EEG-BASED BRAIN COMPUTER INTERFACE (BCI) CONTROLLED FUNCTIONAL ELECTRICAL STIMULATION (FES) THERAPY FOR STROKE REHABILITATION

Kai-yu Tong*, 1 Fei Meng1,2, Ka-him Lui1, Suk-tak Chan1, Wan-wa Wong1, Xiaorong Gao2, and Shang-kai Gao2

1. Department of Health Technology and Informatics, Hong Kong Polytechnic University, Hong Kong, China
2. Department of Biomedical Engineering, Tsinghua University,Beijing China
* Corresponding Author E-mail: k.y.tong@polyu.edu.hk

Abstract

Stroke is a leading cause of long-term disability in adults. Integration of functional electrical stimulation (FES) controlled by biopotential like EMG currently showed significantly improvement in restoring motor function of upper extremities on chronic stroke patients. This study demonstrated the feasibility of using EEG as biopotential to control the FES on six chronic stroke patients. The clinical score included Motor status score and wrist extension range showed improvement of upper extremities function.

1 Introduction

Brain-computer interface (BCI) has been defined as the direct communication channel between the brain and outward environment which did not depend on the peripheral nerves and muscles [1]. In principle BCI technology could be understood as the translator of mental state, which has shown the great potential to help the people with paralysis to regain their motor function by innervate the neuroprosthesis [2]. Meanwhile BCI also possibly facilitate the motor recovery after stroke [3]. By driving the external rehabilitation devices with the users’ intention, BCI could bridge the disconnected central command with the peripheral muscles, even for the totally paralyzed patients.

Inspired by such idea we integrated the BCI and FES technologies together in current study to improve the motor impairment after stroke. The BCI technology in the framework could act more than just a mental trigger to the FES unit. Motor imagery and motor execution appeared to share some common functional circuits that include primary sensorimotor cortex, premotor cortex and subcortical nuclei [4]. Therefore the BCI technology based on motor imagery had the potential to become the optimal command strategy for the system design. The BCI-FES system possibly helped the stroke patients to recover by combining the agitation from the central nervous system (CNS), the corresponding muscle stimulation and the afferent sensory feedback. Study also showed that cerebral plasticity after subcortical stroke could be revealed by cortico-muscular coherence method through EEG and EMG [5].

2 Methodology

Clinical measures included grading of spasticity using the Modified Ashworth Scale (MAS), assessment of motor performance using the upper-extremity portion of Motor static score (MSS) and wrist range of motion. Electroencephalographic (EEG) were recorded with a Neuroscan SynAmps2 and Scan version 4.3 (Neuroscan, Neuroscan Inc.). The EEG signals were acquired with a 64-channel Quick-Cap (Neuroscan, Neuroscan Inc.) and the electrode arrangement configuration was based on international 10-20 system.

![Fig. 1. The BCI-FES training system](image)

A portable FES unit was used in current study to induce the simultaneous wrist extension. The FES unit
was set to generate rectangular stimulation pulse with pulse width 300us at 40Hz for 5 seconds. The current level of FES was a subject specific parameter, ranged from 50-80mA. The stimulation electrode of the FES were located on the skin surface on the extensor carpi radialis (ECR) of affected side. A test of stimulation current magnitude was done before each session. The test was started from the minimum output of the FES and then was adjusted until the subject wrist was passively extended against gravity to maximum range of motion without feeling uncomfortable during stimulation.

Subjects were asked to conduct 20 sessions BCI-FES training with the frequency 2-4 sessions per week. Signals from EEG electrodes on the EEG cap were input to the online control BCI system. The signal was then filtered to extract the mu rhythm (8-15 Hz), as the power in mu band would decreased significantly during imagination of movement. The power of the mu rhythm was then used as the feature vector for classification with Fisher Discriminant Analysis (FDA) to identify the subject intention. The subject was instructed to imagine the movement of affected wrist and hand repeatedly and the imagery state lasted for 6 seconds. The detection of volitional motor imagery resulted in the stimulation of affected wrist by triggering the FES unit, otherwise no stimulation was generated.

3 Results

\[
\begin{align*}
\text{Range of motion during wrist extension} \\
\text{Degree of motion} \\
\text{sessions}
\end{align*}
\]

Fig. 3. Wrist voluntary extension in the 20-session of BCI-FES training period

Six chronic subjects were recruited in this study and the range of motion during wrist extension has significant improvement (P<0.05) after the 20 sessions of BCI-FES training. The motor status score also showed significant difference(P<0.05). However, no significant difference on the Modified Ashworth Scale.

4 Conclusion

An EEG based BCI-FES system was developed which was controllable by stroke patients. This study demonstrated the feasibility of using EEG as biopotential to control the FES on chronic stroke patients. The preliminary data showed the 20-session of BCI-FES training could improve chronic stroke subject range of motion and upper extremity functions. More subjects will be invited to evaluate the training effect on functional recovery of the stroke patients.

Acknowledgement

This work was supported by the research funding of Hong Kong Polytechnic University (A-PA7L, 1-BB50) and the key project of National Natural Science Foundation of China (30630022). We are thankful to Wei Wu and Xiaoling Hu for their valuable suggestions. We are also grateful to the support from staff of Applied Cognitive Neuroscience Laboratory of Hong Kong Polytechnic University.

Reference