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Letter to the Editor

Center of Pressure Speed Changes with tDCS Versus GVS in Patients with Lateropulsion after Stroke

Dear Editor:

We offer this letter to spark discussion about potential transcranial methods to augment rehabilitation to ameliorate lateropulsion after stroke. Patients with lateropulsion after stroke, also known as 'pusher syndrome,' actively push themselves to the weak side and resist passive correction of the posture to the vertical upright [1]. Various lesion sites along pathways which formulate subjective perceptions of verticality have been implicated in lateropulsion. Transcranial direct current stimulation (tDCS) or galvanic vestibular stimulation (GVS) over parts of the impaired pathways may change seated center of pressure for patients with lateropulsion and provide insight into the nature of the lesioned pathway. The parietal-insular vestibular cortex (PIVC) is a multi-modal cortical region that synthesizes sensory input from vestibular, somatosensory, and visual systems to allow dynamic regulation of postural orientation [2]. In addition, trans-mastoidal galvanic vestibular stimulation (GVS) may provide a means of augmenting vestibular neural systems controlling posture and balance. Both tDCS and GVS could be used to impact posture before, during or after physical therapy sessions [3] because they are portable, safe and well-tolerated. We tested the hypotheses that anodal upregulation on the lesion side via tDCS over the area of the PIVC or GVS might change tonic seated posture, as measured by the speed of the center of pressure, in the frontal plane.

Nine patients with ischemic stroke with Burke Lateropulsion Scale (BLS) scores of 2 or greater (BLS range 0 to 17, 17 = maximal lateropulsion) [4] admitted to an inpatient rehabilitation facility participated in this pilot study.¹ Patients were: at least one week post ischemic stroke, able to sit for at least 25 minutes, cleared by admitting physician for study participation, and able to verbalize. Excluded patients had: hemorrhagic stroke, history of seizure or receiving medications that may lower seizure threshold, implanted cardiac devices, prior craniotomy, or cervical fusions with metallic implant.

tDCS and GVS were delivered using a Starstim current limited stimulator (Neuroelectronics®, Cambridge, MA, USA) via two 25 cm² saline-soaked sponge electrodes. Patients were blinded to randomized stimulation sequences on different days: A) bipolar-balanced tDCS anode over the ipsilesional PIVC, defined as the circumcenter of a triangle defined by EEG locations P3, C3, T3 for left brain lesions; and P4, C4, T4 for right brain lesions. The cathode was placed in the

same location on the contralesional side; B) tDCS with anode over the ipsilesional PIVC as for condition A, but with the cathode placed over the contralateral supraorbital region; C) trans-mastoidal GVS with anode over the mastoid on the lesion side; D) sham stimulation with electrodes randomized to one of the above montages but with 30-sec ramp-up to 2 mA then immediate ramp down to 0 mA for the remainder of the test period.

Patients were seated in a specialized chair mounted on an AMTI™ (Advanced Mechanical Technology, Inc., Watertown, MA, USA) force plate, which measured the center of pressure (COP) of the subject over time. AcqKnowledge® software (BioPac® Systems, Inc., Goleta, CA, USA) collected data. A 4th order, low-pass Butterworth filter with a cut-off frequency of 10 Hz was applied. Baseline assessments of COP were recorded for 1 min. A stimulation protocol was initiated and subsequent 1-min recordings of COP were taken at 5, 10, and 15 min. Stimulation was stopped and a final 1-min recording was taken at 20 min.

Data were analyzed using a linear mixed-effect model with time (T0 to T4) and stimulation conditions (A, B, C, and D) as the fixed effects and subject as random effect. The primary outcome variable, mean speed of COP in the roll plane (COP-Xs), was operationally defined as the average speed (cm/s) of oscillation of the displacement of COP [5]. Means were compared using orthogonal contrasts via *t* statistics ($p < .05$, SAS System version 9.2 (SAS Institute Inc., Cary, NC, USA)).

The Fig. 1 illustrates a small but significant increase in mean COP-X speed for Condition A versus D at T1 ($\bar{X}_{diff} = 0.13$ cm/s, 95% CI 0.002 to 0.25, $p = .04$, effect size = 0.22). Mean COP-Xs did not differ significantly for conditions B and C compared to sham condition at any of the time intervals studied. Mean COP-Xs was also significantly different for condition A between time points T0 and T1 ($\bar{X}_{diff} = 0.17$ cm/s, 95% CI 0.05 to 0.29, $p < .001$, effect size = 0.53). Mean COP-Xs did not differ significantly between respective time points for montages B, C and D.

We need to be conservative about the interpretation of these results due to the small sample size. However, the findings open the possibility that anodal stimulation of the affected PIVC and cathodal inhibition of the contralesional "disinhibited" PIVC may reduce the contralesional tonic bias of seated posture of patients with post-stroke lateropulsion. Restoration of "normal" bilateral PIVC balance may provide an opportunity for training more accurate postural control at least for a brief initial interval of tDCS. These findings also indicate that vestibular stimulation via GVS did not change mean COP-Xs as explained in previous studies with healthy subjects [6,7]. The lack of change via GVS may strengthen the argument that postural awareness and control are cortical functions that prioritize visual and proprioceptive sensory input over direct vestibular sensory input. The current density used in our study (2 mA/25 cm² or 0.08 mA/cm²), as described previously [6], may have been too weak to produce an adequate, prolonged neuronal response.

These observations are important to publicize as they may lead to the next step in study design. We plan to explore the use of 2 mA

¹ The study was approved by the Committee on Human Rights in Research (IRB) of the institution. Informed consent was obtained both from the patient and their next-of-kin or health care proxy.

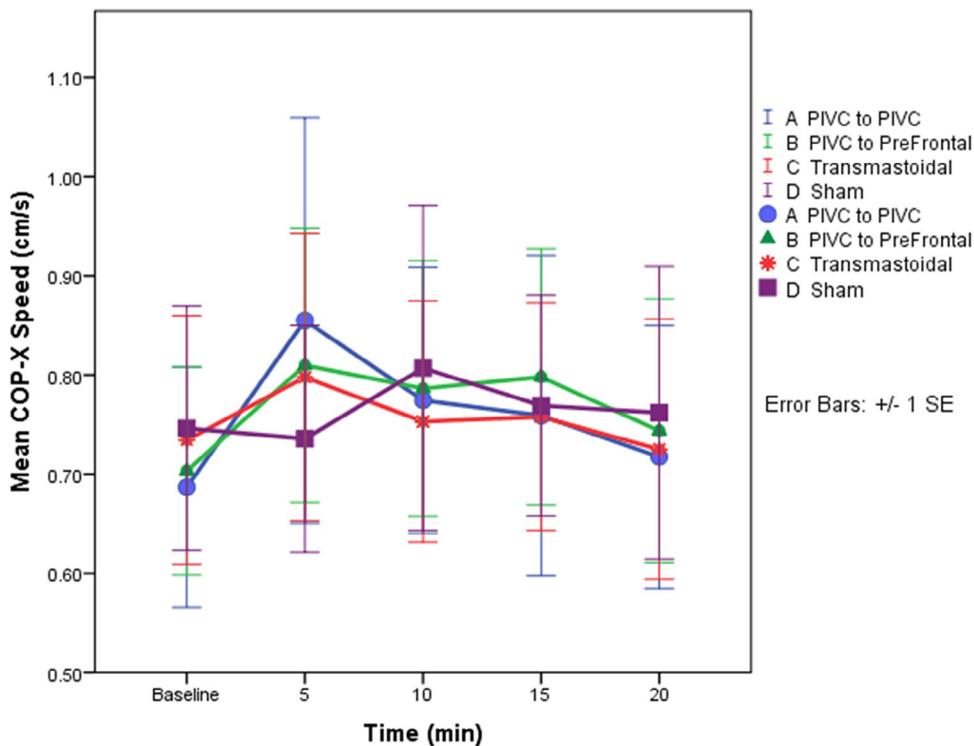


Figure 1. Mean and standard error of speed of oscillation of the center of pressure in the medial-lateral plane (COP-Xs) for each stimulation condition at different times. Condition A: anode over ipsilesional parietal-insular vestibular cortex (PIVC)/cathode over opposite PIVC; Condition B: anode over ipsilesional PIVC/cathode over opposite pre-frontal region; Condition C: anode over ipsilesional mastoid/cathode over opposite mastoid (GVS); Condition D: sham condition. T0: before stimulation; T1: 5 min during stimulation; T2: 10 min during stimulation; T3: 15 min during stimulation; T4: 5 min after the end of stimulation.

delivered via smaller 3.14 cm² gel filled electrodes (0.64 mA/cm²) allowing delivery of higher current density without an increase in skin irritation. Increasing the stimulation duration, and coupling tDCS or GVS with active therapist-guided lateropulsion intervention also warrant further study.

In summary, bilateral stimulation over PIVC but not trans-mastoidal GVS or unilateral stimulation over PIVC produced a small but significant increase in mean COP-X speed when initially applied. Further exploration of alternative tDCS or GVS strategies seems warranted.

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Suzanne Babyar*
Hunter College, The City University of New York,
NY, USA

Taiza Santos-Pontelli
Department of Neuroscience and Behavioral Sciences,
Ribeirão Preto Medical School, University of São Paulo,
Ribeirão Preto, SP, Brazil

Tenysson Will-Lemos
Department of Biomechanics, Medicine and Rehabilitation of
Locomotor System, Ribeirão Preto Medical School,
University of São Paulo, Ribeirão Preto, SP, Brazil

Suleimy Mazin
Department of Neuroscience and Behavioral Sciences,
Ribeirão Preto Medical School, University of São Paulo,
Ribeirão Preto, SP, Brazil

Marom Bikson, Dennis Q. Truong
Neural Engineering Laboratory,
Department of Biomedical Engineering,
The City College of New York of the City University of New York,
New York, NY, USA

Dylan Edwards
Department of Neurology, Weill Cornell Medical College,
New York, NY, USA

Laboratory for Non-Invasive Brain Stimulation and Human Motor
Control, Burke Medical Research Institute,
White Plains, NY, USA

Michael Reding
Department of Neurology, Burke Rehabilitation Hospital,
White Plains, NY, USA

* Corresponding author. Burke Rehabilitation Hospital, 785
Mamaroneck Avenue, White Plains, NY 10605, USA
Tel.: +1 914 597 2839; fax: +1 914 597 2259
E-mail address: sbabyar@burke.org (S. Babyar)

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