Assessment of loss of cerebral blood flow due to cerebral edema using measurement of me gated compliance

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Brain fluid accumulation may evolve after Traumatic Brain Injury (TBI), causing an intracranial pressure (ICP) elevation and intracranial compliance decrease. There are a continuous ICP measurement monitors in TBI patients but no sufficient intracranial compliance monitors. Understanding normal and disturbed complex fluid dynamics of the cranium after TBI and obtaining intracranial compliance measurements may help develop tools for better TBI patients treatment.

Analog circuits, representing lumped-parameter fluid dynamics in the brain were developed. Simulations of the complex interactions in the cranium both in healthy and hydrocephalic conditions were conducted. In addition, an animal experimental model was developed and trials were conducted on pigs. An ECG gated volume pulse to the cranium causes an immediate ICP response. An example of the acquired signals presented in figure 1.

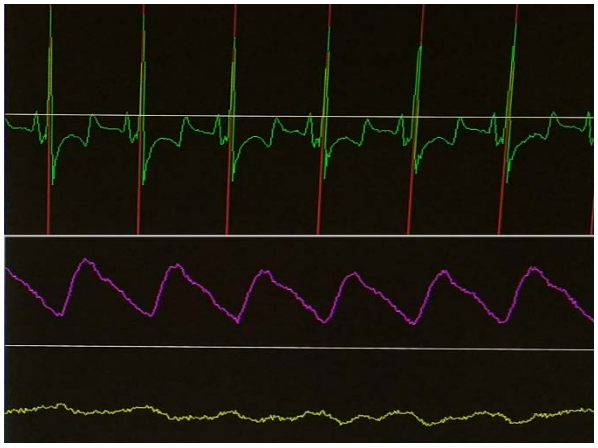

Figure 1: Acquired signals. ECG and R-wave detection presented in the upper window, ABP presented in the middle window and ICP presented in the lower window

An estimation of the intracranial compliance and resistance were acquired from the analysis of the ICP waveform response to the ECG gated volume pulse. Example of ICP response to volume pulse presented in figure 2.

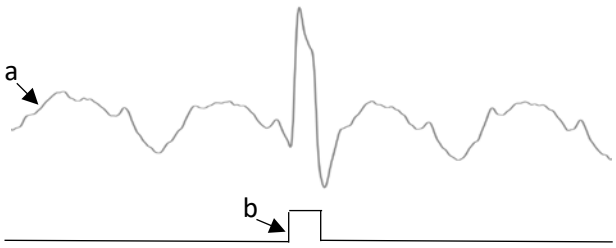

Figure 2: Example of an ICP response to ECG gated volume pulse. a: ICP waveform, b: volume pulse of balloon activation

Induced hydrocephalus pathology, resulting with cerebrospinal fluid accumulation in the cranial vault, caused an ICP elevation and intracranial compliance decrease. Obtained physiological data was analyzed and intracranial compliance was calculated in normal and induced hydrocephalus pathology conditions.

The model reproduced physiological and pathological behavior of intracranial fluids, affecting ICP and intracranial compliance. Induced pathology in the mathematical model resulted in increased ICP and poor intracranial compliance. The mathematical model allows investigation of the complex fluid movement and interactions in various physiological conditions, such as exploration of how changes in the intracranial blood supply affect the cerebrospinal fluid circulation dynamics and how it is affected by ICP changes. ICP changes with the elevation of the resistance to outflow presented in figure 3. Outflow resistance elevation results with ICP elevation.

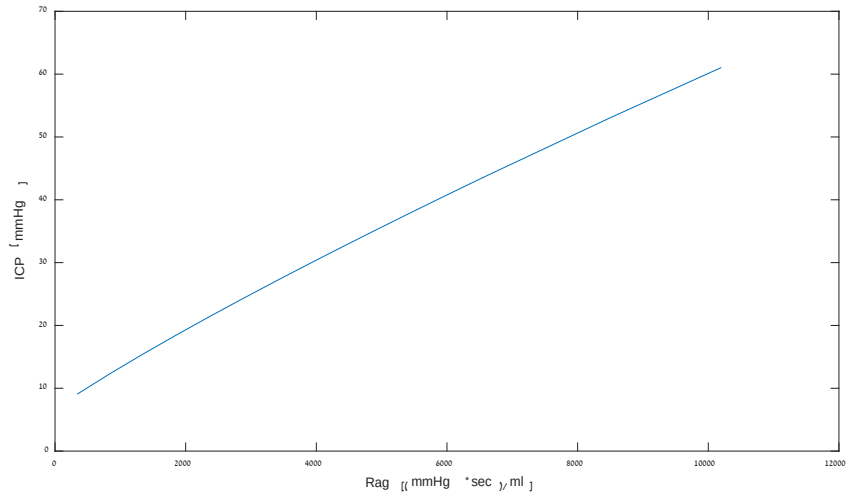

Figure 3:ICP pressure as function of outflow resistance (Rag)

Calculated intracranial compliance of one experimental pig can be seen in figure 4. The analysis shows a decrease in calculated intracranial compliance with ICP elevation.

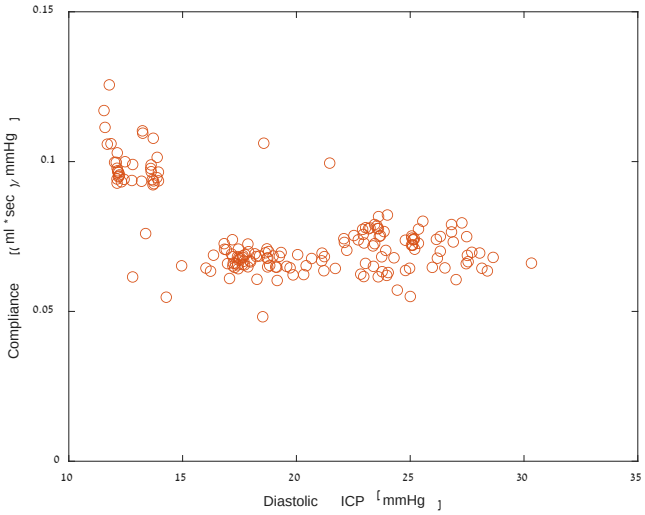

Figure 4: Intracranial compliance as function of diastolic ICP

The computational model and animal trials describe intracranial interactions occurring with hydrocephalus in a physiologically compatible manner. We are aiming to continue acquiring data from more pigs and continue to investigate the intracranial compliance changes with other intracranial changes in a pathological condition.