The mechanisms of consciousness are among the greatest mysteries of neuroscience. Research within the area of disorders of consciousness (DoC) is aiming to broaden our knowledge of the theoretical basis of these processes, and to to provide diagnosis-supporting solutions for healthcare. Studies conducted so far have shown promising results in the use of neuroimaging techniques such as nuclear magnetic resonance (NMR) and electroencephalography (EEG). However, recent applications of both these methods in the assessment of DoC severity leave a room for significant improvements in terms of the signal processing methods, which leads to suboptimal sensitivity and specificity. Furthermore, there is a lack of longitudinal studies combining these two methods while evaluating the patient's state during the DOC evolution from the very beginning, i.e. from the state of coma. The main interest of the project is to fill these gaps within the contemporary research on DoC.

Longitudinal protocol of measurements for each patient will consist of the following steps: an examination immediately after the accident, after approx. 2 weeks since the accident (both measurements conducted during the state of coma), after the awakening from coma (in a vegetative state), in minimally conscious state and after the complete recovery of consciousness. Using the magnetic resonance spectroscopy, biochemical changes in the brainstem will be monitored. Formation of new functional connections will be assessed on the basis of the results of resting state activity in magnetic resonance (MR) scanner, and changes in brain functioning—via observation of resting state electrical brain activity. A reference for the neuroimaging methods described above will be provided by a clinical scale specific for the purpose of monitoring the recovery of consciousness (Coma Recovery Scale-Revised, CRS-R), supplemented by EEG-based indicators developed as a part of NCN project "Brian/neural computer interaction for diagnosis and communication in disorders of consciousness". Analysis of data provided by both of the above mentioned neuroimaging methods (MRI and DOC) require significant improvements for an effective application in DoC research, hence the development and validation of novel algorithms are planned within the Project.

EEG-based studies of coma are traditionally based on visual detection of characteristic structures present in resting state EEG recordings, such as triphasic waves, delta activity, coma spindles and K-complexes. Similar approach, applied to the analysis of circadian activity (presence of which, according to a number of studies, may be an important indicator of the patient's progress) is based on hypnograms. Such evaluation is classically performed by visual inspection of raw EEG recording, which negatively influences repeatability, as well as costs of the procedure and sensitivity of proposed indicators. Applicant has several years of experience in the automated detection of structures present in sleep EEG (such as e.g. spindles, slow waves, K-complexes), based on their definitions used in visual analysis, as well as in the construction of hypnograms based explicitly on the occurrences of automatically detected structures. Approaches published by the Applicant, developed for the purpose of standard hypnograms, were also applied to the parametrization of sleep of patients with DoC, first in cooperation with the prof. Laurey's clinic in Liege, and then as a part of the NCN project "Identification of electroencephalographic patterns in recordings of spontaneous brain activity in children with disorders of consciousness". Results of these studies, published in prestigious journals, point the way to the automation of the assessment of the occurrence of circadian rhythmicity, which could be based on selective detection of relevant structures with parameters from time-frequency space, obtained by decomposing the signal with the matching pursuit (MP) method, introduced to the analysis of biomedical signals by the Applicant.

An important extension of the proposed methodology is the application of structural (sMRI) and functional (rsMRI) Magnetic Resonance Imaging. sMRI offers improved description of patient's structural brains damages, while rsMRI allows to identify a network of "cooperating" areas in the brain, known as default mode network (DMN). MR signal in DMN areas results from convolution of neuronal activity with hemodynamic response function (HRF). HRF response covers a cascade of metabolic processes such as oxygen extraction or regulation of brain perfusion. An important part of the project will include the development of a new method of rsMRI signal analysis, taking into account the spatial variability of HRF. Finally, single voxel MR Spectroscopy (svMRS) will be used for measurements of selected brain metabolites (esp. neurotransmitters), since their concentration may provide indicators related to the changes in the level of consciousness.