# The effect of translational constraint on cervical spine kinetics, kinematics and canal occlusions in impacts inducing lateral bending

Tom Whyte, Angela D. Melnyk, Carolyn Van Toen, John Street, Thomas R. Oxland, Peter A. Cripton

## I. INTRODUCTION

Real world head-first impact events, such as rollover motor vehicle collisions, induce lateral bending of the head and neck [1] and result primarily in asymmetric injuries to the cervical spine [2]. There have been very few studies focused on combined lateral bending and axial compression of the cervical spine, which means that the tolerance and injury mechanisms of the neck under these loads are not well understood [3].

Proposed injury criteria for lateral bending are an average of those in flexion and extension and are not based on biomechanical tests [4]. A further limitation to current neck injury criteria is that they do not incorporate measures of the potential for and the severity of spinal cord injury, one of which is dynamic canal occlusion [3].

In a previous test series conducted by our group, combined lateral bending-axial compression impacts were performed without translational constraint in the direction of lateral bending [3]. In these tests, axial impacts applied further from the specimen midline resulted in lower peak axial forces, inferior displacements and canal occlusions, and higher peak ipsilateral bending moments, ipsilateral bending rotations and ipsilateral displacements [3]. In many real world head-first impact events head pocketing may occur, constraining the spine from translating laterally during the impact. The primary objective of this study is to compare the cervical spine kinetics, kinematics and canal occlusions in impacts inducing lateral bending, with (present study) and without (Van Toen *et al*. [3]) constrained translation.

## II. METHODS

Human cadaveric three-vertebra cervical spine motion segments (n=12) were tested in two equal testing groups, defined by the axial compression force line-of-action being located at either 5% of the specimen lateral diameter from the specimen coronal plane midline (low eccentricity) or 150% (high eccentricity). A custom loading yoke attached to an Instron actuator (model 8874) was used to apply axial compression resulting in a lateral bending moment at the set eccentricity (Fig. 1). The impactor allowed the specimen to rotate in lateral bending and compress, but constrained all other translations and rotations. The impactor was driven at 500 mm/s to a predetermined displacement: 20% of the specimen height for the low eccentricity group and 40% for the high group. The actuator was held at that displacement for 0.1 seconds before returning to its original position at 50 mm/s.

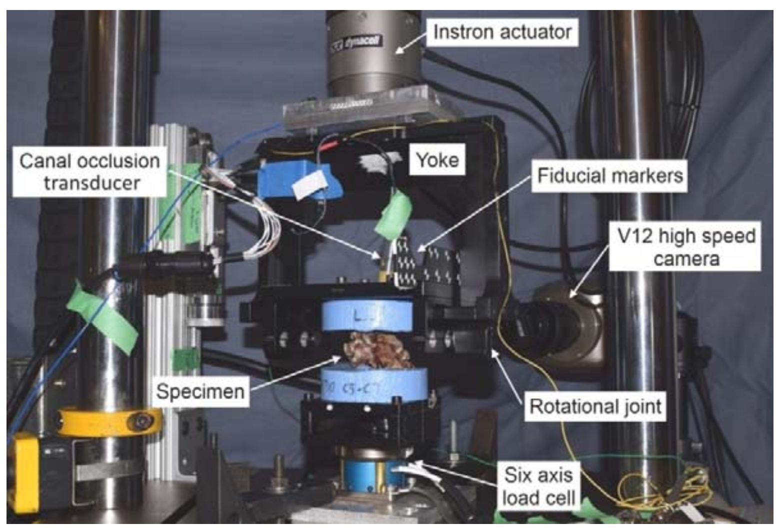

Fig. 1. Specimen impact testing rig, with specimen prepared for testing in right lateral bending.

The impact was captured with four high-speed cameras (two V9s and two V12.1s, Vision Research, Wayne, NJ, USA), three of which were used to identify the time of injury. One camera was aligned with the plane of

T. Whyte (e-mail: tom@mech.ubc.ca; tel: +1 604-652-3004) is a postdoctoral fellow in the Department of Mechanical Engineering at the University of British Columbia, Canada (UBC) and the International Collaboration on Repair Discoveries (ICORD). A. D. Melnyk is a research engineer in the Faculty of Medicine at UBC and ICORD. C. Van Toen completed her PhD affiliated with the Department of Mechanical Engineering at UBC and ICORD. J. Street is a spine surgeon at the Combined Neurosurgical and Orthopaedic Spine Program, Department of Orthopaedics, UBC. T. R. Oxland and P. A. Cripton are Professors in the Department of Mechanical Engineering and Orthopaedics (TRO) at UBC and ICORD.

lateral bending and captured three fiducial markers on the custom loading yoke during impact. A spinal canal occlusion transducer [5] recorded the canal occlusion during impact. A six-axis load cell (model 4366J, Denton ATD Inc., Rochester Hills, NJ, USA) was mounted beneath the specimen.

Mann-Whitney U tests were used to compare the cervical spine kinetics, kinematics and canal occlusions with and without translational constraint of the spine in the direction of lateral bending. Low and high eccentricity groups were compared separately, using a significance level (alpha) of 0.05.

## III. INITIAL FINDINGS

Table I shows the major cervical spine kinetics (ipsilateral lateral bending moment, compression force), kinematics (ipsilateral lateral bending rotation and superior translation) and percentage canal occlusion at the time of injury. There was no statistically significant difference between the spine kinetics at injury with and without translational constraint in either the low or high eccentricity groups. There was a significantly greater inferior translation at injury in the low eccentricity group without translational constraint, compared to impacts on the translationally constrained spine segments. No further difference in spine kinematics at injury was statistically significant.

TABLE I

CERVICAL SPINE KINETICS, KINEMATICS AND CANAL OCCLUSION IN LOW AND HIGH ECCENTRICITY IMPACTS INDUCING LATERAL BENDING WITHOUT TRANSLATIONAL CONSTRAINT (T-FREE) AND WITH TRANSLATIONAL CONSTRAINT (T-FIXED)

| | Low eccentricity | | | | | High eccentricity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T-free | | T-fixed | | p-value | T-free | | T-fixed | | p-value |
| | mean | SD | mean | SD | | mean | SD | mean | SD | |
| **Lateral bending moment at injury [Nm]** | -3.1 | 6.5 | 0.1 | 4.6 | > 0.05 | 37 | 18 | 23 | 9 | > 0.05 |
| **Compression force at injury [N]** | 2700 | 1100 | 3100 | 1300 | > 0.05 | 1000 | 550 | 680 | 330 | > 0.05 |
| **Lateral bending rotation at injury [°]** | 0.95 | 1.44 | 0.50 | 0.36 | > 0.05 | 13 | 4.1 | 15 | 7.4 | > 0.05 |
| **Superior translation at injury [mm]** | -2.2 | 0.66 | -1.3 | 0.42 | **0.045** | -0.17 | 0.77 | 0.18 | 1.76 | > 0.05 |
| **Canal occlusion at injury [%]** | 5.5 | 2.4 | 8.1 | 6.1 | > 0.05 | 3.1 | 2.4 | 6.2 | 3.7 | > 0.05 |
| **Peak canal occlusion [%]** | 53 | 15 | 30 | 16 | > 0.05 | 27 | 5.5 | 13 | 3.0 | **0.005** |

While there was no difference in canal occlusion at injury due to translational constraint, there was significantly greater peak canal occlusion during high eccentricity impact events in spinal segments that were free to translate in the direction of lateral bending (Table I; Fig. 2). The peak canal occlusions occurred after first injury for all tests.

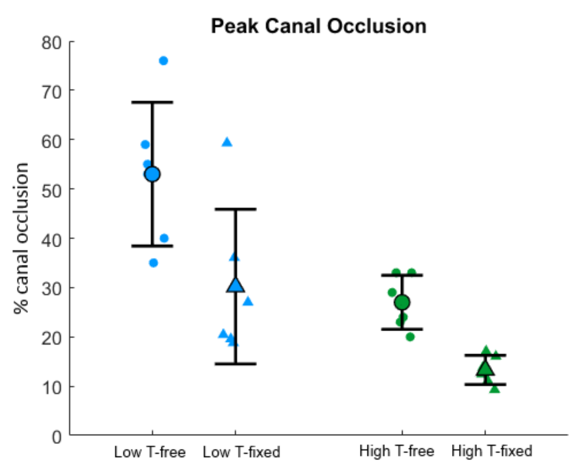

Fig. 2. Peak percentage canal occlusion for axial impacts inducing lateral bending at varying eccentricity (low/high) and without (T-free) and with (T-fixed) translational constraint.

## IV. DISCUSSION

The severity and type of injuries in the constrained end condition have yet to be confirmed and compared to those with free translation.

The results indicate that lateral head escape (i.e. the head translating laterally to escape the incoming torso mass in a head-first impact) may have limited protective potential in combined axial compression and lateral bending, given the greater peak canal occlusions in the free lateral translation condition and the lack of difference in compression forces and bending moments at injury. This is in contrast to the demonstrated effectiveness of flexion-extension head escape in axial compression for neck injury risk reduction [6].

## V. REFERENCES

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