COMMENTARY

Recommendations for enhancing research outcomes and the efficacy of transcranial direct current stimulation in post-stroke motor rehabilitation for local settings

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ABSTRACT

Transcranial direct current stimulation (tDCS) has emerged as a potential adjunct therapy for post-stroke motor rehabilitation. While conventional rehabilitation methods remain the primary approach to improving motor function after stroke, many patients experience incomplete recovery, necessitating the exploration of additional interventions. This commentary article examines the role of tDCS in post-stroke motor recovery, focusing on its mechanisms, efficacy, and limitations. Herein, the variability in research findings and individual patient responses as well as the recommended methods for optimising tDCS use in local clinical settings are highlighted.

KEYWORDS:
Transcranial direct current stimulation, non-invasive brain stimulation

INTRODUCTION

Post-stroke motor impairment is a common consequence of ischaemic and haemorrhagic stroke, affecting millions of people worldwide. Motor deficits, including weakness, spasticity, and impaired coordination, lead to significant disability and reduced quality of life.[1] Conventional rehabilitation, which aims to mitigate these deficits, primarily involves physical (PT) and occupational therapy (OT). However, despite prolonged rehabilitation, many stroke survivors experience limited functional recovery, necessitating adjunctive therapies.

Transcranial direct current stimulation (tDCS) is an emerging non-invasive brain stimulation technique that has demonstrated the potential to enhance neuroplasticity and motor recovery in stroke patients.[2] While early research suggests promising outcomes, challenges such as individual variability and inconsistent findings continue to hinder its widespread application.

In Malaysia, the adoption of tDCS as an adjunctive therapy for post-stroke motor recovery as well as the availability of local research on this technique remain limited. To the best of the author's knowledge, this service is currently available in only a few teaching hospitals, private hospitals, and one government rehabilitation centre. However, there is no information regarding its use in Ministry of Health hospitals. To date, only one case series and a technical report from the Ministry of Health have been published, and only one tDCS model for research purposes is registered with the Malaysia Medical Device Authority. This limited adoption and research base highlight the need for greater awareness, resources, and local studies to explore the potential of tDCS in improving stroke rehabilitation outcomes in Malaysia.

ROLES OF tDCS

tDCS is a cost-effective, portable, and user-friendly alternative to transcranial magnetic stimulation (TMS), enhancing its accessibility for clinical applications. It is generally well-tolerated, with minimal reported side effects. Notably, no seizures associated with tDCS have been documented in the literature to date.

tDCS delivers low-intensity electrical currents via electrodes placed on the scalp, thereby modulating cortical excitability.[2] By altering neuronal excitability, this procedure promotes neuroplasticity and potentially enhances the brain's capacity for motor learning and recovery.[2,3] Depending on electrode placement and current polarity, tDCS can either increase or decrease the excitability of targeted brain regions, facilitating long-term potentiation (LTP) or depression (LTD), both of which are critical in neuroplasticity.[4]

In post-stroke motor rehabilitation, tDCS typically targets the motor and premotor cortices, aiming to stimulate the areas involved in motor function. Several studies have demonstrated that tDCS can aid in motor recovery by improving the brain's ability to reorganise and form new neural connections, leading to positive outcomes in upper limb mobility, gait, balance, and spasticity.[1,2,4-7] Notably, combining this procedure with task-specific motor activity has been shown to amplify its effects.[5,6] For instance, tDCS combined with PT or OT often results in more significant improvements in motor function than when either therapy is used alone.

CHALLENGES

Despite these encouraging findings, several challenges limit the widespread adoption of tDCS in post-stroke motor rehabilitation in Malaysia. Specifically, these challenges can be divided into general and local settings.

This article was accepted: 26 December 2024
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i) Technological and Methodological Gaps

The main challenge faced by most healthcare professionals using tDCS is the inconsistency in research results regarding the overall efficacy of tDCS.[8] While some studies demonstrated substantial benefits, others reported little to no improvement in patient outcomes. This inconsistency can be attributed to diverse biological and patient factors. Biological differences among patients, such as variations in cortical pyramidal cell orientations and their cortical layers,[9] as well as synaptic neurotransmitter concentrations,[3] could impact how tDCS affects neuroplasticity. Patient heterogeneity, such as differences in stroke location, severity, and time since onset, further complicates the predictability of outcomes.

Procedural differences can also exacerbate these inconsistencies. Variations in study design, such as differences in electrode placement, stimulation intensity, and session duration, can result in variable outcomes. These factors make it difficult to standardise protocols and draw definitive conclusions regarding the effectiveness of tDCS across different patient populations.

Compared to TMS, tDCS offers less spatial and temporal precision, which limits its ability to target specific brain regions with high accuracy. The effects of tDCS are typically more subtle and often require multiple sessions to achieve clinically significant outcomes. To address these limitations, advanced navigation tools such as high-definition tDCS (HD-tDCS) have been developed. HD-tDCS allows for the precise delivery of direct currents to both cortical and deeper brain structures, improving the accuracy and effectiveness of stimulation. Despite its potential advantages, the adoption of HD-tDCS in Malaysia remains limited, primarily due to the substantial costs associated with the technology. As a result, alternative approaches, such as using neuroimaging to enhance the precision of electrode placement, are often favoured.

ii) Limited Availability of tDCS Services in Local Settings

The availability of tDCS services across Malaysia remains limited, particularly within public healthcare facilities. Non-invasive brain stimulation techniques, including tDCS, have yet to gain widespread recognition as a standard component of stroke management. This lack of integration into neurorehabilitation programmes restricts access for many patients who might benefit from its application. The scarcity of accessible tDCS services poses a significant challenge, hindering the delivery of comprehensive neurorehabilitation and limiting opportunities for recovery in post-stroke patients.

iii) Trained Personnel for Administering tDCS

A significant challenge in the utilisation of tDCS is the shortage of healthcare providers adequately trained in its administration. Inadequate training can result in improper application, leading to suboptimal patient outcomes or potential adverse effects, thereby compromising patient safety and undermining confidence in tDCS as a therapeutic option. Furthermore, the effective use of tDCS requires the careful selection of suitable candidates, a process that demands thorough assessments by experienced specialists in the field of neuroscience and brain stimulation techniques. These challenges highlight the need for structured training programs and credentialing systems to ensure that healthcare providers are equipped with the necessary skills and knowledge to safely and effectively deliver tDCS. Strengthening professional competence in this area is essential for maximizing the therapeutic potential of tDCS while maintaining high patient care standards.

iv) Lack of Local Research and Publications

The scarcity of locally conducted research and publications on tDCS in Malaysia presents a significant barrier to its utilisation in clinical practice. This gap limits the development of evidence-based approaches tailored to the specific needs and characteristics of the local population and makes it challenging to effectively advocate for the adoption of tDCS in healthcare settings. Moreover, the lack of comprehensive studies on cost-effectiveness, long-term outcomes, and safety further impedes its widespread implementation. Addressing this issue requires prioritizing local research initiatives and fostering collaborations among clinicians, researchers, and academic institutions to build a stronger evidence base for tDCS within Malaysia's healthcare system.

RECOMMENDATIONS

Several strategies can be implemented to address these challenges and improve research outcomes and the efficacy of tDCS in post-stroke motor rehabilitation in Malaysia.

i) Patient-Specific Assessment and Protocol

a) Individualised Assessment: Given the biological variability among patients, a thorough evaluation of neuronal damage after stroke is crucial. In the absence of advanced navigation tools in our local clinical and research settings, a strong foundation in neuroanatomy and the interpretation of neuroimaging, such as computed tomography (CT) and magnetic resonance imaging (MRI), becomes indispensable for precise electrode placement. Pre-stimulation neuroimaging, combined with comprehensive clinical assessment, should be employed to determine the location and extent of lesions. A deep understanding of neuroanatomy and motor representation, particularly the homunculus, is invaluable in guiding electrode positioning and optimising targeted stimulation, thereby enhancing the likelihood of a favourable response. Moving away from a single standardized, one-size-fits-all approach, such as universally stimulating the contralateral C3 and C4 regions for motor weakness irrespective of the severity of neuronal damage, is essential for achieving better outcomes.

b) Patient-Specific Protocols: Tailoring tDCS protocols to individual patients is vital. Factors, such as stroke severity, time since onset, and specific motor impairments, should be considered when designing treatment plans. Standardised scales, such as the Medical Research Council (MRC) scale for motor strength, the Fugl-Meyer Assessment for motor function, and the Modified Ashworth Scale for spasticity, should be used to document patient progress and employ appropriate treatment adjustments. Accurate documentation of patient characteristics and treatment protocols, including the device used, is also essential for facilitating comparisons between institutions and improving research outcomes.

ii) Combining tDCS with Conventional Therapy

The combination of tDCS with PT or OT can significantly enhance the efficacy of the procedure. Research suggests that the synergistic effect of pairing brain stimulation with active motor tasks amplifies neuroplasticity, facilitating greater functional recovery.[5,6] Studies have demonstrated that administering tDCS during rehabilitation exercises ('online') or immediately afterward ('offline') optimises recovery outcomes by targeting the brain's heightened responsiveness to therapy during these periods.

iii) Enhance Training and Skill Development

The development and implementation of comprehensive training programs and certifications for healthcare providers, including both medical practitioners and paramedics, are fundamental to expanding the use of tDCS in clinical and research settings. These programs should focus on equipping participants with the theoretical knowledge and practical skills necessary for safe and effective tDCS delivery. Continuous education initiatives, such as interactive workshops, online courses, and hands-on training sessions, are essential to keep providers updated on the latest advancements in tDCS technology, emerging applications, and evidence-based practices. Disseminating new findings and treatment protocols through these platforms will enhance providers' competency and confidence in applying tDCS. Furthermore, fostering international collaboration with global experts and leading institutions can bring advanced training modules and best practices to Malaysia. Such partnerships not only improve the quality of training but also enable knowledge exchange and exposure to innovative methodologies.

iv) Foster Research and Publications

Promoting collaboration among universities, clinical institutions, and international partners is essential to advancing tDCS research and addressing knowledge gaps. Priority research areas should include investigating factors that contribute to individual variability in treatment response, and developing refined, personalised treatment protocols that can be effectively implemented on a larger scale. Moreover, supporting academic publications and disseminating findings through peer-reviewed journals can strengthen evidence-based practices. Where resources allow, advanced imaging techniques, such as quantitative electroencephalography (QEEG) and diffusion tensor imaging (DTI) tractography, could be utilised to better identify the target areas for stimulation, thereby improving the accuracy and outcomes of tDCS interventions.

v) Expand Accessibility to tDCS Services

Expanding tDCS services in public healthcare institutions is essential to improve accessibility for patients. To further broaden the reach of these services, fostering public-private partnerships can play a pivotal role, enabling collaboration between sectors to enhance resource allocation and service delivery. Additionally, the establishment of a national multidisciplinary tDCS task force comprising clinicians and researchers could help address service gaps and define research priorities. Establishing clear referral guidelines to streamline interdisciplinary referrals for stroke patients to receive tDCS treatment will further promote its clinical adoption. Such measures are key to improving accessibility, awareness, and the effective use of tDCS, ultimately enhancing outcomes in post-stroke motor recovery.

CONCLUSION

tDCS represents a promising adjunctive therapy for post-stroke motor rehabilitation that potentially enhances motor recovery through neuroplasticity. However, challenges related to inconsistent research findings, individual variability, and limited accessibility must be addressed. By implementing individualised treatment protocols, integrating tDCS with conventional therapies, and fostering greater awareness and training among healthcare professionals, this technique can be effectively incorporated into stroke rehabilitation programs. Continued research and collaboration are essential to optimise its use and provide additional treatment options for functionally impaired stroke survivors.

ACKNOWLEDGEMENTS

The author would like to acknowledge Universiti Malaysia Sarawak for the support provided in facilitating this publication.

REFERENCES

1. Dong K, Meng S, Guo Z, Zhang R, Xu P, Yuan E, et al. The effects of transcranial direct current stimulation on balance and gait in stroke patients: A systematic review and meta-analysis. Front Neurol 2021; 12: 650925.
2. Bao SC, Khan A, Song R, Kai-Yu Tong R. Rewiring the lesioned brain: Electrical stimulation for post-stroke motor restoration. J Stroke 2020; 22(1): 47-63.
3. Barbati SA, Podda MV, Grassi C. Tuning brain networks: The emerging role of transcranial direct current stimulation on structural plasticity. Front Cell Neurosci. 2022; 16: 945777.
4. Agboada D, Mosayebi-Samani M, Kuo MF, Nitsche MA. Induction of long-term potentiation-like plasticity in the primary motor cortex with repeated anodal transcranial direct current stimulation - Better effects with intensified protocols? Brain Stimul 2020; 13(4): 987-97.
5. Wong PL, Yang YR, Tang SC, Huang SF, Wang RY. Comparing different montages of transcranial direct current stimulation on dual-task walking and cortical activity in chronic stroke: double-blinded randomised controlled trial. BMC Neurol. 2022; 22(1): 119.
6. Kashoo FZ, Al-Baradie RS, Alzahrani M, Alanazi A, Manzar MD, Gugnani A, et al. Effect of transcranial direct current stimulation augmented with motor imagery and upper-limb functional training for upper-limb stroke rehabilitation: A prospective randomized controlled trial. Int J Environ Res Public Health. 2022; 19(22): 15199.
7. Wang X, Ge L, Hu H, Yan L, Li L. Effects of noninvasive brain stimulation on post-stroke spasticity: A systematic review and meta-analysis of randomized controlled trials. Brain Sci. 2022; 12(7): 836.
8. Feng W, Kautz SA, Schlaug G, Meinzer C, George MS, Chhatbar PY. Transcranial direct current stimulation for post-stroke motor recovery: challenges and opportunities. PM R. 2018; 10(9 Suppl 2): S157-S164.
9. Sánchez-León CA, Campos GS, Fernández M, Sánchez-López A, Medina JF, Márquez-Ruiz J. Somatodendritic orientation determines tDCS-induced neuromodulation of Purkinje cell activity in awake mice. bioRxiv [Preprint]. 2024; 2023.02.18.529047.
10. Kim E, Lee G, Lee J, Kim YH. Simultaneous high-definition transcranial direct current stimulation and robot-assisted gait training in stroke patients. Sci Rep. 2024; 14(1): 4483.