

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide. 10 million people are estimated to suffer from TBI every year, most of them young men below the age of 30. TBI is the result of various events and factors: car accidents, workplace accidents, falls, alcohol. It is associated with high costs of treatment and rehabilitation as well as high social costs. As a result of disability, TBI patients are often unable to return to work, require many years of therapy and a caretaker's assistance in their daily life, which significantly limits their social activities. Methods currently used in treatment of TBI are complex, requiring interdisciplinary approaches and specialist knowledge. Therefore, studies that aim to improve our understanding of the processes occurring in the brain after injury and develop methods which allow for early warning of possible worsening of the patient's condition and support the decision making process for early medical interventions in order to prevent secondary injury are of high socioeconomic importance.

Intracranial pressure (ICP) is routinely monitored in TBI patients in neuro-intensive care units. ICP elevation is one of the life-threatening complications of TBI as it results from increases in additional pathological volume in the intracranial space and may lead to secondary brain injury. The clinician makes decisions about treatment based on, among other parameters, the observation of the ICP value displayed on the screen of a bedside monitor. Medical interventions are usually performed too late, when the increase in ICP and adverse changes in the brain have already occurred. Therefore, sufficiently early prediction of ICP elevation may allow for preventive treatment performed prior to the occurrence of life-threatening situations. However, the measurement of ICP without knowledge about the extent to which the craniospinal space may buffer volume changes is not sufficient to fully characterize the patient's status and introduce effective treatment. A parameter which describes the craniospinal system's ability to compensate increases in volume is termed 'brain compliance'. One of the methods of assessing brain compliance is based on the analysis of the shape of pulse waves of ICP which are the result of increases in cerebral blood volume naturally occurring during each heartbeat. The shape of ICP pulse waves changes with progressive exhaustion of the mechanisms compensating volume changes from a wave with three defined local maxima to a wave resembling a sinusoid. Currently, however, due to the lack of sufficiently accurate computational algorithms allowing for real-time observation of changes in the shape of ICP pulse waves and automatic classification of those shapes, this method is not used in clinical practice.

The aim of this project is to develop methods of monitoring brain compliance based on the analysis of ICP pulse wave shapes in TBI patients. We hypothesize that changes in brain compliance may precede increases in mean ICP and the analysis of ICP pulse wave shapes may be useful in the identification of patients at risk of intracranial hypertension. We plan to classify characteristic patterns of ICP pulse waves using artificial intelligence methods and analyze the changes before and during episodes of ICP elevation. The meaning of different shapes will be extensively studied during clinical conditions of known effect on brain compliance. Based on acquired knowledge we plan to build predictive models that will allow for the prediction of increases in ICP early enough to enable effective medical intervention prior to secondary brain injury. Moreover, we plan to examine the relationship between different shapes of ICP pulse waves and the patient's clinical condition and build a model for early prediction of the patient's outcome. The models are a significant expected result of proposed project. While analysis of ICP pulse waves does not introduce any additional risk for the patient, the invasiveness of ICP measurement is a limitation of proposed method of monitoring brain compliance. The alternative is to measure tympanic membrane displacement (TMD) which, as suggested by previous studies, is correlated with ICP increases and brain compliance. However, TMD measurement using existing commercial solution is relatively expensive and requires a special sensor introduced to the patient's ear. Therefore, in proposed project we will also propose a new, non-contact, cheap, and most importantly non-invasive method of monitoring brain compliance based on recording TMD with a video camera and analyzing the displacements with novel methods of video processing.