Machine and Deep Learning for Image Analysis in the Cervical Spine:
Systematic Review of Available Models and Methods

Background: Automating parts of the radiological image analysis process using Machine Learning could provide more accurate and consistent assessment, eliminating interobserver variability with an increased time efficiency.

Research question: Can we create an overview, first, of publications focusing on automated segmentation, and second, of studies using Machine Learning to study characteristics of the cervical spine**?**

Methods: A systematic literature review was conducted in PubMed, EMBASE and Web of Science, Google Scholar, Scopus, SPIE Digital Library and IEEE Explore databases. Studies were selected using predefined selection criteria and risk of bias was assessed. Publications were excluded from this review if; (1) Not written in English; (2) Conference abstracts; (3) Narrative reviews; (4) Cadaver or phantom studies without proven clinical application; (6) Studies that describe a protocol without any form of analysis; (7) Studies on the thoracic or lumbar spine; (8) Studies on radiation dose, artifact reduction, sequence analysis or robotic surgery; (9) Studies on image processing without segmentation, landmarking or any other measurement on the spine involved. Data on study characteristics and model performance was collected. Included publications were divided into either the 'segmentation' category (further specified into 'Conventional Machine' and 'Deep Learning' subgroups) or the 'cervical spine analysis' category.

Results: In segmentation models, Deep Learning methods show promising results with the application of fully automatic convolutional neural networks (CNN) for MR and CT imaging. In cervical spine analysis, the biomechanical features are most often studied using finite element models. The application of artificial neural networks and support vector machine models looks promising for other classification purposes. The reported outcome measures vary widely, leaving room for standardization in this field.

Discussion: This overview will support future research into computer aided diagnostics of cervical degeneration, as well as other diseases in the neck area. In future research, investigators should aim to increase external validity by reporting similar outcome metrics, include uncertainty metrics in their reporting, as well as share code to increase reproducibility.