A New Fluid Dynamic Module to Extend Human Body FE-Modelling for Multidisciplinary Prediction of Whiplash Injury

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Problem and Purpose

Whiplash injuries stand for over 50% of Sweden's traffic injury costs. Females have twice the risk, but only male size is tested. The injuries are non-life-threatening but often cause medical impairment. Caused below Δv 25 km/h. Collaboration at M2, Vehicle Safety and Fluid Dynamics gave a fluid dynamics software for Human Body Model (HBM) families that predicts nerve injury.
The aim: Improve HBM whiplash injury assessment capability. The HBM motion is coupled to Fluid Dynamics simulation.

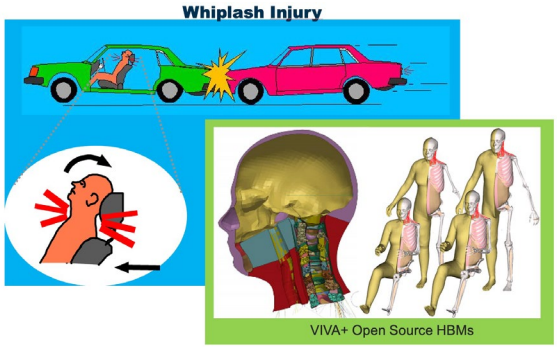
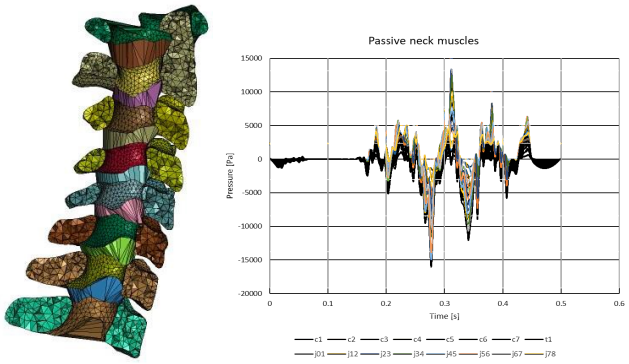


Figure 1: Whiplash injuries cause 50% of injury costs in Swedish road traffic. Aim: Upgrade HBMs, males/females, predict whiplash injury by fluid dynamics simulation.

Realization

The VIVA+ neck vertebral canal (Al-Debis & Mahmoud 2022) was upgraded using membrane elements and compared to earlier experimental data in line with Yao et al. (2016). Available at https://ovto.org.

For additional evaluation the upgraded VIVA+ neck was evaluated in a collaboration with University of British Columbia (UBC). Raw data from recent animal experiments described in Soltan et al. (2025) were analyzed and processed as described in Khalilollahi (2024). The UBC experiments combined X-ray high speed movie recording of the vertebral column and simultaneous pressure measurements at 3 cervical spinal levels.



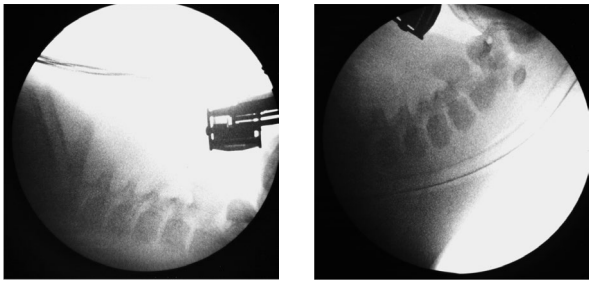


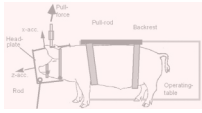
Figure 2: The upgraded VIVA+ neck vertebral column (top left) and an example of simulated pressure transients based on neck motion in a VIVA+ rear-impact simulation (top right). X-ray high speed movie diplaying the vertebral motions in starting position (bottom left) and at full neck extension (bottom right) in the UBC-setup, obtained in collaboration with UBC (Soltan et al.; 2025).

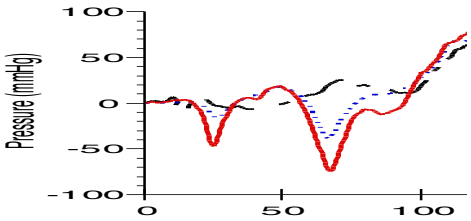
Results

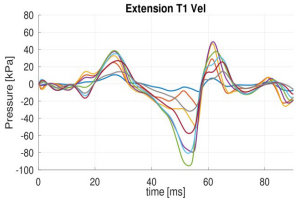
The upgraded VIVA+ spinal canal and the corresponding fluid dynamics software was used to reproduce animal experiments. The results show a surprisingly good qualitative match, in particular for the main negative pressure drop that is hypothesized to be responsible for nerve tissue damage in the intervertebral canals (Fig. 3).

HBMs with the capability to reproduce the precise injury mechanism and predict injury at tissue level are highly needed. They would become a valuable tool I future virtual test methods, both in vehicle development work and in consumer rating and regulatory testing. The potential to assess safety with both female and male models as well as with a range of other parameter variations will improve the possibility to ensure robustness in the protective systems.

The exchange with UBC became key input when Chalmers together with UBC accepted to become part of an EU-MARIE Skłodowska-CURIE ACTIONS consortium from which the proposal "GAPS" was submitted in November 2024.







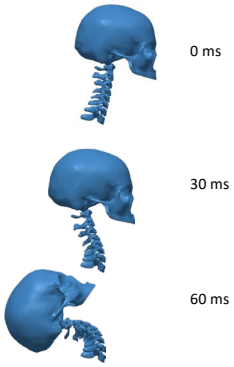


Figure 3: Simulated pressure transients with VIVA+ are compared to animal experiments. The results show a surprisingly good qualitative match, in particular for the main negative pressure drop that is hypothesised to be responsible for nerve tissue damage in the intervertebral canals.

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