ELECTROCORTICOGRAPHY-BASED BRAIN COMPUTER INTERFACE FOR PEDIATRIC PATIENT: *CHALLENGE ON THE HORIZON*

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ABSTRACT

Electrocorticography-based brain computer interface has accepted recognition as modality connecting human brain to computer device for its signal recording excellence and stability. Implantation for medical purpose has welcomed this modality for bypassing existing nervous system and natural organ to create alternative solution towards previously-unsolved medical problems. Clinical trials have already initiated for Electrocorticography-based BCI implantation in adult. Therefore, bridging a direct brain to computer connectivity in pediatric patient should also become possible. However, several characteristics has made Electrocorticography-based BCI for pediatric patient more complex and should await for further technical solution rather than its adult counterparts.

Keywords**:** Electrocorticography, Brain-Computer Interface, Pediatric.

INTRODUCTION

Electrocorticography (ECoG)-based brain computer interface (BCI) is a method to connect brain signal with output devices based on recording of electrode surgically implanted at the brain surface (Hirata *et al*., 2015). An ECoG-based BCI offers benefit in comparison to other signal acquisition system existed for BCI. These includes: low noise and high frequency activities detection ability compared to scalp EEG, superior in long-term stability and less invasive than microneedle electrode. Implantation through surgery makes the ECog-based BCI is not only portable and permanent rather than the functional MRI (fMRI), near-infrared spectroscopy (NIRS) and magnetoencephalography (MEG)-based signal acquisition system (Hirata *et al*., 2015). Signal acquied from ECoG can be modulated to control robotic arm for assistance or move computer cursor for electronic communication (Hirata *et al*., 2015; Yanagisawa *et al*., 2012; Hirata *et al*., 2011; Vastenseel *et al*., 2016). Clinical trial has been started for ECoG-based BCI implantation in adult with Amyotrophic Lateral Sclerosis (ALS) resulting in satisfying result (Vastenseel *et al*., 2016). Although pediatric population also look up for benefit from BCI for communication and controlling artificial limbs, BCI for child is still mainly provided by the non – invasive electroencephalography (EEG)-based BCI (Mikołajewska *et al*., 2013).

DISCUSSION

There are several dilemma before a long-term implantation of an ECoG-based BCI for child is available in the near future. First, *younger the chid, smaller gyri and sulci that they had*. Current clinical-oriented ECoG provides interelectrode spacing at about 1 cm.

When the same interspacing covered smaller anatomical size of cortical gyri, the signal quality will be reduced. A customized electrode with denser arrangement has been proposed with main goal to meet patient's specific contour of gyri and sulci (Morris *et al*., 2015). However, providing an ECoG which sufficiently covered smaller pediatric gyri is much more difficult than adult.

Growth and expansion of cranial content. Implantation of long-term ECoG in adult is unrestrained from cranial expansion problem, while head circumference growth in a child is expected as natural process. Experience from ECoG implant for spikes recording before pediatric epilepsy surgery usually took 2-14 days prior to surgery (Asano *et al*., 2009). This common practice is far shorter than duration of ECoG-based BCI implant in adults which has progressed to more than one year (Vastenseel *et al*., 2016). An implant inside a progressed cranial content may slipped away from desired recording area thus nullifying the optimum signal acquisition. When the head growth is faster on a certain stage of development, the risk will also become higher.

Unknown child's brain tissue reaction to chronic implantation. The long-term effect and histologcal reaction to ECoG implantation needs further evaluation. Some research in animal has described that ECoG implantation for 6-22 months possibly resulted in mild inflammatory process, mild necrosis, macrophages and foreign-body giant cell adherence without reduction of the quality of signal acquisition (Degenhart *et al*., 2016; Romanelli *et al*., 2018). In order to support a decision of surgically-implanted external device to a child's brain along his lifespan, a firm knowledge about long term in-growth brain reaction toward subdural electrode implantation is needed.

Difference of signal characteristics toward ages. Roland *et al* has evaluated the variations of ECoG signals from patient with ages 11-59 years and its implication towards BCI (Roland *et al*., 2011). Although the result supports the high gamma rhythms utilization as separable signal which considered as control features and can be used through the course of patient's life, our understanding on ECoG characteristics of young human brain is still lacking.

Child's learning and adapting process with implanted device. Mental workload during BCI learning and adaptation is noticed within adult (Elizabeth *et al*., 2012). Eventhough it was proven that child can be taught to use BCI platform with satisfying result, there was possible variation of result among childgroup with different ages (Zhang *et al*., 2019). General assumption that adult will cope better with mental workload during learning and also had better experience with electronic communication may applied to the situation.

Considering the underlying problems above, prediction that the future Ecog-based BCI will probably serve the pediatric patient starting from adolescence group. Adolescence will offer much similarity with adult while continuation of trials and research to younger group will provide deeper understanding and solution on how to put permanent cortical electrode to a child at every stage of development. Meanwhile, non invasive BCI will stay as prima donna for brain to computer connectivity in pediatric population.

Although the technical complexity and scope of the problems are beyond the current literature, not to include the ethical aspects of inserting a lifelong brain implant to a child, we believe further research is worth the resources. Considering the assumption of a longer life expectancy than adults, pediatric patients will gain benefit for a longer duration when the technical solution is available.

CONCLUSION

Since the clinical implantation of ECoG-based brain computer interface for adult has been initiated throughout different centers around the world, it is very natural that pediatric BCI implantation also comes to the horizon. However, several characteristics made invasive BCI implantation for pediatric is more challenging. Several uniqueness needs novel soultion before a child can also find benefit of ECoG-based BCI equally as their adult predecessor.

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