Quantifying injurious pelvic deformation of post-mortem human subjects in high-speed rear-facing frontal impacts

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Introduction

Non-traditional seating configurations, such as rear-facing (RF) seats for front-row occupants, may be adopted in vehicles with automated driving systems. Previous studies have found pelvis injuries in high-speed (56km/h) frontal impacts on post-mortem human subjects (PMHS) tested in RF seats. However, the deformation of the pelvis from these tests is not fully understood yet. Through visual inspection of medical images from Computed Tomography (CT) scans, the deformation of the pelvis was evident in injurious conditions, but the exact deformation and its direction were unclear.

Objective

This study aims to quantify the deformation of pelvises in the RF frontal impact scenario using pre- and post-test CT scans.

Methodology

Preliminary data collection progressed with eight PMHS. Pre-test and post-test CT scans of eight PMHS (n = 4 for both injurious and non-injurious conditions) were acquired, and 3D pelvis models were isolated using commercial medical image processing software (e.g., 3D Slicer). The pre- and post-test pelvis models from the same PMHS were overlapped and aligned using several reference points on the sacrum. Landmarks on the pelvis were digitized using 3D Slicer and exported to MATLAB to quantify pelvis deformations. Six variables were determined for both the pre- and post-test pelvis models: (1) distance between the left and right anterior superior iliac spine (inter-ASIS), (2) distance between the left and right posterior superior iliac spine (inter-PSIS), (3) distance between the left and right ischial tuberosity (inter-ischial tuberosity), (4) distance between the left ischial tuberosity and the apex of S5 (LIT-S5), (5) distance between the right ischial tuberosity and the apex of S5 (RIT-S5), and (6) angle of the pubic symphysis with respect to the superior face of S1 in the XZ plane (PSA). The digitization and calculations were repeated twice for each PMHS to establish intra-observer consistency using a coefficient of variation (CV). The variables measured from the pre- and post-test pelvis models were compared using a Mann-Whitney U test.

Results

For the intra-observer consistency check, the average CV was less than 4.0%. In the injurious conditions, there was a significant reduction in average LIT-S5 (5.86 mm, p = 0.043) and average RIT-S5 (5.98 mm, p = 0.021), indicating that the ischial tuberosity was closer to the sacrum in the injured pelvises. In the injurious conditions, the average inter-PSIS distance (5.00mm) and the average inter-ASIS distance (3.84mm) significantly increased, while the average inter-ischial tuberosity distance (3.69mm) significantly decreased (p = 0.021 for each). This indicated that the pelvis experienced outward deformation during the impact. There was a slight increase (5.13°) in PSA from the non-injurious to the injurious condition, however, the increase was insignificant (p = 0.686). The preliminary sample size is too small to establish definitive conclusions in this study. Therefore, outcomes from 6 additional PMHS tests (a total of 14 PMHS) will be investigated and added to this study (prior to the symposium) to enhance efforts to understand the relationship between the exploratory variables and pelvis injuries.