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Simulation of Venous Plexus Blood Flow during Rapid Spinal Bending

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The Spinal Venous Plexus has special properties compared to the veins in most other regions of the body. The plexus has one part situated inside the spinal canal, embedded in the epidural fat, and one part surrounding the spine. These two parts are connected to each other via the intervertebral vein bridges at each spinal level. These vein vessels, unlike most other veins in the body, have no valves so the blood can flow in both directions in every vessel section. The abundance of vein vessels in the spinal region cannot be explained by exceptional nutritional needs and there is no corresponding abundance of arteries.

Svensson et al. (1989) hypothesized that the venous plexus is shaped like this in order to facilitate the change of the spinal canal inner volume that takes place during spinal sagittal bending. During sagittal bending the spinal canal becomes longer in extension and shorter in flexion while its diameter remains almost constant. This leads to a very significant change in the inner volume of the spinal canal during this motion. In the cervical section a volume change in the order of 25% will take place between maximum flexion and maximum extension. Since the contents of the canal are virtually incompressible a mechanism to exchange volume between the inside and the outside of the spinal canal must exist to allow for spinal sagittal bending motion. In the spinal canal there is only one fluid system that allows for a rapid exchange of volume between the inside and the outside of the spinal canal, namely the inner venous plexus and its many connection points to the external vein system.

Svensson et al. (2000) summarized findings of transient pressure changes during experimental rapid neck bending exposures (extension, flexion and lateral whiplash motion). The pressure transients were hypothesized to result from rapid vein blood flow changes. These results were accompanied by findings of spinal ganglion nerve cell membrane dysfunction that potentially was caused by pressure loading in the intervertebral canals.

The present work aims at explaining the flow pattern in the spinal venous plexus during rapid spinal bending. One particular focus is whiplash motion in the neck during a car accident. Recent versions of Computational Fluid Dynamics (CFD) modeling software such as Fluent and Open Foam have been utilized to model the internal venous plexus and its intervertebral vein bridges. The spinal canal length change during experimental and simulated whiplash motion has been used as input to the CFD models. The results indicate complex flow phenomena with rapid flow accelerations that correlate to local pressure transients. The pressure profiles are sensitive to changes in neck motion input such as direction and acceleration magnitude.

References:

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