

Biomechanical Response of the PMHS Thorax to High Speed Lateral and Oblique Impacts

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Abstract

Previous research in the kinematic biomechanical response of the thorax to lateral impact has been limited. Eppinger, in 1984, and Viano, in 1989, conducted lateral and oblique (30° anterior of lateral) pendulum impacts of the thorax that resulted in the development of lateral biofidelity corridors. These corridors are used to design anthropomorphic test devices (ATD) that respond in a human-like way to lateral impacts. Viano determined that oblique impact responses can be grouped with lateral impact responses because the peak forces and deflections were found to be similar. Shaw *et al.*, in 2006, performed lateral and oblique impacts at non-injurious speeds and found the post mortem human surrogate (PMHS) thoracic response to be directionally dependent. A query of the National Accident Sampling System – Crashworthiness Data System (NASS/CDS) shows that the frequency of oblique loading of vehicle occupants occurs at a frequency three times that of lateral loading. Understanding when there is a directional dependence in these types of impacts is critical for ATD development.

In this study, nine PMHS were impacted laterally or obliquely at speeds meant to cause a 50% probability of AIS3+, or serious, injury to occur. Loads imparted to the subject were recorded using a ram mounted accelerometer and thoracic deflections were measured using a chestband. Strain gauges mounted to the subject's ribs allowed the timing of rib fracture to be estimated. In all of the 4.5 m/sec tests rib fractures were the major injuries that were documented. Additionally, the major vasculature, including the superior vena cava (SVC), inferior vena cava (IVC), aorta, and pulmonary arteries and veins, were filled with saline to mimic the vascular pressures of a living human. Internal pressure sensors were placed in the aortic arch to detect pressure changes during the impact in the event of an aortic rupture. None of these impacts resulted in such an injury.

The average peak normalized load for the lateral tests was 2557 N ($\sigma=59.7$ N) and for the oblique tests was 2632 N ($\sigma=346.3$ N). The average peak normalized deflection for the lateral tests was 70.0 mm ($\sigma=0.15$ mm) and for the oblique tests was 56.1 mm ($\sigma=2.85$ mm). The peak pressures recorded from each test are included in the results section. Estimated rib fracture timings are also included in the results section.

It appears from these results that the directionally dependent kinematic response of the thorax is not present when the subject is impacted at injurious speeds. This may be due to the viscoelastic response of the internal thoracic organs taking over at these higher speeds. The structural integrity of the boney thorax was compromised in many of the tests; flail chest was a common injury. When the ribs fracture, the internal organs carry more of the load from the ram plate. More of these types of pendulum impacts should be performed to determine when the directional dependence of the thoracic response changes.