RESULTS OF FIRST FIELD TEST OF TELEMETRY BASED INJURY SEVERITY PREDICTION

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ABSTRACT

Identification of severely injured occupants is of utmost urgency following a crash event. Advanced automatic collision notification (AACN) has great potential to improve post-crash care if the risk of severe injury to a vehicle's occupants can be accurately predicted. The National Expert Panel for Field Triage set a 20% risk of Injury Severity Score (ISS) 15+ injury [1] as the threshold for urgent transport to a trauma center. The objective of this study was to field test real world performance of the published injury severity prediction (ISP) algorithm in collisions involving recent model GM vehicles equipped with OnStar.

This study was approved by the IRB of the Michigan Department of Community Health. There were 924 occupants in 836 crash events, involving vehicles equipped with AACN capabilities, in the state of Michigan which were identified from the OnStar records. The police crash report corresponding to the event was identified in the State of Michigan database and used to confirm data sent by telemetry from the vehicle. The injury status of all occupants in the case vehicles was determined. Occupants not transported for medical evaluation were assumed to have ISS<15. For occupants transported from the scene for evaluation and treatment, medical records and imaging data were obtained from the treating facility. Case reviews were conducted to jointly analyze crash, vehicle telemetry, and injury outcome data. The algorithm was used to calculate the predicted risk of injury based on transmitted telemetry data and this prediction was compared to the observed injury outcome for each vehicle as well as each occupant.

In this field study, the ISP algorithm's ability to predict whether a vehicle had a seriously injured (ISS>15) occupant was, in terms of sensitivity, at 63.64% compared to the model sensitivity of 39.6% and it also came very close to expectations of specificity at 96.12% compared to the model specificity of 98.3% with use of age and gender data. Without use of age and gender, for ISP calculation, the sensitivity performance was 45.45% while the specificity improved slightly to 97.58%. Detailed analysis of cases suggests that further performance gains could be obtained with more detailed definition of crash direction, seating position, and occupant age.

There were 184 candidate crash occupants in 167 vehicles not included in the study analysis due to: A) missing Police accident reports, n=77 in 75 crashes; B) inability to retrieve medical records, n = 71 in 61 crashes; or C) rollover event, n=36 in 31 crashes. Analysis of these excluded cases did not reveal any bias in crash severity or injury that would confound the current study findings.

This study confirms for the first time under real-world field conditions that occupant injury severity can be predicted using vehicle telemetry data. The ISP algorithm's ability to predict a 20% or greater risk of severe (ISS15+) injury was better than anticipated and confirms ISP's utility for the field triage of crash subjects. This analysis suggests that AACN technology can greatly facilitate the collection of field data with ISP also serving as a baseline for potential monitoring of the benefits resulting from vehicle safety design changes.

INTRODUCTION

Over 1.2 million people died worldwide as a result of road traffic accidents in 2009. While many countries do not have data for injuries sustained in motor vehicle crashes (MVC), estimates from the WHO indicate the total number of non-fatal injuries sustained in a MVC is between 20 and 50 million. [2]

In 2013, the most recent year for which US data is currently available, there were 32,719 road traffic fatalities in the United States alone. Additionally, 2,313,000 people were injured (732 per 100,000). [3]

While some vehicle occupants sustain immediately fatal injuries, a substantial portion expire subsequently during transport or in the emergency department as a result of traumatic shock from injuries that compromise oxygenation and ventilation or cause bleeding. Minimizing the time between injury and treatment is absolutely critical to reducing mortality and morbidity. [4] It is therefore crucial to get first responders to the scene quickly – with the appropriate equipment to initially treat the injuries sustained and then to triage and transport the occupants to the appropriate medical center for further care. Level 1 trauma centers are resourced and staffed to provide definitive trauma care. Severely injured patients have a 25% reduction in mortality if transferred to a Level I trauma center versus if they are transported to a non-Trauma center [5]

At the injury scene, EMS providers determine the severity of injury, initiate medical management and identify the most appropriate medical facility destination through a process called "field triage." [6] In 2009, the Centers for Disease Control and Prevention (CDC) convened the National Expert Panel on Field Triage to review and make recommendations for improving the American College of Surgeons Field Triage Decision Scheme which served as the basis for triage protocols used by state and local EMS systems across the United States. [4] The goal of the field triage process is to get the right person to the right place in the right time. Not every MVC victim needs to be transported to a level I trauma center, but for those who do, it is vital that the first responders on the scene recognize this and move quickly. The first two steps of the Field Triage Decision scheme use anatomic (Step 1) and physiologic criteria (Step 2) to identify the most severely injured patients. Step 3 uses mechanism of injury, for which the National Expert Panel targeted a 20% risk of ISS>15 injury. MVCs were the most significant mechanism of injury addressed in Step 3 and the Panel recommended the inclusion of "vehicle telemetry consistent with high risk of injury". This criterion was included in the 2006 revision as a placeholder in anticipation of more widespread adoption of AACN equipped vehicles. [4].

The CDC subsequently convened a subcommittee of the National Expert Panel over 2007-2008 to coordinate the use of vehicle telemetry. [4] This Expert Panel on the Advanced Automatic Collision Notification and Triage of the Injured Patient concluded that AACN showed promise in improving outcomes to severely injured crash patients by a) predicting the likelihood of serious injury in vehicle occupants, b) decreasing response times by pre-hospital care providers, c) assisting with field triage destination and transportation decisions, d) decreasing time to definite trauma care and e) decreasing death and disability from MVCs. This panel recommended that pilot studies be conducted using vehicle telemetry data including

- Delta V (crash severity)
- Principal direction of force (PDOF)
- Seatbelt usage
- Crash with multiple impacts
- Vehicle type.

Additionally, it recommended that voice communication be established with the vehicle occupants to determine the presence of injuries and also to collect additional information such as age and gender that might affect injury risk. The panel also recommended that injury risk should be calculated with all available data and that if the occupant is at 20% or greater risk of ISS>15 injury, the relevant Public Safety Answering Point (PSAP) should be notified that the occupant meets the Field Triage Decision Scheme's Step 3 criterion for "vehicle telemetry consistent with high risk of injury" and appropriate resources dispatched. [4]

Based on these recommendations an ISP algorithm was developed using a logistic regression model of nationally representative crash data (NASS-CDS from calendar years 1999-2008). [7] Vehicle safety systems are constantly evolving, including changes to the vehicle structure and the restraint systems; as such the risk of injury may also evolve as the vehicle fleet changes. Since AACN equipped vehicles are newer and NASS-CDS contains crash data from many model years, NASS-CDS was filtered to include model year 2000 and newer cars, light trucks, and vans. Only planar non-rollover crash events were used as the ISP algorithm is not designed for rollover crashes. Delta-V is calculated within the current generation of Event Data Recorders (EDRs) and is utilized in the ISP algorithm because delta-V has been shown to be predictive of injury within planar crashes; this same relationship has not been demonstrated in rollover crashes. [6]. For the logistic regression model, crash PDOF was binned into four crash directions (front, left, right and rear). Frontal crashes were defined as those with PDOF of 11, 12 or 1 o'clock, right side as those from 2 to 4 o'clock, rear from 5 to 7 o'clock, and left from 8 to 10 o'clock. The ISP algorithm was designed to predict the probability that a crash-involved vehicle will contain one or more occupants with severe injury (ISS>15). Analysis of the logistic regression model and resultant ISP algorithm targeting 20% or greater risk of ISS>15 injury showed that crash direction, seat belt use and Delta-V were the most important predictors of serious injury. The NASS-CDS dataset estimates delta-V on an energy-based calculation using post-crash vehicle deformation.

The ISP model sensitivity, based on the NASS-CDS dataset, was 40% and specificity was 98% using an injury probability cutoff of 20% risk of ISS >15.

The current study was undertaken as a pilot to analyze the field performance of the ISP algorithm for newer AACN-equipped GM vehicles involved in crashes. Study objectives also included assessment of the effects of 1) limiting data collection to a single vehicle manufacturer (GM); 2) substitution of transmitted Delta-V from crash sensors in place of vehicle deformation based crash severity; and 3) substitution of transmitted PDOF from crash sensors in place of vehicle deformation based crash direction.

Methods

Any vehicle involved in a MVC, which had a current subscription to the OnStar telematics program, was eligible for inclusion. The ICAM team received permission from the Michigan Department of Community Health (MDCH) to access medical records for any patient involved in one of these crashes. Both vehicle and occupant identification remained anonymous to GM and OnStar.

For this pilot study, ICAM received a convenience sample of 1,003 OnStar crash cases that took place in the state of Michigan from January 2008 through August 2011. These data included information provided by the SDM to the PSAP. Also included is the latitude and longitude of the scene, delta direction, delta velocity, whether and which airbags deployed, whether multiple impacts occurred, whether a rollover event occurred, vehicle category and type.

As a research institution, ICAM requested and was granted access to the Michigan Department of Transportation User website. With the time and location data from the OnStar, staff members were able to pinpoint each crash and retrieve the Police Accident Report (PAR). The PAR provides extensive detail about the vehicle, crash, and occupants. In order to request medical records, it was necessary to gather the occupants' names and birthdates as well as where they were transported if they needed further care. Matching the vehicle identification number (VIN) from the OnStar data to the PAR, the ICAM team ensured they were looking at the report for the correct vehicle and crash. 1,108 candidate crash occupants were identified using this process.

With names and birthdates, the treating hospitals were contacted to request medical records (EMS transport sheets, Emergency Department notes, operative notes, radiology reports, and discharge notes) as well as radiological data – specifically any computed tomography scans performed on the occupants. ICAM nursing staff then abstracted injury information from the medical records and created a list of injuries sustained for each transported occupant. If occupants were not transported, it was assumed that their injury severity score (ISS) was <15.

Of the 1,003 candidate crash cases, there were 184 occupants in 167 vehicles that were not included in the study analysis due to: A) missing police accident reports, n=77 in 75 crashes; B) inability to retrieve medical records, n = 71 in 61 crashes; or C) rollover event, n=36 occupants in 31 crashes. Analysis of these excluded cases did not reveal any bias in crash severity or injury that would confound the current study findings. In the end 836 crash vehicles with 924 occupants were available for analysis.

The implementation of the ISP Algorithm for seatbelt usage uses a base case of 0 if the seat belt is not used or its use is unknown, for any occupied seat. In this study approximately 40% of the crash incidents did not have complete seat belt information so the base case was applied in these cases in the same way that the OnStar application would process these cases. See Appendix B for relative weights of NASS sample to the convenience sample for key variables.

Concurrently, ICAM's crash investigator with more than 30 years of experience in the crash industry crosschecked the OnStar telemetry data against the PARs for each case. He confirmed that the SDM data matched the PAR data. Any incongruous data was marked for further review.

Study subject confidentiality was protected by having all records and medical data tagged with an anonymous study ID by ICAM medical staff before crash review of GM/OnStar engineers. No subject identifiable data collected by ICAM was made available to GM/OnStar.

A multidisciplinary review panel including ICAM medical and research personnel as well as automotive engineers with previous medical training from GM and OnStar was convened to review all cases where an occupant was transported to a medical center. Furthermore, cases with incongruities between predicted ISP and observed outcomes were reviewed in depth with consideration of all the following factors:

Crash Factors

1. Configuration
    a. PDOF
    b. Angled
    c. Offset (Vehicle Overlap)
    d. Narrow object
2. Compatibility
    a. Mass
    b. Geometry
    c. Stiffness
3. Multiple impacts
4. Rollover
5. Occupant seating position
6. Ejection
7. Entrapment

Vehicle factors

1. Deployment of Airbags
    a. Curtain
    b. Thorax
    c. Pelvic/thorax
    d. Knee
    e. Second stage co-deploy
2. Safety belt restraint
    a. Use
    b. Loading locations on occupant
3. Deployment of Pre-tensioners
    a. Dual
    b. Single
    c. Location (on retractor, buckle, or outboard lap anchor)
4. Head rest configurations
5. SDM
    a. Supplier
    b. Generation

Occupant factors

1. Age
2. Gender
3. Morphomics
    a. Anthropometry
    b. BMD
    c. Muscle Quality/Mass
    d. Fat Distribution/Mass
4. Co-morbidities
5. Stature

RESULTS

As some telematics providers do not collect age and gender information, we examined ISP performance with and without inclusion of age and gender data.

ISP calculated with Known Age/Gender

SENSITIVITY – 63.64%

SPECIFICITY – 96%

	Low ISS	**High ISS**	
Low ISP	**792**	**4**	796
High ISP	**33**	**7**	40
	825	11	836

Table 1 ISP with Known Age & Gender

ISP TRUE NEGATIVES (ISP<.2, no occupant in vehicle with ISS>15): The majority of the vehicle cases were, as expected, those in the low ISP/low ISS category. In fact, there were 792 cases in this category using age and gender when calculating the ISP. The occupants in these vehicles were not transported to a hospital and were considered uninjured. The ICAM panel did not review these cases, as they were considered true negatives.

ISP TRUE POSITIVES (ISP >.2, at least one occupant in vehicle with ISS>15): The initial expectation that there would be few cases with a high ISP and high ISS (true positives) was confirmed. There were seven such cases when age and gender were included in the ISP calculation. (Table 2)

ID	(Age/ Gender)	Veh Occ	PDOF	ISP	ISS
721	(75 M)	Drive	Right	0.31	29
2541	(18 F)	2^{nd} row right	Right	0.4	75
749	(48 F)	Driver	Front	0.58	43
772	(20 M)	Driver	Left	0.66	16
2030	(81 F)	RFP	Right	0.27	22
965	(46 F)	Driver	Front	0.29	29
1522	(55 F)	Driver	Right	0.61	17

Table 2 ISP True Positive Cases

ISP FALSE NEGATIVES: There were four cases in the low ISP/high ISS category. The average age of these case occupants was 46.75. The calculated ISP in this false negative group ranged from 0.03 to 0.19 (3% to 19% risk of ISS>15 injury). The average ISP was 0.12. The average ISS in this group was 24.5. All the cases in this group involved females.

We looked at each of these cases in depth to determine if we could discern potential reasons for the discrepancy between prediction and outcome. As stated previously severely injured patients with ISS>15 require the highest level of care and rapid identification of this group is essential. (Table 3)

ID	(Age/ Gender)	Veh Occ	PDOF	ISP	ISS
1430	(45 F)	RFP	Rear	0.15	26
964	(40 F)	Driver	Rear	0.19	34
1806	(52 F)	2d row right	Right	0.03	17
1403	(50 F)	Driver	Left	0.12	21

Table 3 ISP False Negative Cases

Case 1430

This case occupant was the 45-year-old, female, 3-point-belt restrained, right front passenger of a mid-size sport utility vehicle. The vehicle was involved in a severe rear impact from a semi-truck, followed by a minor frontal impact. The driver of the vehicle, a 50-year-old male, sustained lung injuries, an ISS of 10. The case occupant sustained severe head and chest injuries and had an ISS of 26. The telemetry did not report multiple impacts (it did not meet the 15 mph ΔV notification cutoff for a frontal impact). However, clearly there were multiple collisions (rear followed by front). A potential contributing factor is the incompatibility in terms of stiffness, mass, and geometry between the two vehicles.

Case 964

This case occupant was the 40-year-old, female, with unknown belt status, driver of mid-size sport utility vehicle. The case vehicle was struck in a rear-end fashion by a large semi-truck, which caused the case vehicle to travel diagonally through the intersection and over a curb. She sustained severe head, abdominal, and pelvic injuries and received an ISS of 34, with a calculated ISP of 0.19. The information from OnStar had 2 high ΔVs (>40 mph); the crash was not identified as a multiple impact, but was classified as a rollover. There was no indication on the PAR that a rollover had taken place; the vehicle was on its wheels at the time of the report, hence this case was included for consideration. A potential contributing factor is the large difference in terms of stiffness, mass, and geometry between the two vehicles.

Case 1806

The case occupant was the 52-year-old, female, 3-point-belt restrained, right rear passenger of a mid-size passenger car. The impact was a right sided, T-type impact, essentially occurring at her seating position. Her ISS was 17, due to chest injuries and pelvic fractures and the calculated ISP was 0.03. Both front-seat passengers were belted so the ISP was calculated utilizing their belted status. ISP correctly predicted the outcome for the front seat occupants, however, not correctly for this rear-seated occupant. The current algorithm was designed to predict the probability that a crash-involved vehicle will contain one or more occupants with severe injury (ISS>15) and therefore underweights the injury risk of right sided impacts when there is an occupant located on the right side of the vehicle. Since most of the vehicles in the NASS-CDS dataset used in the previous study to develop the ISP algorithm did not have right front or rear seat passengers, the ISP may underweight the injury risk of passengers at those locations and could be evolved to include a right front passenger variable.

Case 1403

The case occupant was the 50-year-old, female, 3-point-belt restrained, driver of a mid-size passenger car. The case vehicle was struck on the left side, forward of the A-pillar by a school bus and was categorized as a left-side impact in the OnStar data. This very thin occupant sustained severe head injuries, an ISS of 21 and a calculated ISP of 0.12. A potential contributory factor is the case occupant's stature. In our past research, we have found that thin occupants often sustain more serious head injuries than heavier occupants. [8] Another potential contributing factor is the incompatibility in terms of stiffness, mass, and geometry between the two vehicles.

ISP FALSE POSITIVES: There were 33 cases in the high ISP/low ISS category. We analyzed these on a case-by-case basis to assess any potential trends. Twenty-two of these cases were determined to be single impacts and eleven of the cases sustained multiple impacts. Nineteen of the cases (57.6%) were transported to a medical center. The average age in this group was 39.56, which was younger than the 46.75 average age of the ISP false negative group. The average ISP for this group was 0.36, and the average ISS was 3.09. (Appendix A)

DISCUSSION

The results of this field study confirm the utility of vehicle telemetry data transmitted by AACN systems for identification of crash vehicles that contain seriously injured occupants. Multiple models have been developed in the past, but they have all relied on vehicle-deformation based measurement of crash severity and data obtained from the NASS-CDS dataset. This study is the first to utilize actual telemetry data transmitted from vehicles involved in wide variety of crashes to assess real world injury prediction.

The field performance of the Injury Severity Prediction algorithm utilizing the OnStar dataset using age and gender data showed 63.64% sensitivity and 96% specificity. Without age and gender data, sensitivity is 45.45%, while specificity improved slightly to 97.58%. Sensitivity is defined as the probability that a test result will be positive ($ISP \geq 0.2$) when the condition ($ISS>15$) is present. The observed sensitivity performance was better than the 40% performance that the ISP algorithm achieved when applied to the NASS-CDS dataset. There may be several reasons for this including more consistent and accurate measurement of crash severity, more accurate determination of restraint use and more consistent vehicle safety performance as all the crash vehicles were from a single manufacturer and were newer models.

The specificity performance of the ISP in this study was 96%. Specificity is defined as the probability that a test result will be negative ($ISP<0.2$) when the condition ($ISS>15$) is not present. The observed specificity performance was slightly less than the 98.3% performance that the algorithm achieved when applied to the NASS-CDS dataset. While the overall number of cases studied is relatively small, there were fewer ISS>15 injured cases observed than would have been expected based on the number of cases, configuration and crash-severity mix of the crashes included in this study. This trend might be the result of continuously improving vehicle safety performance in the study fleet versus the NASS-CDS fleet used to calibrate the algorithm. The average age of the study fleet was younger than the average age of the vehicles in NASS-CDS.

The results of this field study confirm the importance of age and gender data and also suggest that it may be important to utilize more granular age data than a single threshold at age 55. The sensitivity of the ISP algorithm improved from 45.45% to 63.64% with the inclusion of age and gender data and the false negative group was slightly older on average than the false positive group (46.75 vs. 39.56). It is well known that the increased crash injury risk accelerates with advancing age rather than plateauing at age 55. [5, 9-11] The current ISP algorithm includes age (>55) and gender (presence of a female in the vehicle) as variables. However, SDMs do not have the capability to capture these data. It has been suggested that when the telematics provider contacts the occupants in the crashed vehicle, they can ask questions about who is in the vehicle. In this way, they can obtain age and gender data to send to the PSAPs. The results of the current study confirm the importance of age and gender in injury risk calculation and highlight the importance of collecting this data. Several of the false negative (low ISP/high ISS) cases involving very elderly patients as well as the overall aging population trend suggest that sensitivity might be further improved by including more granular age parameters in the ISP than a single threshold of age 55. Similarly, the younger age in the false positive (high ISP/low ISS) cases suggest that decreasing the risk coefficients for young occupants might also improve ISP performance. These potential benefits must be weighed against the increased time and potential confusion that may result in attempts to obtain this information.

The original algorithm was developed from data culled from the National Automotive Sampling System (NASS) and defined crash direction into only four categories (front, left, right, and rear). This study followed that convention. However, real world crashes do not always fit precisely into these categories, and frequently fall into offset or narrow configurations that may have a different impact on the occupant injury risk. The large number of offset frontal and sideswipe cases among our false positives suggests that improving telemetry data to better differentiate these crash configurations may help improve ISP performance.

Right oblique and right side impact crashes are underweighted in the original ISP algorithm. Our data with 1 of the false negative cases involving right side occupant suggest that it may be beneficial to adjust the right side impact coefficients to reflect a higher risk of severe injury if it is determined by telemetry or communication that right sided seats are occupied in a right oblique or side impact crash.

Telemetry data regarding possible occupant ejection would also be very useful if automotive grade sensors for this application are created.

While the study covered all types of vehicles, from compact car to large pickup, we limited the specific vehicle models in order to see injury patterns more clearly. The type of vehicle can affect the pattern and risk of injury, especially in two-vehicle crashes where there is vehicle incompatibility in terms of mass and geometry. The sensitivity of this study is better than originally predicted (40%) possibly in part due to the consistency of the vehicles from a single manufacturer with a consistent occupant protection strategy.

While the specificity of this study is a little less than expected, it is quite good for a preliminary study. This specificity performance may allow very large potential savings as technology becomes more comprehensive and reliable. The observed specificity performance in the field by the ISP suggests that it may become possible to decrease the dispatch of limited EMS resources to the scenes of low risk crashes. With new safety systems coming on line within the next few years as well as enhancements in the SDM systems, we anticipate continued improvements in ISP specificity performance.

Study Limitations

When selecting for convenience samples, it is important to recognize that there are limitations to the collection and reporting of the data.

One significant challenge for collection of telemetry crash data is that the SDMs can vary from vehicle to vehicle, depending on the vehicle model year and the evolution of module hardware/software upgrades. In order to build the sample, OnStar collected data on vehicles where the SDMs were known to have the capability needed to support the algorithm calculation. As such, the mix of vehicles in the study differs slightly from the NASS-CDS ISP development sample and has a higher percentage of sport utilities and a lower percentage of pickups and vans compared to the development sample. See Appendix B for the full weighting comparison.

Another limitation of the study relates to seat belt status. For any front occupied seat, the ISP algorithm assumes a base case if the seat belt is *unbelted* or its use is *unknown.* The probability of injury severity is lowered if the belt status is determined to have been buckled. Therefore, in the case of unknown belt status, the ISP will have a higher probability of injury severity than if the algorithm assumed the belt was used. In this study, approximately 40% of the crashes did not have complete seat belt information and for these cases the *unknown* base case was applied – as ISP algorithm would code them in a real-world situation. It should be understood that had seatbelt status been known and if the occupants in these cases were belted, the outcome of the study could have been slightly different. For the seven cases classified as High ISP/High ISS (true positive), it is possible that some of these cases would have had a lower ISP and been classified as a false negative, thereby reducing sensitivity. Similarly, for the 33 cases in the High ISP/Low ISS category (false positive), some of those cases would have possibly been classified as true negative, thereby increasing specificity. The cases with Low ISP/Low ISS (true negative) and Low ISP/High ISS (false negatives) would be unaffected as reducing the ISP would not change the categorization of these cases.

Another limitation is that the “multiple impacts indicator” is an element that varies fairly significantly from NASS-CDS to GM’s telemetry protocols. In NASS-CDS, multiple impacts are flagged anytime a vehicle has two impacts regardless of their severity. For example, in NASS-CDS, if a vehicle hits a mailbox and subsequently hits a tree, both events are recorded and the multiple impacts indicator is turned on. At GM/OnStar multiple impacts is turned on if two or more qualifying events occur in the same ignition cycle. A qualifying event is an event that has a Delta V over a predefined level. In our example the impact with the mailbox would not have a Delta V significant enough to be a qualified event and the multiple event indicator would not be turned on. See Appendix B for the full weighting comparison.

Finally, due to IRB limitations, the study was conducted using only state of Michigan crashes. However the sample does include crashes from varying years, seasons, weather conditions, times of day, and days of the week.

CONCLUSION

The level of sensitivity for severe injury achieved by ISP in this field study was a remarkable 63.64%. This performance is impressive from a medical perspective, especially considering that it is achieved with only data or communication transmitted from the vehicle and before dispatch of EMS to the scene.

Since the consequence of missing a severe injury is immediately life-threatening, sensitivity has generally received the highest priority in trauma care. The longstanding Field Decision Scheme has been used as the basis for triage protocols in state and local EMS systems across the United States for many decades. The combined sensitivity of the first two steps (Physiologic and Anatomic) of the Decision Scheme has consistently remained around between 40-50% with field data collected first hand by EMS during the pre-hospital phase of care. [12-15] Newer crash sensors may also support improvements in the performance of the ISP algorithm. As the SDM systems in vehicles change and more detailed telemetry data collection is possible, ICAM anticipates improvements in risk prediction. The fleet is in constant flux with new safety systems as well as enhanced SDMs. [16, 17]

Michigan, parts of the United States, and the world all have many rural areas where reports of crash events to public safety may be delayed, leading to slow response by EMS. [18, 19] These same areas are also characterized by long transport distances that will delay the transfer of the severely injured to medical facilities. Automatic collisions notification alone, without additional vehicle telemetry for injury prediction, can save significant lives [20]. Time is of the essence in these cases and getting these occupants to the proper medical destination capable of definitive trauma care is essential. Transmitted telemetry data from AACN can not only provide notification that a crash has occurred, it can also alert the local first responders as to what type and how severe of crash they are responding to – they will know what equipment to bring in order to best triage and treat the occupants. There is potential also to immediately initiate air transport and get them to the scene quickly as well.

The resources utilized in the emergency care of crash injuries place a significant burden on local communities, especially rural ones. Over triaging patients without severe injuries to trauma centers or other medical centers for unnecessary evaluation is expensive and wasteful. The recent changes to Step 3 (mechanism of injury) of the Field Triage Decision Scheme is estimated to provide yearly US savings of over $500 million in medical costs alone. [21] With widespread use of AACN, those savings can be multiplied.

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Appendix A

UMID	Age	Gender	Veh Occ	PDOF	Veh Type	ISP	ISP A/G	ISS	Mult	Trans	Review Notes
633	37	F	Driver	Front	CAR	0.16	0.23	4	N	Y	near-side offset frontal
2105	21	F	Driver	Left	CAR	0.18	0.25	0	N	N	near-side sideswipe
2106	32	F	Driver	Left	CAR	0.14	0.20	0	N	N	full frontal
644	16	M	Driver	Left	CAR	0.71	0.71	1	Y	Y	near-side offset front corner hit, into a near-side sideswipe
716	49	F	Driver	Front	UTILITY	0.17	0.24	0	Y	Y	near-side offset frontal (tree)
1233	17	F	Driver	Left	UTILITY	0.27	0.36	1	N	Y	near-side L-type front
743	56	F	Driver	Left	CAR	0.21	0.52	2	N	Y	near-side T-type (21 mph delta V)
751	18	F	Driver	Front	CAR	0.18	0.26	10	N	Y	full frontal
837	80	F	Driver	Front	UTILITY	0.26	0.59	11	N	Y	full frontal
1248	99	M	Driver	Front	CAR	0.16	0.35	0	N	N	severe frontal into a guardrail/barrier
863	50	F	Driver	Right	CAR	0.29	0.39	0	N	N	full frontal
892	20	F	Driver	Right	CAR	0.14	0.21	0	N	N	minor near-side sideswipe followed by far-side offset frontal into tree
551	53	F	Driver	Front	CAR	0.41	0.52	11	Y	Y	near-side frontal into mailbox (minor) followed by center frontal into tree
919	40	M	Driver	Front	CAR	0.26	0.26	0	Y	Y	near-side offset frontal followed by a near-side offset frontal tree impact
938	17	M	Driver	Front	UTILITY	0.37	0.37	1	Y	Y	full frontal
946	48	F	Driver	Front	UTILITY	0.24	0.33	14	N	Y	near-side sideswipe, followed by offset near-side frontal
1253	18	M	Driver	Left	CAR	0.57	0.57	1	Y	Y	near-side sideswipe (minor), followed by offset near-side frontal
955	62	F	Driver	Front	CAR	0.12	0.36	5	Y	Y	3 impacts (front, left, and rear) with a ditch
957	43	F	Driver	Front	UTILITY	0.13	0.29	2	N	Y	frontal
997	26	F	Driver	Front	UTILITY	0.22	0.31	0	Y	N	near-side L-type rear followed by minor frontal into tree
1001	39	F	Driver	Right	UTILITY	0.28	0.38	9	N	Y	far-side T-type
1024	36	F	Driver	Front	UTILITY	0.33	0.43	1	N	Y	full frontal
1027	57	M	Driver	Left	CAR	0.12	0.27	14	N	Y	near side T-type
1040	58	F	Driver	Front	UTILITY	0.08	0.28	0	N	N	offset frontal
2533	59	F	Driver	Left	CAR	0.17	0.47	0	N	N	near-side T-type
1078	23	F	Driver	Front	CAR	0.27	0.36	0	N	N	full frontal

UMID	Age	Gender	Veh Occ	PDOF	Veh Type	ISP	ISP A/G	ISS	Mult	Trans	Review Notes
1172	22	F	Driver	Left	CAR	0.22	0.30	0	Y	N	near-side from pickup, followed by narrow frontal into pole/tree
1186	24	M	Driver	Front	CAR	0.53	0.53	10	N	Y	near-side offset frontal
1221	62	F	Driver	Right	CAR	0.08	0.26	5	Y	Y	far-side T-type, followed by near-side T-type
1291	22	F	Driver	Front	CAR	0.22	0.31	0	N	N	far-side offset frontal
1521	35	F	Driver	Left	UTILITY	0.22	0.31	0	N	N	near-side offset frontal
2107	43	F	Driver	Left	CAR	0.30	0.40	0	N	N	near-side L-type front
1768	24	M	Driver	Left	PICKUP	0.28	0.28	0	Y	N	near-side sideswipe followed by offset frontal

Appendix B

Seat Belt Usage

The implementation of the ISP Algorithm for seatbelt usage uses a base case of 0 if the seat belt is not used or its use is unknown, for any occupied seat. For seat belt usage by all occupants the belt usage coefficient is used in the ISP calculation. In this study approximately 40% of the crash incidents did not have complete seat belt information so the base case was applied in these cases in the same way that the OnStar application would process these cases. In those cases where seat belt information was unavailable and the Police report indicated belt use, or the injury patterns indicated belt use, then the belt usage coefficient was used in the ISP calculation.

Vehicle Models

The vehicle makeup in this study is influenced by the fact that all of the accidents were confined to the state of Michigan. The original study, by Kononen, Flannagan, and Wang, relied on a much larger source of information (NASS/CDS). It is important to understand the differences in vehicle types.

Multiple Impacts

Multiple impacts were determined by the availability of secondary delta V data. If the secondary delta v was null then the accident was a determined to be a single impact.

See following table for full comparison to NASS-CDS development data set.

		Average Values		
		All Cases	Complete Cases	Complete Cases
Variable		**NASS-CDS**	**NASS-CDS**	**ICAM Sample**
	ISS15+	0.124	0.108	0.012
	Median ln(Delta-V mph)	2.820	2.820	2.606
Direction	**Front**	0.800	0.780	0.695
	Left	0.082	0.088	0.100
	Right	0.074	0.080	0.122
	Rear	0.044	0.052	0.083
Vehicle_Type	**Car**	0.675	0.676	0.700
	Utility	0.168	0.174	0.2810
	Pickup	0.101	0.093	.0780
	Van	0.057	0.056	0.000
	Multiple Events	0.395	0.364	0.021
	RFP Present	0.274	0.278	0.318
	all_belted	0.774	0.793	0.345
	any_female	0.573	0.597	0.573
	maxvehage2	0.192	0.196	0.269