasticity can be manipulated by effective rehabilitation treatments to enhance motor function recovery and QoL [11, 13].

Focused motor practice is crucial to aid in the healing of motor deficits following a stroke. It is also crucial to know that in order to promote cerebral plasticity, retention, and the restoration of lost abilities, acquiring new skills through physical therapy modalities is necessary [6].

Application of transcranial direct current stimulation (tDCS) in stroke:

To promote neuroplasticity in the cerebral cortex, tDCS is a non-invasive technique. Corticospinal excitability may be selectively altered by tDCS [9, 14, 15]. tDCS changes resting membrane potential, as demonstrated by animal models. Anodal stimulation causes neurons to depolarize, whereas cathodal stimulation causes neurons to hyperpolarize. Alterations in intracellular calcium concentrations have the potential to magnify adjustments brought on by stimulation [16].

Since almost all tissues and cells are susceptible to electric fields, tDCS may potentially cause modifications in the brain's non-neuronal tissues, such as endothelial or glial cells. The therapeutic benefits of tDCS may possibly include these non-neuronal effects, which have not yet been thoroughly identified [17].

To apply tDCS, two superficial electrodes are placed on the scalp to produce a weak direct current. The advantages of tDCS over other stimulation techniques are its low cost, mobility, and safety [18].

tDCS uses low amplitude currents, ranging from 0.5 to 2 milliamperes. A number of models for the application of tDCS are available: (a) Anodal stimulation, which increases cortical excitability; this model is positioned on the ipsilesional cerebral hemisphere in stroke cases (b) Cathodal stimulation, which decreases cortical excitability; this model is positioned on the contralesional cerebral hemisphere in stroke cases, and (c) dual stimulation, which combines anodal and cathodal stimulation [19]. tDCS is frequently utilised to activate the motor region (M1) in stroke patients [14, 19].

The effects of tDCS extend beyond the location of stimulation and can modify the functional networks that connect neighbouring brain regions. It has been shown that tDCS can improve the brain's local blood flow, which aids in reducing inflammation and preserving neurons in ischemic regions [14].

The excitability of the ipsilesional hemisphere is lower than that of the contralesional hemisphere following a stroke, and this asymmetry becomes less pronounced in the first three months of recovery. This was shown by a decrease in the ipsilesional resting motor threshold, which coincided with better upper limb (UL) results [20].

The subacute period of stroke is thought to present a favourable opportunity for tDCS to alter the excitability of the ipsilesional and contralesional hemispheres because neurophysiological changes promote spontaneous recovery during this stage [20]. Electroencephalography and motor evoked potential results supported the considerable effect of anodal tDCS at 1 mA for 20 minutes in subacute stroke patients [21, 22].

Adding tDCS to motor rehabilitation:

In order to maximise advantages over therapy alone [8, 24, 25], tDCS might be used to increase cortical excitability in stroke patients in conjunction with motor rehabilitation [6, 23]. It can also reinforce the long-term benefits of motor rehabilitation following a stroke.

Numerous studies have shown the usefulness of tDCS, mostly as an adjunct to rehabilitation, and its benefits may extend into the chronic phase of stroke recovery [27]. Significant effects of tDCS usage were shown in a research by **Van Hoornweder *et al.*** [28] notably in patients with chronic stroke.

Using anodal tDCS over the lower limb (LL) motor region in conjunction with traditional physical therapy methods increases the excitability of the affected area, which in turn improves motor recovery in subacute stroke patients. Consequently, tDCS may be applied as a supplemental measure to enhance LL results in stroke patients [20]. By restoring equilibrium between the afflicted and unaffected hemispheres, tDCS can aid in motor recovery [7]. When dual tDCS is applied in conjunction with constraint-induced movement therapy (CIMT) or its modified form, (mCIMT), synergistic benefits are achieved as the two interventions have a similar neural recovery principle [29]. In various stages of stroke recovery, functional independence and upper limb motor functioning were examined in a number of randomised clinical trials that studied the impact of adding tDCS as an extra treatment to CIMT or mCIMT. The majority of these studies found that tDCS significantly improved these outcomes[25–30].

CONCLUSION

The use of tDCS for motor areas may provide further advantages for stroke patients. It can alter cortical excitability and counteract the inhibitory imbalance between the afflicted and unaffected hemispheres that occurs after a stroke, so improving stroke recovery. The addition of tDCS to standard physical therapy methods is seen to be a viable technique in the rehabilitation of stroke patients, since it can improve the outcomes of these methods. Despite these promising findings, further primary and secondary research are needed to establish sufficient evidence for using this form of stimulation in clinical practice.

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