SIMULATION OF DORSAL ROOT GANGLION DEFORMATION DURING WHIPLASH MOTION

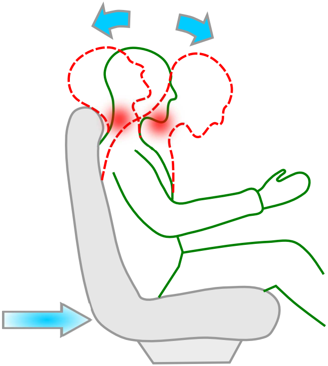
Hua-Dong Yao, Mats Y Svensson, Håkan Nilsson

Department of Applied Mechanics,
Chalmers University of Technology

Nov 11, 2015

What is whiplash injury?

- The whiplash injury commonly exists after the rear-end collision of auto-vehicles.



Background

USA

- In USA, the annual number of the whiplash injuries was 800,000 (National Highway Traffic Safety Administration, 2004).

EU

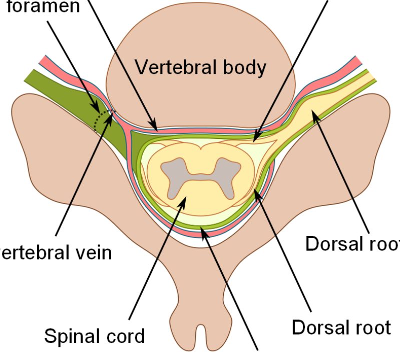
- In EU, the annual number of whiplash injuries was also 800,000, of which 40,000 suffered long term pains (Linder et al. 2013).

Sweden

- In Sweden, the whiplash injuries accounted for 64% of all injuries leading to disability due to vehicle crashes (Gustafsson et al. 2015).

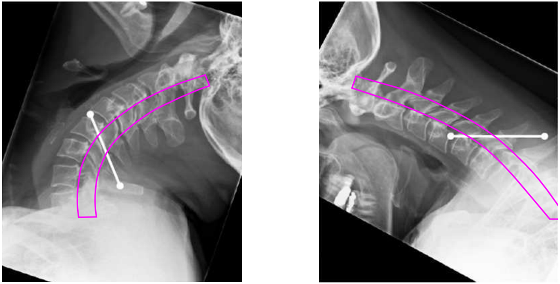
Dysfunction of Dorsal Root Ganglion (DRG)

- Blood pressure pulses in the interval vertebral venous plexuses (IVVP) can potentially deform the DRG and impair its function, (Svensson et al. 1993).



Whiplash Motion of Human Neck

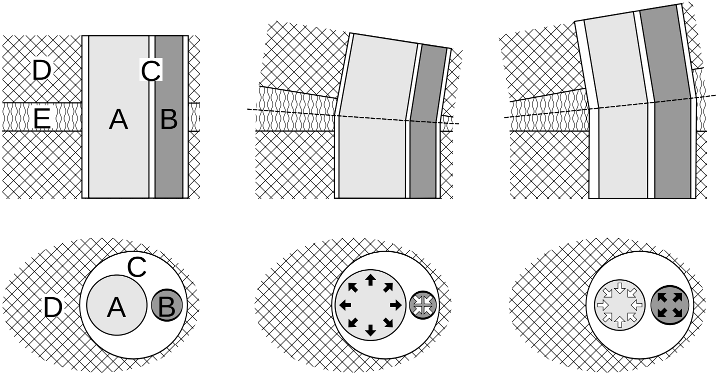
- The volume inside the spinal canal varies due to the neck motion.



The X ray pictures of the cervical spine during (a) extension and (b) flexion. The white line is parallel with the facet joint plane between C5 and C6. Courtesy of Jonsson, 2008.

Hypothesis of Compensating Blood Flow

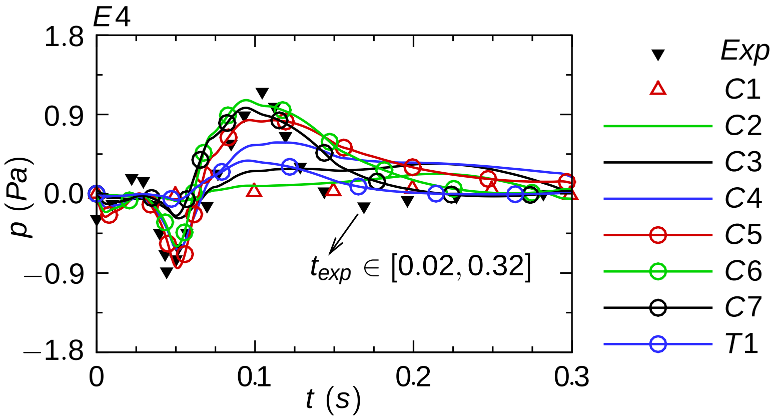
- The volume change are assumed to produce compensating blood flow in the IVVP.



A: soft tissues, B: internal vertebral venous plexus, C: arteries, D: vertebral body, E: intervertebral disc.

Measurements and model results

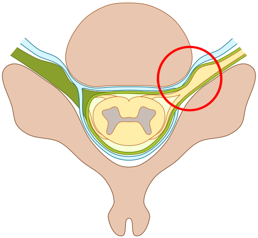
- The pressure pules were observed in experiments (Svensson et al. 1993), and were reconstructed using a numerical model (Yao, Svensson, Nilsson, 2014).

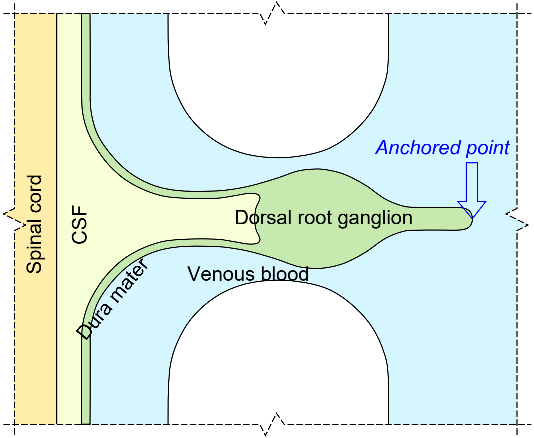


The experimental data was measured for C4 with a pulling force 600N

Objective & Idea: Fluid-Structure Interaction

- The objective is to elaborate the mechanism how the compensating flow can play a role on deformation of the DRG.
- The anatomy around the foramen is simplified for the computation.

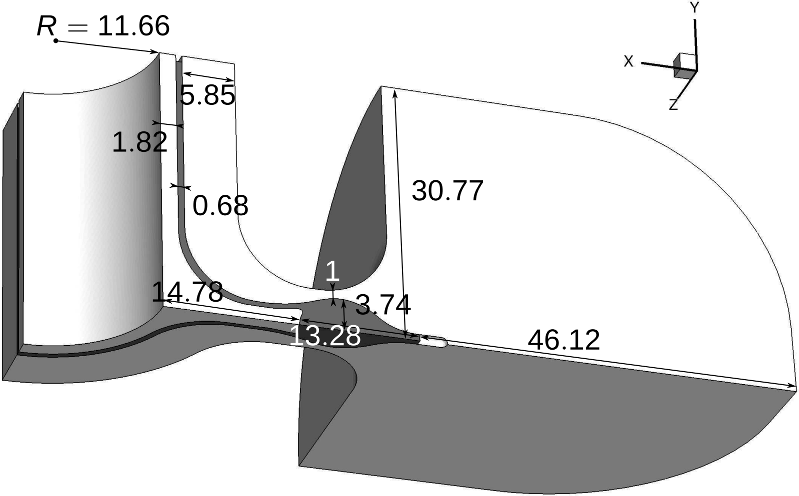




Computation Tool – FOAM-extend

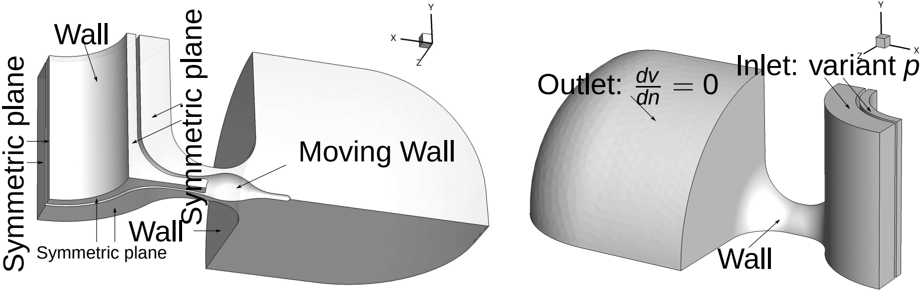
- The FSI solver of FOAM-extend is used for the simulation.
- The fluid is incompressible.
- The solid is linear elastic.
- The fluid solver utilizes the PISO algorithm.
- A strong-coupling partitioned method with the Picard iterative process is employed to couple the fluid and structure solvers.
- Acceleration of the coupling process adopts the Aitken relaxation algorithm.

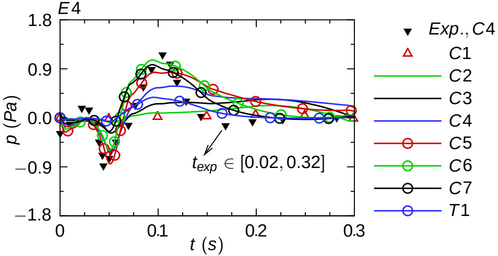
Computational Domains



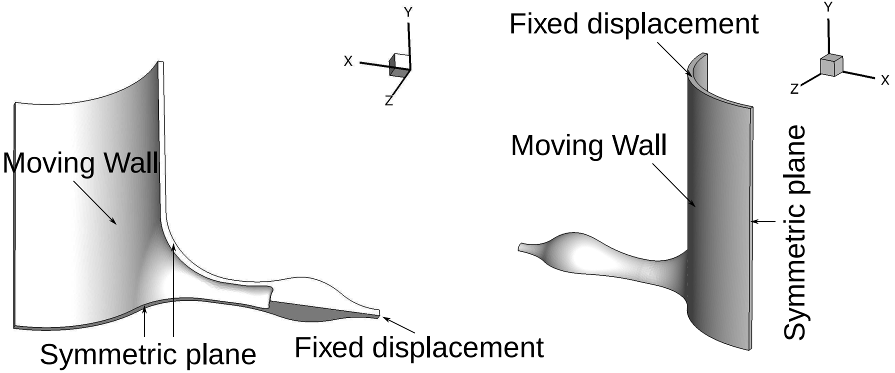
Non-dimensional scales calculated based on the width of the minimum annulus crossing area at the foramen $W = 6.5 \times 10^{-4} m$.

BOUNDARY CONDITIONS OF FLUID DOMAIN



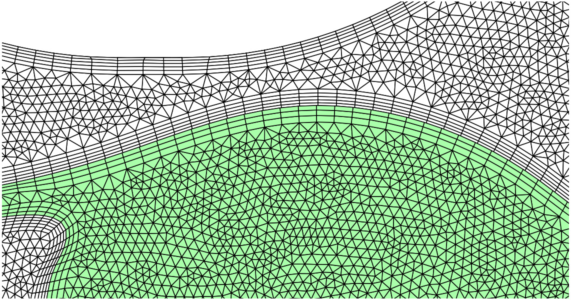


Boundary Conditions of Structure Domain



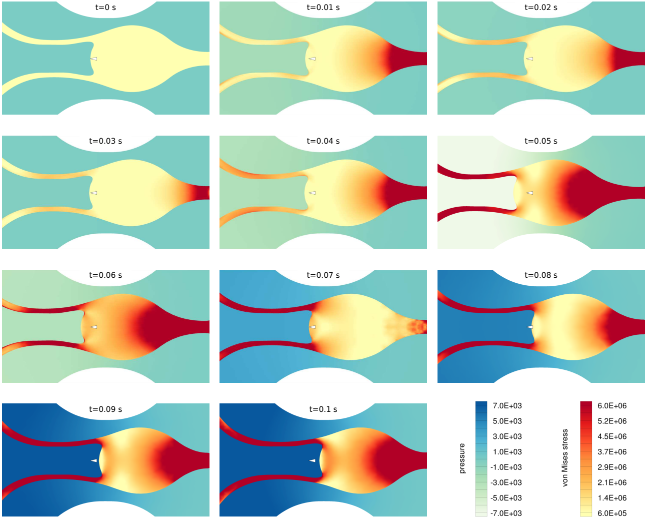
Boundary Conditions of Structure Domain

- The height of the first cell near the wall is $0.05W_{min}$ in the fluid mesh and $0.11W_{min}$ in the structure mesh.
- The maximum cell length in both domains is $0.15W_{min}$.



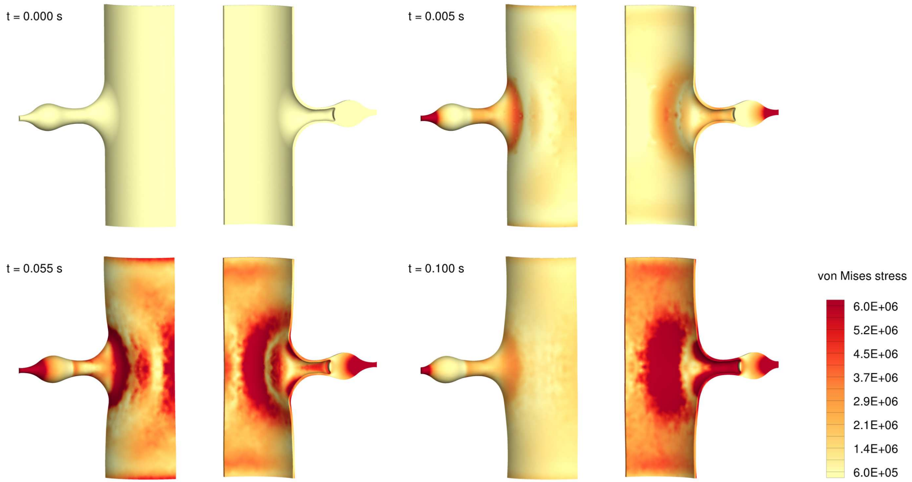
The fluid and structure meshes near the foramen.

Result – FSI



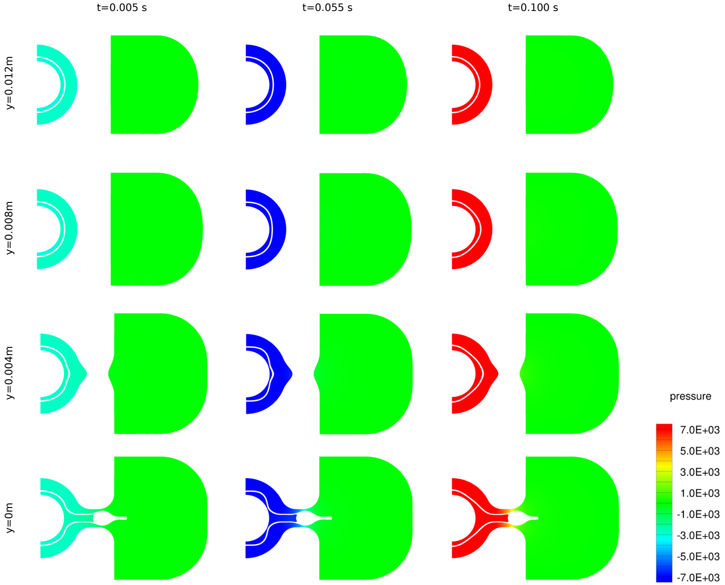
The FSI in terms of the pressure and von Mises stress

RESULT – GANGLION DEFORMATION

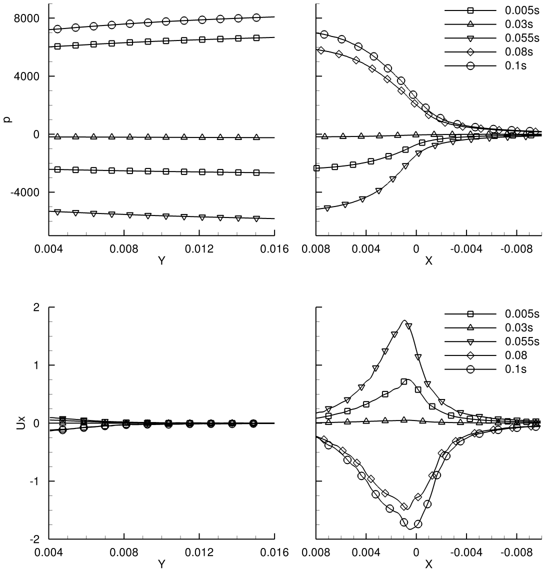


The DRG deformation viewed from the outside and inside of the DM.

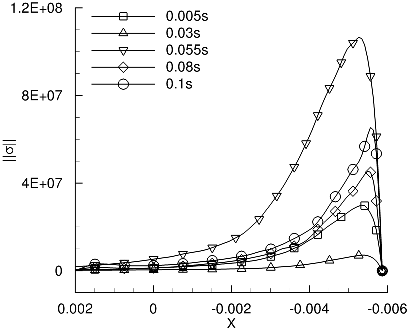
Result – Pressure fields



Result – Quantities in Flow Fields



Result – Von Mises Stresses in Structure Field



Conclusions

- The interaction includes two basic actions: the pulling process and the pressing process.
- The stretching appears as the internal pressure fields are negative, and the compressing happens as the internal fields are positive.
- Rapid changes of the internal pressure field renders external domain steep pressure changes at the foramen.
- The compensating flow described in the hypothesis is observed in the simulation.
- The deformation extent of the DRG is determined by the magnitudes of the internal pressure field.

Thanks