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PATIENT-SPECIFIC FE MODELING OF THE INFERIOR CERVICAL SPINE

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Summary: Neck pain, together with lower back pain, is the second most important cause of invalidity in high-income countries. To better understand spinal biomechanics and related issues, the use of finite element (FE) models becomes increasingly popular. However, due to the complex cervical spine morphology and the high inter-subject variability, the development and validation of such a model is proven very difficult. The aim of this study is to propose a patient-specific FE model of the inferior cervical spine and a protocol to validate the model behavior for different configurations. The model consists of four cervical vertebrae (C4 to C7), the associated intervertebral discs and the spinal ligaments. CT- and biplanar X-ray-based 3D reconstructions of six human cadaveric C3-T1 samples were performed. An initial FE mesh was generated from the biplanar X-ray data, as described in Laville et al. (2009), and adjusted automatically to match the CT data. A generic FE model was calculated from the averaged reconstruction. The vertebrae, the nucleus and the annulus matrix were meshed with hexahedral elements, while tension-only cable elements represented the ligaments and IVD fibers. The elastic and isotropic material properties were derived from the available literature and calibrated with the generic model. Flexion/extension, lateral bending and axial rotation motions were simulated.

In-vitro experiments were performed on the same six cadaveric samples. The recorded load vs. displacement curves were compared with the numerical ones.

The generic model reproduced the typical non-linear behavior and predicted consistent coupled motions. The mean RMSE was 0.8° [0.4° - 1.3°] for the principal and 0.6° [0.2° - 2.4°] for the coupled motions. A one-to-one comparison to assess the effect of geometry on spinal kinematics and a comparison between the CT-based and biplanar X-ray-based meshes, is currently ongoing.

Besides providing experimental data useful for model validation, this study proposes a generic FE model of the C4-C7 segment of which the predictions were evaluated against experimental data. This model might provide a useful basis for the study of spinal biomechanics and for implant design. A subject-specific analysis is ongoing and should open the way for introduction in a clinical context.