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Physical Model for Investigating Intracranial Pressure with Clinical Pressure Sensors and Diagnostic Ultrasound

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Background

The sources influencing ICP waveform characteristics largely remain unclear. To gain additional insight into the contributing mechanisms we created a physical head model. The model allows for iterative improvements to closely mimic the clinically observed ICP signal.

Methods

A head phantom modeled after CT images of a human head was 3D printed in ABS/PLA plastic (Figure 1). The skull was modified to allow for mounting of a linear ultrasound transducer (type 8811, BK Medical, Denmark) looking from the neck up to the top of the head in the mid-sagittal plane. A pressure sensor (Neurovent-P, Raumedic, Germany) was inserted at Kocher’s point. The volume corresponding to the soft brain tissue was filled with soft tissue-mimicking material (agar, evaporated milk, silica dioxide, water, and alcohol) with a water-filled balloon inside. This balloon was connected via a water filled catheter to an external balloon allowing for simulation of blood induced pressure changes.

Figure 1: Experimental setup.

Simultaneous recordings of the pressure signal and real-time ultrasound images allow for studying blood pressure induced ICP changes, and at the same time follow the spatial development of the compression wave in the soft tissue due to the dynamic volume changes of the internal balloon.

Results

An example of the generated waveforms can be seen in Figure 2, where no subpeaks can be observed. To make the setup more realistic, an artificial heart with valves will be used as the pressure driving force.

Figure 2: Example of generated waveform.

Conclusion

Despite the simplifications the physical model allows for alternative and potentially more useful modelling approaches compared to more common computer simulation models. Planned model improvements include artificial ventricles as well as a full spinal column to more accurately model pressure changes along the cranio-spinal axis.