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PRELIMINARY STUDY OF THE IMPACT OF SPINAL CORD NERVE ROOTS AND DENTICULATE LIGAMENTS ON DRUG MOVEMENT IN THE CERVICAL SPINAL SUBARACHNOID SPACE

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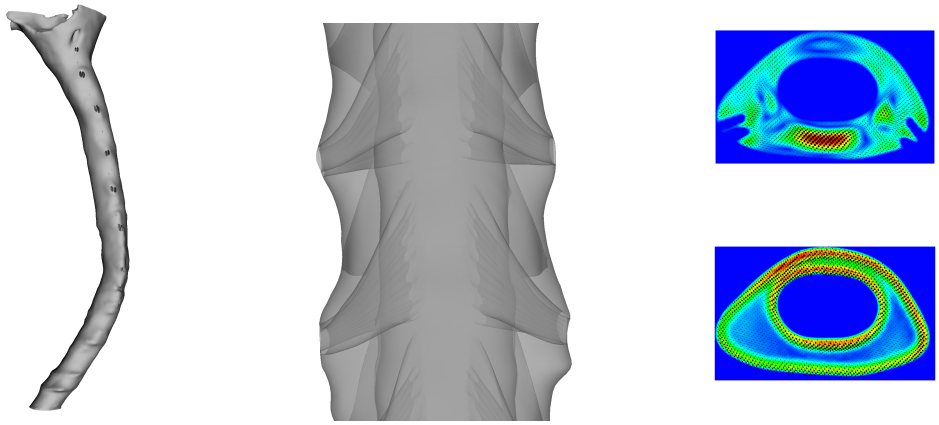
Transport of drugs that are infused in the cerebrospinal fluid (CSF) within the spinal subarachnoid space (SSS) for chronic neurological conditions is poorly understood. For example, the impact of fine anatomy on drug movement is not known. The lack of understanding is largely due to the difficulties in measuring the cervical SSS fluid flow.

In this work we utilize computational fluid dynamic (CFD) simulations of CSF to provide detailed information about the impact that nerve roots and denticulate ligaments (NRDL) in the upper cervical SSS have on massless particle movement. The particles are assumed to have similar hydrodynamic properties as a drug that could be injected into the SSS. To understand the importance of NRDL, two simulations are completed, one with and the other without NRDL present in the upper cervical SSS.

A three dimensional geometry of cervical SSS is shown in Figure 1. The anatomical model was constructed based on manual segmentation of T2-weighted magnetic resonance (MR) image sequences of a healthy volunteer using freely available software ITK-Snap (Version 2.2, University of Pennsylvania). Idealized NRDL were separately constructed and added to the model using Autodesk Maya (Autodesk Inc., Cleveland, OH). Nonuniform unstructured computational meshes were generated using ANSYS ICEM CFD (ANSYS Inc., Canonsburg, PA). The complete geometry [Figure 1 (a, b)] is 18 cm from top to bottom and the two end planes are both placed in the xz-plane.

Simulations have been performed using the Open Source Navier Stokes solver *Oasis* [2]



(a) (b) (c)

Figure 1: SSS geometry and computational surface mesh. (a) Complete surface model. (b) Transparent model showing nerve roots and denticulate ligaments. (c) CSF velocities in a cutplane from the model with (top) and without (bottom) nerve roots and denticulate ligaments.

- a high-level/high-performance solver utilizing the Python interface to FEniCS [1]. We solve the incompressible Navier-Stokes equations for the fluid flow and a scalar advection equation for the injected drug, represented by massless particles with viscosity and density of water at body temperature.

In this talk we will put the focus on the impact the nerve roots and denticulate ligaments, fine structures that so far usually have been ignored in simulations studies, have on the CSF flow and in particular on the drug distribution in SAS.

REFERENCES

[1] A. Logg, K.-A. Mardal, G. N. Wells, Automated Solution of Differential Equations by the Finite Element Method, Springer, 2012. url:http://fenicsproject.org.

[2] https://github.com/mikaem/oasis.