Comparison of Pelvis Injury Patterns and Loading Mechanisms in PMHS Tests and Real-World Side Impact Collisions

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Introduction:

Pelvis fracture remains one of the most common types of AIS 2+ injuries in side impacts (e.g. Figure 1). These injuries are particularly concerning due to the possibility of instability in the pelvic ring and proximity to major organs and blood vessels. Additionally, virtual testing with human body models (HBMs) has the potential to capture the complex loading mechanisms that contribute to pelvis fractures, but injury prediction with HBMs must be refined and validated using physical test data. While there have been many PMHS studies testing side impact scenarios focused on pelvic injuries, many of these experiments use simplified test modes rather than simulating realistic boundary conditions. It is crucial to understand the differences between pelvis fractures resulting from in-lab tests and those sustained in real-world collisions.

Objective:

This study seeks to compare injury types and loading mechanisms from existing PMHS tests to those observed in real-world side impact collisions to examine their suitability for refining HBM injury prediction for the pelvis.

Methodology:

The literature was reviewed to identify PMHS test series involving side impacts resulting in pelvis injury. Each impact environment was assessed for modeling suitability considering PMHS weight, impactor speed and shape, and boundary condition details. Pelvis AIS scores and fracture types were noted for each test and compared against real-world cases from CIREN. 185 CIREN cases with pelvis injuries were collected from 2017-2025. The original list was filtered to 34 cases that included side impacts, belted occupants, and available imaging. Side impact was defined as having a principal direction of force (PDOF) between 60 and 120 degrees, or 240 and 300 degrees, to account for near-side and far-side crashes.

Results:

From the literature, 198 side impact tests were compiled from 11 studies, including impactor and sled tests. 22% of selected tests were performed on female PMHS and 35% resulted in pelvis fractures. 72% of tests with fractures occurred in the anterior region of the pelvis, 27% in the iliac wing, 29% in the sacroiliac region, and 14% in the acetabulum. Among the 34 CIREN cases that were analyzed, 88% involved drivers. 68% were female and 32% were male occupants. The mean BMI was 26, and there was a combination of low and medium severity cases. A pattern of interaction with the center console in far-side crashes and “squeezing” the pelvis between the intruding door and the center console in near-side crashes was observed. The percentage of acetabulum fractures in CIREN cases, 36%, was larger than the percentage seen in injurious experimental tests (14%), which may be related to the boundary conditions in a commercial vehicle.

Conclusions:

Comparison between fractures in experimental cases and real-world scenarios provides a meaningful look into how in-lab boundary conditions affect representation of real-world outcomes. This research is part of an ongoing project to develop IRFs for the THUMS and SAFER HBMs to predict pelvis fractures in side impacts. It is important to verify if the resulting IRFs can predict the effect of real-vehicle boundary conditions and "squeezing" mechanisms.

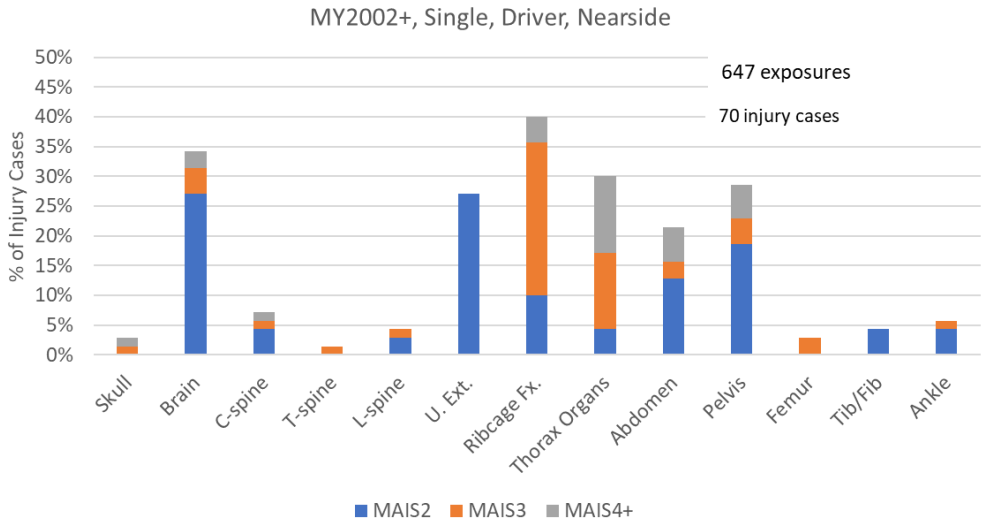

Figure 1: Distribution of AIS2+ injury types in single-event nearside collisions (PDOF 240-300 degrees), by injury severity (CISS collection years 2017-2022, belted driver, MY 2002+, unweighted).