Neuroscience Letters 589 (2015) 115–120

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Effects of transcranial direct current stimulation on naming and cortical excitability in stroke patients with aphasia

Dongyu Wu[a,*,1], Jie Wang[a,1], Ying Yuan[b]

[a] Department of Rehabilitation, China–Japan Friendship Hospital, No. 2, Yinghuadongjie, Chaoyang District, PO Box 100029, Beijing, China
[b] Department of Rehabilitation, Xuanwu Hospital of Capital Medical University, China

HIGHLIGHTS

- Anodal tDCS over the left posterior perisylvian region can improve picture naming in new onset aphasic patients.
- Anodal tDCS may up-regulate excitability of a language network.
- Nonlinear dynamics analysis can reflect cortical activation during language tasks.

ARTICLE INFO

Article history:
Received 6 November 2014
Received in revised form
15 December 2014
Accepted 16 January 2015
Available online 17 January 2015

Keywords:
Aphasia
Brain stimulation
Electroencephalography
Nonlinear dynamics
Rehabilitation

ABSTRACT

This study aimed to investigate the effects of anodal transcranial direct current stimulation (A-tDCS) over the left posterior perisylvian region (PPR) on picture naming and cortical excitability measured with electroencephalography (EEG) nonlinear dynamics analysis (NDA) in aphasic patients. Twelve aphasic patients received 20 sessions of speech-language therapy during each of three phases: sham tDCS (Phase A1); A-tDCS to the left PPR (Phase B); and sham tDCS (Phase A2). Picture naming and auditory word-picture identification were measured before and after each phase. The EEG nonlinear index of approximate entropy (ApEn) was calculated for all subjects and 12 normal controls. Picture naming and auditory word-picture identification was significantly improved after phase B. The EEG ApEn analysis indicated that improved picture naming correlated with a higher activation level in wide areas of the left hemisphere and in isolated areas of the right hemisphere after phase B. These results revealed that A-tDCS over the left PPR coupled with speech-language therapy can improve picture naming and auditory comprehension in aphasic patients. tDCS not only modulates activity in the brain region directly underlying the stimulating electrode but also in a network of brain regions that are function-related.

1. Introduction

Transcranial direct current stimulation (tDCS), a non-invasive method, delivers a weak polarizing direct current (1–2 mA) to the cortex via two electrodes placed on the scalp. Cathodal stimulation (C-tDCS) reduces cortex excitability, whereas anodal stimulation (A-tDCS) increases cortex excitability.

Several studies of healthy and aphasic subjects have suggested that tDCS could be used to improve language performance through exciting or inhibiting corresponding cortical areas. Picture naming performance improved following C-tDCS over the right Broca's homologue area in ten aphasic patients [1]; and A-tDCS over the left frontal cortex in 10 patients with chronic stroke-induced aphasia [2], left posterior cortex in 8 chronic fluent aphasic patients [3], and the right temporo-parietal cortex in 12 chronic post-stroke aphasia patients [4]. Therefore, tDCS has been proposed as a clinical tool for rehabilitation of picture naming in brain-damaged patients and as a supplementary treatment approach for anomia [5].

Language function such as word repetition involves several cerebral areas, particularly the superior temporal gyrus responsible for spoken word recognition, articulatory representations in the ventral premotor cortex (vPM), and the posterior part of the inferior frontal gyrus (pIFG). The word repetition and picture-naming tasks are performed through the interactions of these areas. Therefore, local A-tDCS over the left PPR possibly could activate

* Corresponding author. Tel.: +86 10 84205968.
E-mail address: wudongyu73@hotmail.com (D. Wu).
1 Both authors contributed equally to this work.

http://dx.doi.org/10.1016/j.neulet.2015.01.045
0304-3940/© 2015 Published by Elsevier Ireland Ltd.

these anatomic regions and improve language performance in post-stroke aphasic patients.

In a study of arterial spin labeling, A-tDCS not only modulated activity in the brain region directly underlying the stimulating electrode, but also in a network of brain regions that were functionally related to the stimulated area [6]. Several issues have yet to be clearly addressed, such as the excitability status of the underlying cortical tissues before and after tDCS; how the cortical status of other regions is impacted or influenced if one area of the network was stimulated by A-tDCS; and whether cortical excitability is associated with language performance.

To the best of our knowledge, cortical neuroelectrical activation after A-tDCS in aphasic patients has not been studied. Moreover, tDCS may directly change the electrical activation of cortical neurons, and the most easily performed clinical technique for observing cortical electrical activation under different language tasks is electroencephalography (EEG).

EEG is thought to be complex and of limited predictability because its ultra-high dimensional nature makes it a stochastic system [7,8]. Nonlinear dynamics analysis (NDA) can characterize the dynamics of the neural networks underlying the EEG and provide a powerful tool for studying the dynamic changes and abstracting correlative information from cortical networks [9]. With NDA, the degree of suppression for unconscious patients is quantifiable. The changes in brain function in unconscious subjects can be captured by NDA, and may predict the prognosis of unconscious patients by assessing the interrelation among sensory and other residual cortical functional islands [10]. Therefore, NDA could be utilized to provide some information about cortical excitability.

The purpose of this study was to determine whether aphasic patients with a post-stroke onset of 3–6 months could benefit from tDCS plus speech-language therapy and to investigate cortical activation changes using NDA. Our hypotheses included the following: (1) A-tDCS over the left PPR may improve picture naming in post-stroke patients with aphasia and potentially enhance the cortex to a "near normal" activation pattern, which could be associated with better recovery. (2) NDA could reflect cortical activation under language tasks. To investigate, A-tDCS and sham tDCS were applied over the left PPR and the EEG nonlinear index of ApEn was calculated for all of the patients.

2. Methods

2.1. Design and procedures

Thirty minutes of daily speech-language therapy was provided over four weeks using an A1-B-A2 design. Sham tDCS was administered during Phases A1 and A2, and A-tDCS was given during Phase B. Each subject received a standardized aphasia assessment battery before and after each treatment phase. An EEG was recorded after each treatment phase. The trial structure is illustrated in Fig. 1.

2.2. Participants

The study was performed in the Department of Rehabilitation, Xuanwu Hospital of Capital Medical University, Beijing, China. All participants were right-handed and native speakers of Mandarin Chinese. The hospital ethics committee approved the study. Informed written consent was obtained from each subject.

2.3. Patient group

Inclusion criteria included: (1) 3–6 months after the onset of a stroke, (2) no previous brain injury, (3) no significant improvement in picture naming found after a 4-week language-based treatment period (Phase A1), and (4) no significant difference found in left Wernicke's point (see Section 5) via EEG ApEn index during word repetition task compared with the resting condition before entering Phase B. Exclusion criteria included: (1) severely impaired auditory verbal comprehension (auditory word-picture identification <6/60), (2) inability to repeat three-syllable words, (3) history of seizures in the last 12 months, (4) history of implanted metal objects, (5) history of seizures or other neurological condition, and (6) history of psychiatric disease or dementia.

Twelve (10 men) of the original fifteen aphasic patients qualified for the study. Two patients withdrew from the trial for personal reasons, and one patient did not meet the inclusion criteria. Patient demographics and stroke characteristics are reported in Table 1. Twelve healthy age-, sex-, and education-matched controls (10 men) also participated in this study.

2.4. Aphasia assessment

Aphasia type and severity were evaluated using the Boston Diagnostic Aphasia Examination-Chinese version. All subjects underwent an evaluation involving picture naming and auditory word identification according to the Psycholinguistic Assessment in Chinese Aphasia (PACA). Four 60-test-item lists were randomly selected from a total of 90 items in the PACA. The lists were controlled for word frequency, familiarity, visual complexity, grammatical class (nouns) and length in syllables (two syllables, i.e., two Chinese characters). The four 60-test-item lists were randomly used in four aphasia assessments. The reaction time for each item was limited within 20 s. No cue was provided if the patient did not respond correctly.

2.5. Speech-language therapy

Speech-language therapy was conducted with a computer system. A total of 500 treatment items were used. The subject received a picture-naming treatment, which consisted of a series of steps encouraging the subjects to activate and link information about meaning and sound characteristics of a target picture/word. In the treatment, a picture was presented, the subject was asked to name the picture, if failed the semantic cues were provided, such as the object's preposition, function and features. The initial phoneme of the word was provided if the patient could not retrieve the first sound of the word.

2.6. Transcranial direct current stimulation (tDCS)

To administer tDCS, direct current was applied through a saline-soaked pair of surface sponge electrodes (4.5 cm × 5.5 cm) and delivered by a specially developed, battery-driven, constant-current stimulator (IS200, Chengdu, China). A constant current with an intensity of 1.2 mA was applied for 20 min once daily, 5 days per week.

In this study, A-tDCS was applied over the left posterior perisylvian region (PPR). tDCS and speech-language therapy started simultaneously. According to Friederici's method, the left Wernicke's area was defined in the posterior temporal region as a crossing point between T3-P3 and C3-T5 [11]. This crossing point was known as the "left Wernicke's point (LWP)". The cathodal electrode was placed on the unaffected shoulder to prevent any adverse effects. For the sham stimulation, the stimulator was turned off after 30 s. For both active and sham tDCS treatments, current intensity was gradually increased and decreased [12].

2.7. EEG recording

The subject was awake during the entire recording process and lay comfortably in a quiet ward. A 16-channel EEG (Wireless Digital