Rapid developments in intensive care technology can save human lives even in seemingly hopeless cases, such as stroke or traumatic brain injury. However, in extreme cases, vital functions are saved for the price of falling in coma - a state of deep disturbance of consciousness, very similar to symptomatic brain death, in which the patient does not respond even to very strong stimuli. In majority of patients coma lasts for several days, but unfortunately not for all; in some cases it changes into chronic coma, lasting years, either in vegetative or minimally conscious state. Unfortunately, contemporary medicine can not predict either the chance of recovery or effects of undertaken rehabilitation. The reason for this lies in the low level of understanding of the basic mechanisms of the brain functioning, among which the main challenge is consciousness.

Up to now we do not understand neither how consciousness is generated in the human brain, nor which areas are crucial to it. The current state of the art in coma research shows that disorders of consciousness are inhomogeneous and very diverse, both in terms of level of preserved consciousness and observed symptoms. Nowadays, researchers are seeking for neuronal indicators of coma emergence. It would improve medical diagnosis of such patients and help to chose the most appropriate treatment and rehabilitation.
The main aim of this project is to develop methods for the analysis of brain electrical activity measured by electroencephalogram (EEG), which will allow for isolating neural indicators. It could be support an objective diagnosis of patients in DOC treated in "Budzik" clinic.

Observed in children, stronger brain plasticity gives better chance to extract neural correlates of recovery process. Due to this fact, patients in age 8-16 will be taken into consideration. Additionally, clinic "Budzik" runs a unique program of complex rehabilitation, which eases monitoring of changes in brain functioning during the 12-month stays at the clinic.

Brain research in the field of post-traumatic disorders of consciousness (DOC), which includes coma, minimally conscious state (MCS) and vegetative state (VS, recently called rather UWS - unresponsive wakefulness syndrome), gives hope for better understanding of the neural correlates of consciousness, and is particularly relevant for clinical applications. Most studies are performed on adults and based upon neuroimaging data from either functional magnetic resonance imaging (fMRI) or electorencephalography (EEG).

The main problems of using fMRI method in research on DOC are high costs of scanning, limited accessibility and transport, and necessity of scanning in anesthesia. Also, most clinical centres are not equipped with an MRI scanner offering resolution sufficient for functional studies. For this reason, this project is based on non-invasive measurements of EEG, according to the approach described below:

1. Longitudinal experimental scheme -- the current state of the art research dedicated to coma addresses primarily the differentiation between MCS and VS patients, and no attempts to examine the dynamics of coma emergency have been reported. Due to this fact, we decided to conduct the study in longitudinal paradigm (measurements in every 2 months). Children in “Budzik” clinic undergo an intensive programme of rehabilitation which combined with stronger brain plasticity of young patients, gives opportunity to monitor and parametrize the consciousness recovery process.
2. Resting-state EEG -- most of research of EEG in DOC patients described in current literature is based on the analysis of functional paradigms, which require an implementation of elaborated experimental procedures; nevertheless, their results has been ambiguous in the assessment of the consciousness level. However, there have been attempts to differentiate MCS and VS/UWS patients on the basis of circadian rhythms and spontaneous brain activity analysis. Research conducted by Faculty of Physic (University of Warsaw) in collaboration with Steven Laureys’ team from the University of Liège, and summarized in (Malinowska et al., 2013), showed that EEG profiles of MCS patients with residual consciousness are much more complex than those of VS patients, thus resembling profiles of healthy individuals. Unfortunately, due to inhomogeneous group of subjects and presence of the arbitrary factor in visual assessment of constructed profiles, it has not been possible to extract measures directly correlating with the level of consciousness.
3. Development and adaptation of advanced signal analysis methods and statistical procedures.

The goal of the Project is to develop novel and objective methodology based on advanced EEG signal processing methods allowing for parametrization of EEG profiles and selection of features correlating with behavioural assessment and the process of regaining consciousness. Construction of EEG profiles is based on parametrization of signals by means of the matching pursuit algorithm, being developed at the Faculty of Physics at the University of Warsaw (FUW). Functional connectivity between brain regions present in both resting-state EEG and long-duration recordings, will be analysed with directed transfer function (DTF), also developed at FUW, and partial coherence measures.