Exploratory Analysis of Injury Classification of Crash Victims Using Crash-Medical Linked Data in California

Background

With the passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21), there is a growing emphasis among states to include serious injury as a traffic safety performance measure, in addition to fatalities [1]. Currently, a formal national standard medical definition of serious injury related to motor vehicle traffic crashes does not exist. However, the Federal Highway Administration's Notice of Proposed Rulemaking published March 11, 2014, proposes a uniform definition for national reporting: the 'suspected serious injury' ('A' on the KABCO Scale) classification as defined in the latest revision of the Model Minimum Uniform Crash Criteria (MMUCC) guidelines (4th edition) [2, 3]. The proposed rulemaking also recommends states prepare to determine serious injuries using a medical records injury outcome reporting system that links injury outcomes from medical records to crash reports by the year 2020 [2].

This preliminary report uses linked data from the California Crash Medical Outcomes Data (CMOD) Project[1] to assess how current injury categories used by officers responding to collisions compare with medical injury severity scores. California collision data reported by law enforcement officers is collected on the California Highway Patrol (CHP) 555 form and entered in the Statewide Integrated Traffic Records System (SWITRS). Based on the current MMUCC guidelines, when injuries are associated with a collision, the responding officer (CHP and local law enforcement) assigns an injury severity classification [3]. The classification assigned follows the CHP's Collision Investigation Manual (CIM) guidelines to classify the injury into one of three non-fatal injury categories with the following definitions, similar to the KABCO Scale [4]:

- Severe Injury: An injury other than a fatal injury which results in broken bones, dislocated or distorted limbs, severe laceration, or unconsciousness at or when taken from the collision-scene – it does not include minor laceration.
- Other Visible Injury: This includes: bruises (discolored or swollen); places where the body has received a blow (black eyes and bloody noses); and abrasions (areas of the skin where the surface is roughened or broken by scratching or rubbing which includes skinned shins, knuckles, knees, and elbows).
- Complaint of Pain: This classification could contain authentic internal or other non-visible injuries and fraudulent claims of injury. This includes: (1) persons who seem dazed, confused, or incoherent (unless such behavior can be attributed to intoxication, extreme age, illness, or mental infirmities); (2) persons who are limping but do not have visible injuries; (3) any person who is known to have been unconscious as a result of the collision, although it appears he/she has recovered; and (4) persons who say they want to be listed as injured, but do not appear to be so.

For medical data from emergency department and inpatient hospital admissions, the Injury Severity Score (ISS) is a standard summary metric of injury. Originally developed to predict injury survivability, it has been used for various applications in medical research, particularly in assessing trauma, and is an accepted standard in injury severity measurement [5]. The ISS is a score that ranges from 1 to 75 based upon the Abbreviated Injury Scale (AIS), which classifies injury descriptors using the International Classification of Disease 9th Revision – Clinical Modification (ICD-9-CM) diagnoses codes into nine body region categories. It assigns each injury a score ranging from one to six (minor injury to maximum injury). The ISS computes an overall score based on AIS scores of the three most severely injured body regions [5].

In this report we used the ISS to assess the degree of concordance of injury classification as reported in SWITRS. To calculate the ISS we used the ICDPIC module for Stata v14 (StataCorp, College Station, TX) and ICD-9-CM diagnoses codes from inpatient and emergency department visit records. We applied the standard cutoff of scores used by the American College of Surgeons for the National Trauma Data Bank: 15 or less to represent non-severe injury, and 16-75 to represent severe injury [6].

[1] The Crash Medical Outcomes Data (CMOD) Project, modeled after the National Highway Transportation Safety Administration's Crash Outcome Data Evaluation System (CODES), probabilistically links law enforcement collision records to health data from emergency department visits and hospitalizations (OSHPD).

Results

From 2008 to 2012, SWITRS reported 1,156,150 persons non-fatally injured in motor vehicle traffic crashes. Of those injured, 5% were classified as severe injury, 26% as other visible injury, and 69% as complaint of pain. Among these cases, 56% were linked to an emergency department or hospital inpatient medical record. It is expected that records for those with more severe injuries are more likely to link to an emergency department or hospital inpatient record because these individuals are more likely to seek medical treatment. As shown in Table 1, the cases that were linked to an emergency department or hospital inpatient record are demographically similar to those that were not linked, suggesting the linked data represent a reasonably non-biased sub-sample of the total SWITRS sample.

Table 1. Demographic Characteristics and SWITRS Reported Degree of Injury for Non-Fatally Injured Persons Involved in Motor Vehicle Traffic Crashes by Crash-Medical Linked Data Status, California, 2008-2012 (n=1,156,150)

	Linked Status		
Victim Demographics and Reported Degree of Injury	Linked (%) n=648,364	Non-Linked (%) n=507,786	**Total** (%) n=1,156,150
Sex			
Male	49	50	49
Female	51	50	51
Age			
0-15	8	8	8
16-24	24	25	24
25-44	34	35	35
45-64	25	25	25
65+	8	8	8
Reported Degree of Injury			
Severe	7	2	5
Other Visible Injury	28	24	26
Complaint of Pain	66	73	69

In this report, we focused on the 647,775 non-fatally injured persons for whom we have both Crash-Medical linked data from 2008-2012 and an ISS. As displayed in the Total column in Table 2, 7% of these non-fatally injured persons were reported in SWITRS to have a severe injury, 27% reported to have a visible injury, and 66% were reported to have complaint of pain. Among those cases of non-fatal injuries, 87% involved a visit to the emergency department, and among these the majority were reported to have complaint of pain as the degree of injury. Of the 13% admitted as inpatients to a hospital, 35% were reported to have sustained a severe injury.

Table 2. SWITRS Reported Degree of Injury for Non-Fatally Injured Persons Involved in Motor Vehicle Traffic Crashes, by Level of Service, Crash-Medical Linked Data, California, 2008-2012 (n=647,775)

	Level of Service		
SWITRS Reported Degree of Injury	Inpatients	Emergency Department Visits	**Total**
Severe	29,177 (35%)	13,440 (2%)	42,617 (7%)
Other Visible Injury	28,366 (34%)	149,457 (27%)	177,823 (27%)
Complaint of Pain	25,662 (31%)	401,673 (71%)	427,335 (66%)
Total	83,205 (13%)	564,570 (87%)	647,775

An observation of the breakdown of ISS by level of service (Table 3) yielded similar results- most injuries were non-severe (97%), and 87% involved a visit to the emergency department. Three percent of those non-fatally injured sustained a severe injury, and 93% of these were inpatients.

Table 3. Injury Severity Scores for Non-Fatally Injured Persons Involved in Motor Vehicle Traffic Crashes by Level of Service, Crash-Medical Linked Data, California, 2008-2012 (n=647,775)

	Level of Service		
Injury Severity Score	Inpatients	Emergency Department Visits	**Total**
Severe (16-75)	17,066 (21%)	1,289 (0.2%)	18,355 (3%)
Non-Severe (0-15)	66,139 (79%)	563,281 (99.8%)	629,420 (97%)
Total	83,205 (13%)	564,570 (87%)	647,775

To compare the SWITRS reported degree of injury and ISS derived from emergency department or hospital data, we used three standard measures of diagnostic accuracy: sensitivity, specificity, and positive predictive value (PPV). Diagnostic accuracy is the amount of agreement between results from a diagnostic test and those from a reference test. For our purposes, we used this model to analyze the agreement between the SWITRS-reported degree of injury (diagnostic test) and the ISS (reference test). Sensitivity describes the ability of SWITRS to show a positive result (reported severe injury) for all who have the target condition (severe ISS), the true positives. Specificity describes the ability of SWITRS to show a negative result (reported other visible injury or complaint of pain) for all who do not have the target condition (non-severe ISS), the true negatives. The PPV assesses the accuracy of a test, describing the probability of having the target condition (severe ISS) given a positive result (SWITRS-reported severe injury). Values of sensitivity, specificity, and PPV of 100% indicate a perfect match [7].

When comparing the SWITRS reported degree of injury to ISS (Table 4), we found the majority of the injuries with a non-severe ISS were reported as other visible injury or complaint of pain. This produced a specificity value of 95% which indicates a high likelihood that truly non-severe injuries were classified as such by law enforcement officers. However, analysis of severe injuries, found a sensitivity value of 58%, demonstrating that less than 6 out of 10 injuries with a severe ISS were reported as severe in SWITRS. This indicates that the SWITRS classification missed 42% of the severe injuries. In addition, although SWITRS reported 42,617 severe injuries for the years 2008-2012, only one-quarter of these actually had a severe ISS, yielding a PPV of 25%.

Table 4. Comparing Injury Severity Scores to the SWITRS Reported Degree of Injury, California, 2008-2012 (n=647,775)

	Injury Severity Score					
SWITRS Reported Degree of Injury	Severe (16 – 75)	Non-Severe (0 - 15)	**Total**		**Diagnostic Accuracy Measures**	
Severe	10,645	31,972	42,617		Sensitivity	58%
Visible Injury or Complaint of Pain	7,710	597,448	605,158		Specificity	95%
Total	18,355	629,420	647,775		PPV	25%

To assess whether other visible injuries were more similar to injuries classified as severe, we combined these two groups and applied the diagnostic accuracy measures (Table 5). We found that the sensitivity increased to 83%, indicating a higher likelihood that truly severe injuries were actually classified as severe by officers. However, the specificity value decreased to 67% and the PPV decreased to 7%.

Table 5. Comparing Injury Severity Scores to the SWITRS Reported Degree of Injury with Severe Injury and Other Visible Injury Grouped Together, California, 2008-2012 (n=647,775)

	Injury Severity Score					
SWITRS Reported Degree of Injury	Severe (16 – 75)	Non-Severe (0 - 15)	**Total**		**Diagnostic Accuracy Measures**	
Severe or Visible Injury	15,179	205,261	220,440		Sensitivity	83%
Complaint of Pain	3,176	424,159	427,335		Specificity	67%
Total	18,355	629,420	647,775		PPV	7%

To provide further insight into the injuries classified by these two methods, we examined the types of injuries that occurred among motor vehicle crash victims. Based on the ISS, the body regions where injuries occurred most often were the spine and back (25%), torso (15%), and upper extremities (13%). Among severe injuries documented by the ISS, the most common were traumatic brain injury (38%), and injuries to the torso (29%) and lower extremities (14%). Among severe injuries reported by SWITRS, the most common were injuries to the lower extremities (27%), traumatic brain injuries (20%), and injuries to the upper extremities (17%).

As shown in Table 6, the SWITRS sensitivity values for correctly classifying a severe injury that is truly severe by specific body part ranged from 51% to 76%. The body region with the highest sensitivity involved the lower extremities, while the lowest sensitivity was the torso. The most common body regions for injuries that SWITRS classified as other visible injury or complaint of pain, and had an ISS for severe injury were traumatic brain injury and injuries to the torso (not shown in Table 6). As found for injuries overall, we also observed that when grouping other visible injuries with severe injuries, there was a substantial increase in the sensitivity values across body regions.

Table 6. Injuries by Body Region: Sensitivity Measures of SWITRS Reported Degree of Injury Compared to ISS, California, 2008-2012 (n=647,775)

Body Region	Total Injuries	Sensitivity (Severe alone)	Sensitivity (Severe + Visible)
Spine and Back	164,418	56%	78%
Torso	93,818	51%	76%
Upper Extremities	82,550	62%	87%
Lower Extremities	74,688	76%	92%
Other Head and Neck	62,056	57%	92%
Traumatic Brain Injury	60,359	57%	84%
All Other Regions[1]	109,886	53%	73%
Total	647,775	58%	83%

[1] All other regions includes other and unspecified, system-wide/late effects, and non-injury

Summary

We examined the concordance of SWITRS reported degree of injury and medical injury severity scores for non-fatally injured persons involved in motor vehicle traffic crashes using linked crash medical data. There was a high level of agreement among the non-severe injuries. The data showed that most injuries with a non-severe ISS were reported in SWITRS as other visible injury or complaint of pain (high specificity). However, officers reported less than two-thirds of injuries with a severe ISS as severe (low sensitivity). In addition, for every four severe injuries reported in SWITRS, only one had a severe corresponding ISS. When injuries that were reported in SWITRS as other visible injury were combined with those reported as severe, we found that the matching of severe injuries increased (higher sensitivity). Following a more detailed inspection of the injuries, we found that the injuries with the highest levels of discrepancy were those of the torso, head and neck, and traumatic brain injuries.

Sensitivity and specificity are comparative tools for which the cutoff or ideal scores depend on the purpose of the assessment. As demonstrated in this study, there is a tradeoff between sensitivity and specificity when assessing the injury categories reported by SWITRS in comparison with medically assigned injury scores. While sensitivity and specificity of 100% is ideal, in some instances a lower sensitivity or specificity might be acceptable. From a public health surveillance perspective, sensitivity is considered an important attribute. If the purpose is to monitor trends, lower sensitivity may be acceptable if the methodology is consistent over time, and the target condition is representative. However, if the purpose is to assess the impact of a health problem, high sensitivity is needed [8].

Other studies of motor vehicle injuries conducted in the United States and internationally have reported similar findings, that law enforcement injury severity scales do not effectively capture injury severity or injury outcome as measured by standard medical injury metrics such as ISS and AIS. Among these studies, the sensitivity percentages for severe injury reported by law enforcement that matched medically determined severe injury cases ranged from 49% to 78% [9-14]. These studies found law enforcement scales were better at classifying non-incapacitating or non-severe injuries [10, 14], but overestimated severe injuries [12]. These studies also found that reported use of a standard medical metric was found to be more consistent between states than law enforcement crash injury scoring using KABCO [9, 12]. Suggested reasons for discrepancies between law enforcement and medical injury classification include: severe injuries without outward signs may be missed by law enforcement officers [11, 13]; and visible injuries may initially appear more serious than they actually are [11, 14]. Injury classifications in crash reports are determined by law enforcement officers who are typically not medically trained, and are based on the appearances and circumstances at the scene of a crash. The responding officer is not expected to make a clinical judgment at the scene. Therefore, it is likely that some injuries which may be life threatening are not obvious, such as internal injuries; and those that are not life threatening may appear more severe, such as minor lacerations with profuse bleeding, leading to misclassification.

Conclusion

This report demonstrates the usefulness of crash-medical linked data, allowing us to examine the concordance between SWITRS-reported degree of injury and medical injury severity scores for non-fatally injured persons involved in motor vehicle traffic crashes. Strengths of this approach include using linked data that are demographically similar to non-linked cases, and the use of ISS, a recognized standard among medical injury scores. The ability to link crash and medical data allows for the inclusion of more information to better understand injuries resulting from motor vehicle crashes. The call has been made for further use of crash-medical linked data for improved understanding of injury outcomes [1, 15, 16]. Using standard metrics obtained from medical data makes it possible to further evaluate crash injuries and allows for more accurate reporting and comparisons between states, as well as for more targeted interventions. Given these findings, we hope this report will inform discussion about the MAP-21 serious injury classification.

References

1. United States Department of Transportation Federal Highways Administration, *MAP-21, Moving Ahead for Progress in the 21st Century, Highway Safety Improvement Program (HSIP) Map-21 Interim Eligibility Guidance.*
2. Department of Transportation, F.H.A., *National Performance Management Measures; Highway Safety Improvement Program. A Proposed Rule by the Federal Highway Administration on March 11, 2014*, F.H.A. Department of Transportation, Editor. 2014: Federal Register. p. 13845-13871.
3. Governor Highway Safety Association, *MMUCC Guideline Model Minimum Uniform Crash Criteria*. 2012, Department of Transportation, .
4. Department of California Highway Patrol, *Collision Investigation Manual*. 2003.
5. M Stevenson, M.S.-G., I Lescohier, C Di Scala, G McDonald-Smith, *An overview of the injury severity score and the new injury severity score.* Injury Prevention, 2001. **7**: p. 10-13.
6. American College of Surgeons, *NTDB Annual Report 2015*. 2015.
7. Karlijn J Van Stralen, V.S.S., Johannes B Reitsma, Friedo W Dekker, Carmine Zoccali, Kitty J Jager, *Diagnostic Methods I: Sensitivity, Specificity, and Other Measures of Accuracy.* Kidney International, 2009. **75**(1257-1263).
8. Kenneth J Rothman, S.G., Timothy L Lash, *Modern Epidemiology*. 3 ed. 2008, Philadelphia, PA: Lippincott Williams & Wilkins.
9. Burch, C., L. Cook, and P. Dischinger, *A comparison of KABCO and AIS injury severity metrics using CODES linked data.* Traffic Inj Prev, 2014. **15**(6): p. 627-30.
10. CL Popkin, B.C., AR Hansen, RR Stewart, *Analysis of the Accuracy of the Existing KABCO Injury Scale*. 1991: University of North Carolina Highway Safety Research Center.
11. Compton, C.P., *Injury severity codes: a comparison of police injury codes and medical outcomes as determined by NASS CDS Investigators.* J Safety Res, 2005. **36**(5): p. 483-4.
12. Farmer, C.M., *Reliability of police-reported information for determining crash and injury severity.* Traffic Inj Prev, 2003. **4**(1): p. 38-44.
13. Huelke, D.F., M.J. Murphy, and H.W. Sherman, *A reappraisal of the use of police injury codes in accident data analysis.* Proceedings: American Association for Automotive Medicine Annual Conference, 1976. **20**: p. 128-138.
14. McDonald, G., G. Davie, and J. Langley, *Validity of police-reported information on injury severity for those hospitalized from motor vehicle traffic crashes.* Traffic Inj Prev, 2009. **10**(2): p. 184-90.
15. Cambridge Systematics, I., *Measuring Performance Among State DOTs: Sharing Good Practices -- Serious Crash Injury, Prepared for the American Association of State Highway and Transportation Officials/STanding Committee on Performance Management*. 2013.
16. J Milani, J.K., G Bergen, EJ Novicki, C Burch, SM Ho, BA West, *Assessment of characteristics of state data linkage systems*. 2015, National Highway Traffic Safety Administration. Centers for Disease Control and Prevention.

About the data

This report uses various sources (hospital emergency room and inpatient data and police collision reports) to describe motor vehicle traffic collision injuries among Californians. Each source captures a different aspect of the overall burden of these injuries. Information for persons injured in crashes in California may be accessed through the CMOD online query Linked Crash-Medical Data. This query is part of the EpiCenter California Injury Data Online accessed at http://EpiCenter.cdph.ca.gov. There you may create tables to see how victim characteristics and crash circumstances affect the victim's medical outcome.

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