C13 Catastrophic Spinal Injury to Restrained Occupants in Frontal Crashes

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Attendees will learn how restraint system design affects the potential for catastrophic spinal injury through the analysis of fourteen passive seatbelt cases.

This presentation will impact the forensic community and/or humanity by demonstrating how certain seatbelt designs increase the risk of catastrophic spinal injury in frontal crashes.

In this presentation, spinal injury mechanisms related to restraint usage are identified and analyzed. The analysis of fourteen passive seatbelt injury cases reveals how catastrophic spinal injuries are related to the belt fit, torso belt load and belt geometry. Injury locations include the lower cervical and upper thoracic spine. Although such injuries can occur in high-speed impacts to a vulnerable person using an ordinary three-point restraint, such injuries should not occur at lower speeds. Yet, such injuries are not uncommon when automatic or passive belt systems are utilized. Passive systems produce these injuries even in moderate speed collisions. Some injury patterns related to single torso belts have been reported. However, the reported injuries, their mechanisms andlocations are, for the most part, different than those in this study. The current study relates only to catastrophic spinal injury and to impacts less violent than many reported in the literature. Even though these restraint systems have been discontinued (passive belt restraints have been replaced by airbags), analysis of passive belt injuries reveal dangerous design parameters that can be useful in evaluating risk factors in other designs, such as the new all-belts-to-seat designs.

By definition, passive belt systems position themselves on the occupant without any action by the occupant. The particular passive design most frequently associated with these injuries is the passive torso belt that travels on a track along the door or doorframe. This system has a separate manual lap belt, but use of the lap belt does not prevent these injuries.

The mechanism in all cases was neck flexion or flexion with distraction. The injuries were located at or between the C3 and T2 vertebrae. The outcome was paralysis from cord damage at those locations or death. Women suffered the most injuries by a ratio of six to one. The prevalence of women may be related to their typically shorter stature, which can contribute to poor belt positioning, their lower neck strength, and reduced shoulder-belt effectiveness because of the compliant female chest. The age range was 17 to 84 years. But the age distribution indicates, as would be expected, that older individuals were more likely to be injured.

Slightly more passengers were injured than drivers, but the difference was insignificant. The vehicles' change of velocity ranged from 17 to 33 mph. A relationship between injury severity and change in velocity was not apparent in this small data set. The shortest person was 4 foot 10 inches tall, while the tallest was 5 foot 10 inches. The mean height was 5 foot 4 inches, or approximately the average height for a woman. The weight ranged from 100 pounds to 260 pounds and no obvious correlation with weight was found. Nine injuries involved C7; this can be explained by the structural discontinuity that exists between the cervical and thoracic spine at C7. The thoracic spine is less flexible and buttressed by the ribs.

The factors common to these passive restraints that contribute to injury are as follows. The torso belt track mount/anchor and inboard lap belt buckle are mounted forward of the typical D-ring and buckle locations. The upper torso belt anchor is forward of the B-pillar, positioning the torso belt forward of, and often several inches higher than, the occupant's shoulder. This geometry can position the belt dangerously high against the neck of a short-statured occupant. The forward, upper mount also created risk to taller occupants, who have their seats further back. They have to move forward into the webbing before experiencing any restraint. Thus, their chest and neck develop a velocity relative to the belt before belt contact and they strike the belt with force. The reduced length of the torso belt also increases the risk. This short length provides less stretch. As a result, the belt develops high-tension forces. Corresponding high stresses develop in the body under and adjacent to the torso belt path, leaving obvious belt marks high on the upper chest or at the base of the neck.

Contributing to the high torso belt loading and resulting injuries is the forward position of the lap belt buckle. The inboard lap belt buckle is forward and above the seat bite (intersection of seat back with seat bottom) in some vehicles by up to seven inches. With this placement the belt cannot fit snugly against the pelvis. Poor lower body restraint, due to poor lap belt fit or no lap belt at all, allows the lower body to submarine relative to the torso belt. As a result, the torso belt moves up towards the neck and distraction forces on the neck are increased.

Half of the injured individuals in this study were wearing their lap belts. These occupants moved forward several inches before the lap belt provided appreciable restraint. As a result, high torso belt forces developed before the lap belt restraint became effective. Clearly the lap belts included with these passive belt systems are ineffective in restraining the lower body and distributing belt forces to the pelvis. Failure of the lap belt to effectively restrain the lower body resulted in higher shoulder belt forces than would be experienced with a continuous loop three-point belt system. This was confirmed by MADYMO simulation of some cases.(1) MAthematical DYnamic MOdeling (MADYMO) is a human body computer program for simulating threedimensional injury events. These simulations showed high torso belt loads and the effect of the lap belt buckle location described above.

In summary, the injury mechanisms related to poor belt fit are identified. This study confirms the importance of good belt geometry, fit and design. A restraint system without these qualities can cause unanticipated catastrophic spinal injuries, especially to women.

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Reference:

(1) Ward CC and Der Avanessian H, "Passive Restraint Injury Analysis," TOPTEC, May 1995.

Passive Restraint Systems, Automatic Shoulder Belts, Spinal Injury