Enhancing Cortical Representational Plasticity with Non-Invasive Direct Current Stimulation to Accelerate Upper Limb Recovery in Quadriplegia
Motor Rehabilitation

Kelsey Potter-Baker, Daniel Janini, Nicole Varnerin, David Cunningham, Vishwanath Sankarasubramanian, Ken Sakaie, Frederick Frost, Ela Plow
Cleveland Clinic Foundation, Cleveland, OH, USA

Current published work suggests that a minimum of 9 months of rehabilitation is required to elicit significant improvement in upper limb function following incomplete spinal cord injury (iSCI). With over 12,500 new cases and a prevalence of 337,000 in the U.S. alone, however, such extensive rehabilitation programs are impractical. Here, we tested the hypothesis that the brain and its residual descending pathways represent the most spared, and hence ideal, innovative targets for maximizing and accelerating upper limb recovery in iSCI. In particular, since loss of representation of weaker muscles in the motor cortex exaggerates muscle weakness and limits recovery following iSCI, we aimed to boost inherent adaptive plasticity of weak representations using transcranial direct current stimulation (tDCS). We hypothesized that tDCS would accelerate increases in weak muscle cortical representational plasticity while also enhancing excitability of their descending pathways to paretic limbs to ultimately maximize functional outcomes following rehabilitation. To test our hypothesis, eight patients with chronic iSCI received either upper limb rehabilitation with tDCS (2 mA anodal) to motor cortical representations of weak muscles or rehabilitation alone. Representational plasticity was measured using TMS before and after treatment and diffusion tensor magnetic resonance imaging (DTI) quantified sparing of descending tracts. Functional recovery and muscle strength was assessed before and after treatment. We found that patients who received tDCS plus rehabilitation demonstrated significant focal increases in the cortical representation of their weaker muscle, where its excitability increased by 60% ($p<0.05$). Representational plasticity changes were associated with gains in motor function and muscle strength. In addition, level of recovery was related to cortical tract integrity, wherein patients that demonstrated the most recovery had greatest tract sparing following their iSCI ($r=0.97$; $p<0.0001$). Our results suggest that long-term pairing with tDCS applied to the motor cortex could result in significant functional improvements by facilitating more permanent plasticity of weaker cortical representations. Further, descending tract integrity, as measured with DTI, may serve as a valuable prognostic marker of impairment and functional recovery potential.