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Mild Rear Aligned Crashes in the United States – Toward Addressing a Paucity of Real World Crash Data

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ABSTRACT

*In the US there exists a paucity of real world aligned mild crash data (delta-V<15 km/h), including the
relationship between acute injury distribution and vehicular dynamics. This is particularly startling when
US occupants in 2005 developed symptoms in approximately 272,000 "whiplash" (WAD) crashes resulting
in a cost of $3.2 billion, exceeding the $2.4 billion in fatal rear crashes. This study aims to improve US real
world mild rear aligned crash research by relating injury to vehicle dynamics.*

METHODS

The study includes data from US real world mild rear aligned crashes. In each crash, at least one struck vehicle occupant was diagnosed within one month of the crash with at least one unique WAD-type complaint attributed to the crash. Crash inclusion criteria incorporated (1) a crash involving exactly two passenger vehicles, (2) a single aligned impact between the front bumper of the striking vehicle and rear bumper of the struck vehicle and (3) absence of airbag deployment for both vehicles. All crashes were investigated by professional forensic engineers. Because of errors in computer reconstruction programs at mild delta-V, vehicle delta-V and acceleration were calculated using validated methods involving physical equations of motion, momentum, energy and restitution. Occupant anthropometry, repair cost and police reported speed were compiled. An indepth examination of the crash dynamics and occupant complaint diagnoses using ICD-9 and AIS2005 was completed.

DATA SOURCES

One hundred three (103) mild crashes out of approximately 60,000 available crashes met the acceptance criteria. Crashes were sought from CIREN, NASS-GES/CDS, CODES, FARS, SDRS and from

the files at a forensic engineering company. Crashes occurred in twenty (20) states from 1994 to 2004. Police reports, medical records, vehicle inspections, vehicle photographs, witness statements and damage costs were collected and analyzed for each crash.

RESULTS

No cases were suitable for inclusion from CIREN, CODES, NASS, FARS or SDRS. For all included crashes, mean struck vehicle delta-V was 6.3 km/h (s.d.= 2.1 km/h). The mean of all average struck vehicle accelerations was 1.4g (s.d.= 0.5g). Police reported mean closing speed was 17.8 kmh (s.d.=11.3 km/h). The average struck vehicle repair cost was $634 USD (s.d. = $568 USD). A total of one hundred eleven (111) occupants were diagnosed during initial emergency department or primary care physician visits within one month after the crash. Female occupants (69% of total) averaged 40.2 years (s.d.= 11.8 years), 78.9kg (s.d.=23.1kg) and 1.63m (s.d.=0.075m). Male occupants averaged 38.8 years (s.d.= 12.0 years), 92.1kg (s.d.=13.0kg) and 1.76m (s.d.=0.084m). ICD-9 enabled coding of 720 complaints and AIS2005 recorded 413 acute injuries (99.3% AIS-1) within one month of the crash. The [ICD-9/AIS2005] distribution was [39%/29%] cervical, [22%/23%] lumbosacral, [10%/15%] thoracic, [10%/12%] upper extremity and [6%/9%] head.

CONCLUSIONS

The current study aims to call to attention the lack of real world aligned mild rear crash data in the US and help elucidate the sometimes confounding relationship between WAD symptomology and vehicle dynamics. The results presented here can assist the US automotive community in designing vehicles, developing testing standards, including evaluation of myriad proposed mild rear crash injury criteria such as NIC, WIC, Nkm, LNL, etc., and conduct research to help reduce WAD injuries in the US. Comparisons can also be made between these results and currently published mild crash literature including activities of daily living, live subject testing and cadaveric testing. Reasons for the large number of ICD-9 diagnoses (43%) due to degenerative conditions sustained in the crash is not known (AIS2005 codes only for acute injuries.)

This data set is but one small step toward answering two fundamental but currently unresolved questions regarding WAD in the US: (1) What are the most frequently diagnosed complaints/injuries in mild rear crashes in the US? and (2) What are the typical vehicle dynamics in mild rear crashes in the US? But this data set has limitations: the primary limitation is that this study contains a biased set of crash data from a random sampling of twenty (20) US states and territories. The small sample size greatly reduces statistical significance and any resulting conclusions. A final limitation is that this study is biased toward mild crashes, with a delta-V of less than 15 km/h.

In 2006, the International Research Council on the Biomechanics of Injury indicated that the relationship between WAD injury criteria and specific injury mechanisms required further clarification. In order for the US automotive community to help in determining this relationship, the distribution of injuries seen in the field and their relationship to vehicle dynamics is essential. This study is a first step towards increasing the dearth of real world US mild rear crash data. Equipped with this data, existing and proposed WAD injury criteria can be validated with real world occupant responses. In this way, the US can add to the current knowledge base established by many countries, including Australia, Canada, Germany, Japan and Sweden, relating mild crash dynamics and occupant injury. Ultimately, establishing the relationship between WAD injury criteria and injury mechanisms requires a global effort and this study will assist the US in contributing to this effort.

DISCUSSION

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PRESENTER: *Adam Bartsch, Cleveland Clinic Spine Research Laboratory and Case Western Reserve University*

QUESTION: *Richard Kent, University of Virginia*
Thanks for the presentation. This points out something that everybody gets confused is the sign of force vectors. And so, I was wondering if we could look, again, at the force that you were saying was J211. Could we go to that slide and look at that?

ANSWER: Which?

Q: You showed some force vectors and you said, "This is J211." I didn't catch it. It was one of the first couple you showed. You said J211 was left-handed, I think.

A: No, it's not right-handed.

Q: Yes. You said it's left-handed.

A: No, it's not right-handed.

Q: Well, if it's not right-handed, it must be left-handed.

A: It's right-handed at FZ (*Shashi Kuppa's comment*).

Q: So my point is that diagram's not right and those green arrows are not right. So I think we have to be careful here because we have external applied moments and forces. We have internal resultants. We had a force the head puts on the neck and we had a force the neck puts on the head.

A: Head. Right. (*Shashi Kuppa's comment*)

Q: So you can draw those arrows all sorts of different ways, but I think the bottom line is J211 is right-handed, and it's not exactly the way those green arrows are.

A: Yes. I should have been more clear when I put this on here. It's actually the manipulation you would do as if you would fix the thorax and you would push the head rearward relative to the thorax.

 It's an applied force (*Erik Takhounts's comment*).

Q: That's positive FX.

A: Right. And that's what I'm showing here. That's something that I failed to mention.

Q: But then if you're showing the internal forces on the neck as a result of interacting with the head, then that's a negative MY.

A: These would actually be—The direction of the manipulation's required to give you the positive forces in J211. So you'd actually pull vertically on the head. You would push the head rearward with respect to the chest, and your positive MY would be flexion of the chin towards the chest.

Q: Yes. The bottom line, I think, is it's a right-handed coordinate system for any of those forces you're talking about, I'm pretty sure.

A: Okay.

Q: But double-check it with free-body diagram. The other thing is: I would suggest that maybe, aside from these kinds of questions you're talking about, maybe the reason that Nij's not working very well is it's based on Beam Theory and that's not a beam. I wonder if you've thought about that and how that might be corrected for this multi-segmented spine.

A: Well, I mean there's an issue of all the structures in the human cervical spine versus the ability to create a dummy that would accurately model that. I know there's an issue in terms of the occipital moments. You can get very large moments with very little rotation, which, in the human head or in the human cervical spine, you don't really see that. And being able to accurately look at all of the ligaments in the cervical spine, as opposed to just a global kind of lump sum Beam Theory: That's something that we're definitely interested in. By no means have we gotten to the point where we could even look at that. But, that's definitely—hopefully down the road.

Q: *Shashi Kuppa, NHTSA*
Yes. J211 is a right-handed system and NHTSA follows J211 for the neck loads.

A: Okay.

Q: And all the data that's available from the advanced airbag rule is all J211. A long time ago until, I think, the early 90s, we were following a different system, but there was not much neck loads captured in many of the crash tests. But I would say at least since '95 or so, we were using SAE J211 and J173, which is the sign convention.

A: Sure. Sure. Yes. I don't actually think it's the difference in switching sign conventions over the years. I think it's actually a matter of maybe during the course of all these massive calculations—I mean there was probably several hundred million calculations that had to be performed over the course of '98, '99 to generate the Nij numbers.

Q: But all that was captured in J211 and we analyzed it as an SAE sign condition.

A: Right.

Q: There was nothing--

A: Right.

Q: There's always these issues of how the airbag is loading the neck, and I think—

A: Right. Just let me give you an example. I guess maybe this'll help—

Q: I know that.

A: I guess in the actual table, we have—Just for the moment example, we have a negative 15 and 42 for the flexion and extension. And let me actually go back one. So we have Test 2997. We have the fact that positive axis had head forward; positive Y had left, positive Z had up. So that's the convention we're talking about for this specific test. And here is—

Q: But no, FZ should not be—I don't know which test is it. When was this test run?

A: This would be an NCAP test. I don't know the exact--

Q: No. If it was NCAP, it had to be collected.

A: Okay. That's in the crash test report. I'm just pointing it out there.

Q: But FZ cannot be positive. If it is according to the NHTSA sign convention or the SAE J211, at FZ: downwards.

A: It's the manipulation. It's the head up tension giving the positive.

Q: Okay.

A: So you have negative 15 extension and negative 42 flexion. And actually, you are utilizing the convention that's reported. In the actual crash test, you actually end up with different numbers.

Q: I don't know what you're talking about.

A: Sure.

Q: But you know you have—There's so much work done on the pig data afterwards. In 2003, Dr. Martin Krasaz wrote a paper on the pig data. You didn't reference to that. Dr. Nusholtz has written a number of papers and showing that neck tension is the high, best predictor of injury for these pig tests.

A: Right.

Q: Even we say that in the 208 technical report: that tension was the best predictor, but you have to include moments for the global kind of loading that occurring on the neck.

A: Right.

Q: So, I'm not sure what you're referencing to. It's already been done, much of this work.

A: Well, I think maybe the point here is: If we're looking forward to the future, in terms of rollover, in terms of rear crashes, and in terms of lateral impacts, we really want to make sure that if it is true that the bending moment actually reduces our neck injury prediction accuracy, I notice some of the rear impact criteria specifically have examined combination of forces and moments to predict injuries. So if we're basing criteria on something that might reduce the accuracy, maybe we need to examine exactly why we use it as a foundation.