A simulation study on the safety of brain during ocular iontophoresis

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Abstract – Safety evaluation of ocular iontophoresis is necessary to apply to human. In this study, we calculated the electric field in the eye and the brain to assess the safety of these tissues according to the amount of injecting current. For simulation, finite element model of human head including the eye tissues was constructed. The results showed that 3.5 mA of injecting current was less stimulating the brain compared to conventional tDCS on the scalp.

Keywords: Ocular iontophoresis, safety, finite element method, electric field, simulation, eye

1 Introduction

Ocular iontophoresis is a non-invasive system which transmits weak electrical current to the eye through electrode pads on the skin for delivering charged drugs into the deep eye tissues. It has been used for treatment of eye diseases. During ocular iontophoresis, electric current applied through electrodes flows into brain and it may affect neuronal excitability of brain. However, safety of brain during ocular iontophoresis has not been investigated and assessed yet. For evaluating safety, electric field in the tissue should be accurately identified. In our study, calculation of electric field was conducted using finite element method (FEM). We compared the electric fields inside brain by ocular iontophoresis and conventional transcranial direct current stimulation (tDCS), and determined the safe level of the magnitude of injecting current.

2 Methods

Human head model was constructed from T1-weighted MR image with 1 mm resolution. Five tissues including scalp, skull, cerebrospinal fluid (CSF), gray matter and white matter were segmented using ITK-SNAP. The eyes were segmented into six tissues: sclera, vitreous body, retina, lens, ciliary body, and iris region and anterior. The dimension of the eye was determined based on MR images and a previous study [1]. We combined head and eye models to create FE model consisting of 600,609 nodes and 4,102,984 tetrahedral elements. Two square electrode pads with a diameter of 2 cm were considered.

The conductivity of each tissues was decided by the previous study [2]. The electric field was evaluated using FE analysis as varying the magnitude of injecting current ranging from 1 mA to 5 mA in interval of 0.5 mA. The electric field by tDCS was also calculated using FE model with various electrode montages. For tDCS simulation, 2 mA which rarely caused serious adverse events in previous literatures was assumed.

3 Results and discussion

The maximum electric field in the brain was 1.12 V/m when 3 mA was injected through the electrodes. The maximum electric field by tDCS was 1.22 V/m which is the highest value among the electrode montages. This results showed that the electric field level in the brain was similar between ocular iontophoresis and tDCS. Most reported adverse events of tDCS were not related to brain but skin problems such as tingle, itching and burn. Hence, it seems that ocular iontophoresis would not cause adverse events. However, no one can assure that ocular iontophoresis does not modulate neuronal excitability. Therefore, further study should be necessary.

4 References
