

The Need to Better Control Shoulder Belt Routing in Frontal-Crash Testing

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Résumé

Les protocoles actuels pour tester les collisions frontales permettent de régler l'ancrage de la ceinture de sécurité à la plus haute position disponible. Ceci fait en sorte que la ceinture n'est pas placée au centre du sternum et qu'elle s'éloigne du potentiomètre qui mesure la déformation de la poitrine. Conséquemment, la mesure de la compression de la poitrine est diminuée et les manufacturiers peuvent respecter la norme plus facilement et produire de meilleures cotes de sécurité dans les documents d'information livrés aux consommateurs. Cependant, la compression exercée sur la poitrine est plus élevée dans les collisions réelles, ce qui occasionne des blessures plus sévères et cette situation est préoccupante pour la sécurité des personnes plus âgées.

In North America, frontal-crash protection is increasingly being driven by New Car Assessment Programmes (NCAP) sponsored by both the US National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS). Starting with vehicle model year 2011, NHTSA introduced several changes to the nature and structure of the star-rating scheme used in NCAP. In the context of assessing chest injury risk in frontal crashes, the more significant changes included: substituting chest deflection in place of chest acceleration; and, substituting a Hybrid III 5th percentile female dummy for the 50th percentile male dummy in the right front seating position. Also, from the standpoint of advancing chest protection for elderly occupants, the changes had the drawback that the selected chest injury risk functions were expressed specifically in terms of risk to a 35-year-old occupant.

Numerous studies have shown that the chest area is much more vulnerable to life threatening injuries in the older population. In order to reflect the fact that chest injury risk for the elderly is four to five times that of younger occupants, Digges et al. (1) proposed a "Silver Rating" for NCAP. The

suggested rating uses chest injury risk functions based on the higher vulnerability of the elderly to chest injuries, and the consequent higher risk of death associated with these injuries.

With the increased weighting of injuries to the chest relative to other body regions in the Silver Rating scheme, the accuracy of the chest injury estimates becomes critically important. In current NCAP tests, chest compression is measured by a single chest deflection gauge at the centerline of the sternum of the dummy. The location of the shoulder belt, and hence the degree of chest loading measured by the deflection gauge, are highly dependent on the adjustment of the upper anchorage (D-ring).

The importance of controlling belt positioning in frontal belted testing with restrained Hybrid III dummies has been noted by several researchers. Significant reductions in measured chest compression, of the order of 34%, have been determined as belt placement moved away from the shoulder region and onto the neck.

The location of the upper anchorage is not prescribed by the regulation on frontal crash testing, nor in the protocol for NCAP testing. Instead, the vehicle manufacturer is allowed to specify which adjusted position of the seat belt D-ring is to be used in crash tests. As a result, over 90% of frontal belted tests are currently being conducted with the D-ring in the uppermost position, even though it is readily evident that the belt is then located in close proximity to the neck (see

Figure 1). In the case of regulated frontal tests, this position generates the greatest compliance margin. And, in the case of NCAP tests, it affords a means of greatly reducing the measured chest deflection to produce the highest chest deflection star component rating. Thus, while the belt configuration benefits manufacturers, it does not produce a meaningful assessment of chest injury risk. Consequently, the test does not serve as an instrument of promoting enhanced occupant safety.



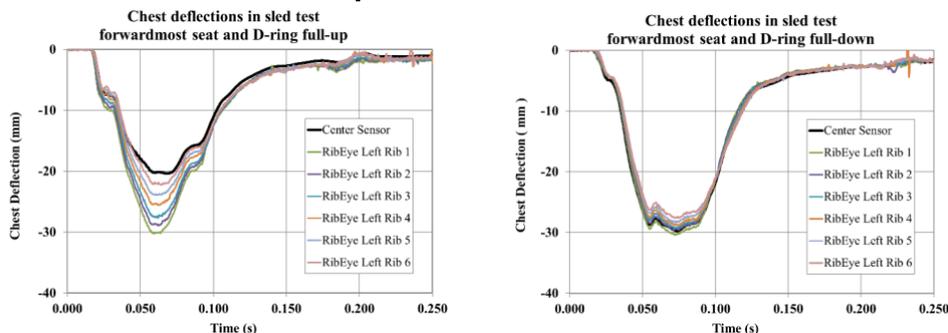
Figure 1. Shoulder belt routing of small female passenger dummy in an NCAP test

In order to highlight the importance of chest deflection measurements in relation to shoulder belt placement, the author and his colleagues constructed a test buck using the same vehicle that was the subject of the above-noted NCAP tests. The test buck was mounted on a sled and used in multiple test runs. The study quantified the variations in measured chest deflection as belt placement was changed as a function of D-ring location. Both a standard chest

potentiometer and a supplementary multi-point chest deflection measurement (RibEye) system were used in the tests.

Tests were conducted using a 5th percentile female Hybrid III dummy, in the right front seating position with the seat fully forward. Chest deflections observed in the test series are depicted in Figure 2 for both the full-up and full-down D-ring positions.

Figure 2. Chest deflection comparison for sled tests



In the official NCAP test, the D-ring was in the full-up position. Consequently, the shoulder belt was routed high, touching the dummy's neck (Figure 1). The measured chest compression on the right front passenger was only 11.8 mm. The extremely low value measured on the central potentiometer in the NCAP test is consistent with the pattern of chest deflection observed in the sled test with the D-ring in the full-up position.

Note that, in the sled tests, the rib deflections across the chest vary considerably, ranging between 20 and 30 mm (Figure 2, left), when the D-ring is in the full-up position and the shoulder belt is moved away from the sternum. In contrast, the loading to the region is much more consistent, at about 30 mm (Figure 2, right) when the D-ring is in the full-down position and the shoulder belt is positioned more appropriately over the shoulder and across the sternum.

The deflection recorded in NCAP can be seen to considerably understate the degree to which the chest was actually compressed, as indicated by the deflections observed with the RibEye assembly. The chest compression of 11.8 mm, as measured in the NCAP test, would be associated with a very low risk of serious (AIS 3+) injury. In particular, this risk would

be determined as just 0.6%, using the NCAP rating risk function (based on an occupant age of 35 years).

In order to complement the current series of sled tests, a full-scale frontal-crash test was conducted by IIHS. A 5th percentile female Hybrid III dummy was placed in the right front seat of the subject vehicle, and the seat-belt's D-ring adjusted to the full-down position. The measured chest compression on the dummy in this test was 34.5 mm, corresponding to a 15% risk of AIS 3+ injury (also based on an occupant age of 35 years).

The increase in injury risk resulting from belt placement becomes even greater when considering elderly occupants. Prasad et al. (2) constructed an injury risk function for older females based on chest compression measurements for the 5th percentile female dummy. For an elderly female, an 11.8 mm chest deflection would be associated with a 0.6% risk of AIS 3+ chest injury, whereas 34.5 mm of chest deflection would produce a 44.7% risk of chest injury.

Clearly, shoulder belt position, as defined by the adjusted location of the upper anchorage, strongly affects the assessed risk of chest injury. Moreover, this is particularly the case for the elderly, who have much less tolerance to injury than their younger counterparts and are, therefore,

at a greater risk of serious injury or death. This highlights the need for a seat-belt positioning procedure based on dummy landmarks rather than the current system that uses vehicle-specific locations. Such changes would ensure more controlled and consistent belt location relative to the chest

deflection potentiometer and provide more appropriate chest injury risk assessment. While this would be beneficial for all motor vehicle occupants, it would be particularly advantageous for the elderly who currently form a large and growing proportion of the occupant population.

While NCAP programmes have been found to be effective in advancing vehicle safety, they are most efficient at doing so if the safety ratings are based on meaningful metrics which are accurately measured. In the case of frontal chest injury assessment, this goal is not being presently achieved due to the lack of an effective belt positioning procedure. What, in reality

constitutes a 2-Star rated vehicle in terms of frontal crash performance, can be made to appear as a 4-Star vehicle by simply

manipulating the location of the seat belt through adjusting the position of the D-ring. The challenge is to ensure that the test protocols which assign a 4-Star or 5-Star rating actually reflect occupant restraint designs which afford 4-Star or 5-Star performance in the field.

Given the integrated nature of the automotive industry in North America, responsibility for maintaining the technical quality of regulations and associated testing requirements is shared by both Transport Canada and NHTSA which, in theory, is addressed through the Canada-United States Regulatory Cooperation Council (RCC). For reasons which are difficult to understand, the necessity of addressing proper belt deployment procedures in both regulated and NCAP tests continues to be ignored.

References

- (1) Digges K, Dalmotas D, Prasad P and Mueller B; The Need to Better Control Belt Routing for Silver NCAP Ratings; Paper No. 17-0403-O; Proc. 25th ESV Conf.; Detroit, MI; 2017
- (2) Prasad, P., Mertz, H., Dalmotas, D., Augenstein, J. and Digges, K.; Evaluation of the field relevance of several injury risk functions; Stapp Car Crash Journal; Vol. 54, 2010.

