D38 Cervical Spine Injury of Postmortem Human Subjects in Rear-End Impacts

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Learning Overview: After attending this presentation, attendees will have an appreciation for interdisciplinary research in skeletal trauma analysis, specifically regarding the cervical spine. Attendees will learn why cervical spine injury still occurs in rear-end impacts based on experimentally driven biomechanical responses for forensic engineering purposes and understand the importance of utilizing biomechanical data to investigate potential injury mechanisms of the cervical spine in rear impacts.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by demonstrating the need for interdisciplinary biomechanical analyses of trauma in the cervical spine in moderate-speed rear-end impacts. Biomechanical data for intervertebral kinematics and injuries of the cervical spine in moderate-speed rear-end impacts will help attendees understand a potential injury mechanism for the cervical spine and ultimately improve injury analyses in forensic engineering.

In the United States, claims of cervical spine injuries (e.g., whiplash) in rear impact collisions are very common and result in enormous societal cost, with estimates of $2.7 billion annually.[1] Even though cervical spine injuries can result from frontal and rear impact crashes, their risk in rear impact crashes is twice that of frontal impact crashes.[2] Several types (e.g., muscles, ligaments, facet joints, intervertebral discs, nerves) of cervical spine injures in rear-end impacts have been reported.[3] Although extensive research using both volunteers and Postmortem Human Subjects (PMHS) has been conducted with a focus on cervical spine injuries due to low-to-moderate rear impacts, relevant anatomical sites, clinical evidence for injury, and the mechanisms of injury are still unclear. Therefore, the aim of this study was to investigate intervertebral kinematics and injuries to the cervical spine of whole body PMHS by exposing them to moderate-speed rear-end impacts in both experimental and production seats.

Twenty-one rear impact sled tests using 15 PMHS (73 ± 12 year old, 178.6 ± 6.3cm of stature, and 78.7 ± 6.2kg of weight) were conducted with Delta Vs ranging from 17 to 24km/h (Federal Motor Vehicle Safety Standard [FMVSS] 202a, Japan New Car Assessment Program [JNCAP], and 10.5g/24km/h). PMHS were placed in both experimental and production seats that exhibited seat back rotations ranging from 5 to 35 degrees. Head kinematics of the PMHS were measured using six accelerometers and three Angular Rate Sensors (ARS) mounted on the head. In order to measure both gross and intervertebral kinematics of the cervical spine, three accelerometers and three ARS were installed on the anterolateral aspect of the cervical vertebral bodies using custom wing mounts. A three-point belt without a pretensioner or a load limiter was used to restrain the PMHS on the seats, with initial belt tensions of 17.8N (4lb) for the lap-belt and 26.7N (6lb) for the shoulder-belt. The initial seat-back angle was approximately 25 degrees from vertical.

Results show that the intervertebral rotations of the cervical vertebrae represented flexion (i.e., relative forward rotation of upper vertebra relative to lower vertebra), although all cervical vertebrae rotated rearward in the global coordinate system. This relative forward rotation occurred in all three moderate speed conditions, at all intervertebral levels, for both experimental and production seats: 6.5 ± 3.6 and 4.2 ± 2.8 degrees for C2/C3, 6.2 ± 4.2 and 4.0 ± 2.3 degrees for C3/C4, 10.2 ± 5.8 and 6.3 ± 3.8 degrees for C4/C5, 7.6 ± 4.7, 6.1 ± 3.5 degrees for C5/C6, and 6.7 ± 3.8 and 5.8 ± 3.2 degrees for C6/C7, respectively. Several laxities between cervical vertebrae were discovered and identified from post-test dissection. The cervical flexion kinematics observed in this study using both experimental and production seats are not representative of traditional neck extension injuries, but results from this study indicated that intervertebral flexion kinematics may be regarded as an additional potential injury mechanism of the cervical spine during moderate-speed rear-end impacts.

Reference(s):

1. NHTSA, *Federal Motor Vehicle Safety Standards; Head Restraints (FMVSS 202a)*, Federal Register 49 CFR Part 571, Docket no. NHTSA-2004-19807, December 14, 2004.
2. Kuppa S. *Injury Criteria and Anthropomorphic Test Devices for Cervical Spine Injury Assessment.* NHTSA Docket No. 19807, 2004.
3. Siegmund, Gunter P., Beth A. Winkelstein, Paul C. Ivancic, Mats Y. Svensson, and Anita Vasavada. The anatomy and biomechanics of acute and chronic whiplash injury. *Traffic Injury Prevention 10*, no. 2 (2009): 101-112.

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