EXPERIMENTAL STUDY OF CERVICAL SPINE INJURY AND KINEMATICS IN LATERAL HEAD IMPACT

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Introduction

Lateral head impact occurs in motor vehicles roll-over crashes [1]. Roberts et al [1] have reproduced rollover crashes on post-mortem human surrogates and dummies and have noted that the Nij is ineffective to assess neck injury. Moreover, most previous experimental studies on neck injury have focused on axial compression or sled impact and the cervical spine kinematics during a lateral head impact have not yet been described nor associated with the risk of neck injury. This experimental study objective was to evaluate head kinematics and cervical spine injuries from a lateral head impact on human cadavers.

Methods

Five post-mortem human surrogates (2 males and 3 females) wearing a motorcycle helmet were hit to the lateral side of the head with a 37 kg impactor with a 45 degrees inclined surface at 3,5 (low velocity) or 5,1 m/s (high velocity). The impact conditions were chosen from previous multibody karting rollovers simulations showing that the head impact occurs in average at 4.5 m/s with an important tangential velocity. A previously designed test bench was used [2]. The surrogates were equipped with accelerometers at the sternum, at the vertebra T1, in the mouth and on the helmet. A load cell was placed on the impactor. Markers were positioned on the surrogates' helmet to measure the head kinematics by stereography (figure 1). After the impact, the surrogates were imaged by tomodensitometry and the cervical spine was dissected.

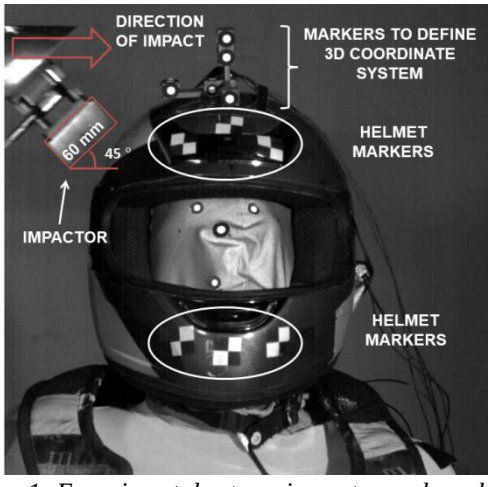

Figure 1: Experimental set-up, impactor and markers position.

Results

The cervical spine injuries found were: rupture of the posterior ligaments (at C1-C2 and C2-C3 for subject 1 and at C5-C6 for subject 4), articular facet fracture at C4-C5 for subject 4 and lamina fracture (at C3 for subject 2 and C7 for subject 1). The injuries were coherent with a previous roll-over experimental study [1]. Head maximal lateral bending during the impact was 35 to 53 degrees (table 1). The reported physiological head lateral bending is 44.5 degrees in each direction [3] which shows that lateral bending under or close to the physiological limit can cause injury. The average maximum resultant impact force was between 1800 N and 5600 N.

Subject number	Sex	Maximum resultant force (kN)	Maximum lateral bending rotation (degrees)	Maximum resultant acceleration (mouth) (g)
1	F	2.1	35	20
2	F	1.8	35	13
3	F	2.4	40	50
4	M	4.7	44	51
5	M	5.6	53	47

Table 1: Impact force, maximum head lateral bending in frontal plane and resultant acceleration recorded at mouth accelerometer.

Discussion

The forces and head kinematics measured in this experimental study are new and important data to understand the cervical spine response to head impact. They will serve as reference for neck injury tolerance and to design more efficient protective devices. This set of data has been used to validate finite elements simulations in an ongoing study which will enable the development of a new neck injury criterion specific for lateral head impact.

References

1. Roberts et al, Clin Biomech, 64, 2019.
2. Beauséjour et al, Clin Biomech, 92 : 105552, 2022.
3. Watier et al, ITBM-RBM, 27, 2006.

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