C39 Artificial Injury Criteria and Chaotic Dummy Responses

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The goal of this presentation is to establish how injury criteria are dubious.

This presentation will impact the forensic community and/or humanity by demonstrating making the forensic community aware of the consequences of using unreliable injury criteria, which can underrate or overrate the risk of injury.

This presentation discusses the dubiousness of established injury criteria.

The public relies on the National Highway Traffic Safety Administration (NHTSA) to ensure that all U.S. vehicles provide appropriate protection to vehicle occupants. To that end, NHTSA requires that automobile manufacturers comply with Federal Motor Vehicle Safety Standards (FMVSS) before the vehicles can be sold in the U.S. One of the standards that must be met is FMVSS 208, Occupant Protection. In FMVSS 208, anthropomorphic dummies are placed in the front outboard seats of vehicles that then experience dynamic loading in the form of a frontal impact or simulated frontal impact. Electronic data is collected from the anthropomorphic dummies during the tests. The data collected is then compared to established injury tolerance criteria such as the head injury criteria (HIC) and the neck injury criteria (Nij). The FMVSS 208 standard is designed to evaluate the safety provided by the vehicles. The safety performance of the vehicle is rated by comparing the dummy measurement data to the injury criteria threshold values. If the dummy values exceed the established criteria threshold values, the vehicle fails the test and cannot be sold in the U.S. As a result, vehicle manufacturers explicitly design their vehicles not to exceed the injury criteria. Thus, the established injury criteria values directly affect vehicle design, which makes them vital to public safety.

The first head injury criteria adopted by NHTSA, established in the early seventies, was the HIC, which was based on a variety of studies, recorded injuries, and tests. In this criterion, the dummy resultant head acceleration trace is integrated to an exponential power over a finite time interval. The integration over the time interval that provides the highest value was defined as the HIC. If the value of the integration exceeded 1000, the vehicle failed the test. This standard was later changed such that the time segment over which the integration was performed was limited. Currently in FMVSS 208, the maximum duration of the integration for HIC is either 36 milliseconds or 15 milliseconds, depending on the crash conditions. For HIC_{36}, the threshold value is still 1000; however, for HIC_{15}, the threshold value is 700.

The most unreliable criteria is the Nij, especially for the child dummies (6-year-old, 3-year-old and 1-year-old). The tolerance levels used to calculate the Nij are referred to as intercept values or protection reference values (PRV). Twenty-eight different PRV's have been established for the various dummies and positions, although not all of these are used in FMVSS 208. For the family of dummies, these PRV's include neck bending moments (flexion and extension) and neck loading forces (tension and compression). If a dummy were biofidelic, that is, if the dummy produced the same response as the human in a crash condition, the injury tolerance levels obtained from injured humans would be the same as the PRV values. Unfortunately, the dummy is not truly biofidelic and the child dummies only roughly approximate the responses of human children. The dummy neck where the data are obtained is not at all like a human neck. Only 11 tests have been performed on child cadavers with ages ranging from 2 years to 13 years and in only four of these tests were spinal data recorded. Obviously, children cannot be used as volunteer test subjects to study injury. As a result, the criteria for children have been developed using very limited data. Many of the child PRV's are scaled from the adult values. Even the adult dummy neck was designed to represent a human neck in a 30 mph frontal crash. Although not part of the 208 requirements, the dummy neck has even been extended to measure neck response under far different conditions and without verification. For example, injury measures using the dummy neck have been used to evaluate neck compression loads in rollovers.

Consequences of using unreliable criteria are many and serious. Depending on the event, the criteria can both underrate or overrate the risk of injury. Injury crashes that were recreated in crash tests using instrumented dummies are presented. The actual injuries are compared to the dummy measurements. In these investigations, conditions that were unsafe can appear safe based on the dummy data. The cases presented will demonstrate the gross inconsistency between the actual injury and that predicted by the HIC and Nij criteria. If a crash is recreated and the dummy data indicates no injury is expected, frequently in litigation the actual facts of the case are questioned rather than the basis of the criteria or the effect of dummies' lack of biofidelity.

Dummy Biofidelity, HIC, Nij

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