INJURY BIOMECHANICS RESEARCH
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Ranking Injury Codes Using Optimization Methodology

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ABSTRACT

This paper focuses on establishing a new ranking system using an optimization methodology for ordering the AIS injury codes. Codes are assigned mortality rate values, which can be used to get an idea on which injuries are critical and thus should be prevented and how many lives will be saved as a result of preventing that injury. For better statistical correlation, an injury coding scheme is applied which condenses 551 7-digit AIS injury codes down to 50 unique codes. The crash victim's injury profile is characterized by the top three injuries which are used to calculate the victim's probability of fatality. Optimization solvers are used to assign mortality rates to each of the 50 codes. Based on the average deviance value, fatality predictions using the optimized mortality rates show better predictive capability over other schemes, including the Maximum AIS score and the Injury Severity Score. Comparisons are made between results derived from the Crashworthiness Data System (NASS-CDS) and the Crash Injury Research and Engineering Network (CIREN).

INTRODUCTION

Each year in the United States, several motorists get injured as a result of crashes on the roadways. The overall goals of the National Highway Traffic Safety Administration (NHTSA) are to reduce fatalities, mitigate injuries, and decrease economic losses to society. Highway crash reporting and investigations are devoted to developing a system of rating the severity of motor vehicle crash-related injuries that could be utilized by medical and non-medical researchers alike.

The injuries sustained by these motorists are denoted with a seven-digit code in accordance with the Abbreviated Injury Scale (AIS) and are recorded in the epidemiological databases maintained by the National Highway Traffic Safety Administration (NHTSA): the Crashworthiness Data System (CDS) and the Crash Injury Research and Engineering Network (CIREN). The CDS is a nationally representative probability sample of all automobile crashes in the United States and records around 4000-5000 crashes per year. CIREN, on the other hand, records around 300-400 crashes per year in which a vehicle occupant was admitted to a Level 1 trauma center. There are over one thousand seven-digit AIS injury codes for distinct injury types that one could sustain in an automobile accident. These codes can be found in the AAAM's AIS Injury Coding Manual (AAAM, 1998).

With so many injuries happening in the real world, it becomes imperative to answer a few questions for crashworthiness research:

- What types of injuries are critical and should be prevented?
- How many lives can be saved if a particular injury is mitigated?
- How much cost can be saved under a given performance requirement?
- What capabilities are required of an Anthropomorphic Test Dummy (ATD)?

These questions can be answered by using a data driven approach: analyzing and ranking the injuries recorded in the epidemiological databases, CDS and/or CIREN. Such an analysis was carried out in the past (Martin and Eppinger, 2003b) in which the CDS data was analyzed for ranking the injury codes using a "Cause of Death" approach where "Cause" corresponded to the coded injury or injuries identified as those that directly contributed to the motorist's death. The mortality rate values were obtained for the injury codes using this "Cause" approach which were then used for ranking the injuries based on threat to life. The absence of the "Cause of death" data for certain cases and also the subjectivity involved in listing the "Cause of death" put limitations on this approach.

The objective of this paper is to show an alternate approach for analyzing and ranking the injury codes, recorded in the epidemiological databases, by using an optimization methodology. The mortality rate values of the injury codes are obtained using optimization, which are then used for ranking the injury codes.

DATA SOURCE

Both CDS and CIREN datasets could be used for the study. CDS is a national sample and records more cases than CIREN. To qualify for the CDS, a crash must involve at least one passenger car that was towed from the crash scene due to damage resulting from the crash. Each case is assigned a weighting factor that represents an estimate of the number of like-mannered cases that occurred during the sample year. On the other hand, CIREN cases only involve those in which a motorist was admitted to a Level 1 trauma center. Level 1 accreditation indicates that the quality of care, equipment, and facility meets the highest standards for trauma care. CIREN cases tend to have occupants who suffer more severe injuries than CDS cases.

Even though CDS dataset has more cases and represents national estimates of injury, it has certain limitations:

- Injury data is not always complete or detailed (less clinical data).
- It has a large contingent of occupants with either no injuries at all, or only low-severity injuries with a maximum AIS score (MAIS) of only 1 or 2.
- Compared to CIREN, it used many more "Not Further Specified (NFS)" codes where the specifics of the injuries are unknown.
- Compared to CIREN, it has a lot of apparent "undercoded" cases where injury records are incomplete. This is especially true for fatal cases where the victim is "Dead on Arrival" (DOA) and there is no hospital record.
- Also in CDS, high-severity cases (including fatalities) are oversampled and assigned relatively low case weights to compensate for oversampling. Nonetheless, the majority of CDS cases are very low-severity, which are given high case weights. Thus an optimization based on weighted CDS cases will be driven by the vast majority of the low-severity, non-fatal cases and this would result in a much higher average deviance for the high-severity cases after optimization as compared to the corresponding CIREN dataset.

Also CIREN is a much richer dataset with more detailed clinical evaluation of injuries, fewer NFS codes and fewer incomplete records and thus was chosen for this optimization study.

CIREN Dataset:

The analysis presented herein was carried out on a CIREN dataset from 1993 - April 2006. The data used for analysis was filtered based on certain inclusion/exclusion criteria's:

1. Since the analysis is based on computing the mortality rate values of the injury codes and it is known that the mortality rates of many types of injuries vary significantly among children (Sartorelli et al., 1999), only cases were the occupant age was 15 or more were considered.
2. Only AIS 2+ injuries were included in the dataset. This was done for two reasons: (1) AIS 1 injuries are never fatal and can be assigned mortality rate value of zero and (2) To reduce the number of design variables in the optimization problem.
3. Cases with MAIS 2 were excluded from the dataset, as all were non-fatal.
4. All cases where the motorist died because of previous complications or from complications resulting from the injury were excluded as the main aim of the problem was to find the mortality rate value of the injury.
5. All Principal Investigator-select cases were excluded. These PI-select cases are special interest cases selected by the principal investigator due to varied reasons, and these might not confer to the inclusion criteria used for majority of the CIREN cases. Such cases can lead to discrepancies in the data and therefore were excluded.
6. All cases with MAIS 6 were excluded. These cases were removed as these are always fatal and the fatality is always due to the AIS 6 injury code which can be assigned a mortality rate value of 100%. Any such case if used in the dataset can lead to discrepancy in the mortality rate values of the lower level AIS injury codes present in these cases if they are not represented properly in the dataset.
7. Also all cases with injury code **59**.7 were excluded for the same reason as point 6.

After these inclusion/exclusion criteria were applied to the CIREN dataset, a total of 2058 cases were obtained of which 174 were fatal and 1884 were non-fatal.

INJURY CODING SCHEME

In CIREN, a seven-digit code (Figure 1) is assigned to each occupant injury in accordance with the Injury Coding Manual, which is adopted from a very similar manual developed by AAAM (AAAM, 1998). The first digit of the code identifies the body region; the second digit identifies the general anatomic structure; the third and fourth digits identify the specific anatomic structure or, in the case of injuries to an external region, the specific nature of the injury; the fifth and sixth digits identify the level of injury within a specific body region and anatomic structure; the seventh digit is a general severity level referred to as the Abbreviated Injury Scale (AIS) score. AIS score takes integer value from 1 (low severity) to 6 (maximum). If a motorist suffers an injury of an unknown type, a score of 7 is assigned

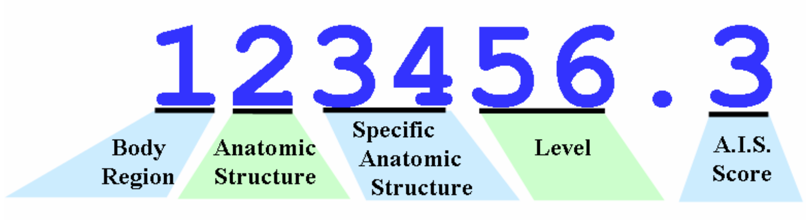

Figure 1: Seven-Digit Injury Code.

The CIREN dataset that was analyzed in this study used 551 seven-digit injury codes. Several of these codes were used only once or twice. Under-representation of data during optimization can lead to a discrepancy in the calculation of mortality rate values. Hence for better statistical correlation, an injury coding scheme was used which condensed the seven-digit injury code to a two/three-digit injury code based on seventeen general body regions (Table 1).

Table 1. Seventeen General Body Regions.

Base Code	Category	Base Code	Category	Base Code	Category
1	Skull	7	Chest/breast/abdomen	13	Pelvis bone and external
			Thoracic organs/blood vessels		Hip/thigh
2	Brain/Intercranial				
		8	Ribs/sternum	14	Knee
3	Ear				
	Eye and Adnexa	9	Back (including vertebrae)	15	Lower extremities, superficial
	Neck-Internal organs/blood vessels				Lower leg
		10	Trunk-Superficial		Ankle/foot/toes
4	Nose/mouth/face/scalp/neck		Trunk, multiple/unspecified		Lower extremities, multiple/unspecified
			Trunk, other organs/blood vessels		
5	Neck-Spinal cord			16	Burns, unspecific body part
		11	Trunk-spinal cord		
6	Shoulder/clavicle/scapula/upper arm			17	Whole body-minor external
	Elbow	12	Liver		
	Upper extremities, superficial		Spleen		
	Forearm		Kidney		
	Wrist/hand/finger/thumb		Gastrointestinal		
	Upper extremities,multiple/unspecified		Genitourinary		

For example, a seven-digit injury code 140446.5, which represents a brain injury (large subdural hematoma), became 2.5. Since it was a brain injury, it picked up the base code of 2 (Table 1) followed by the AIS score. This injury coding scheme was applied to the CIREN dataset, which reduced the number of injury codes from 551 unique seven-digit injury codes to 50 unique two/three-digit injury codes. Following this condensation from 551 to 50 injury codes, it was found that there were codes that were still being used once or twice. Since under-representation can cause discrepancy, a cut off value of 10 was assumed. All codes having an incidence of 10 or more were optimized and all other codes with an incidence of less than 10 were combined with similar codes in the same body region or were hardcoded (i.e., not optimized but assigned a mortality rate value (Figure 2), which remains unchanged during optimization).

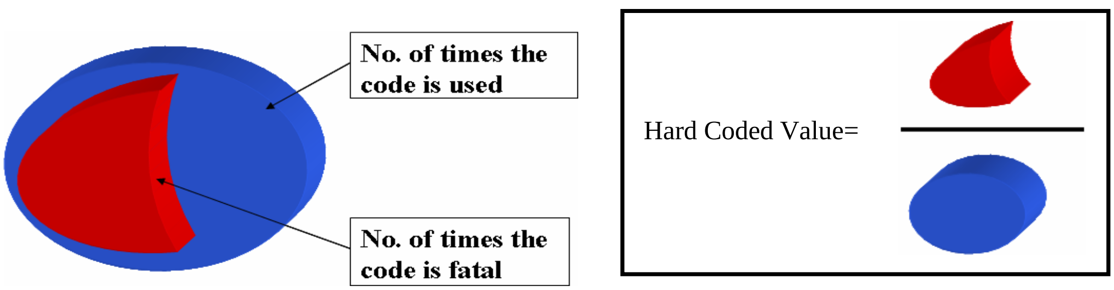

Figure 2: Hard Coded Value.

OPTIMIZATION METHODOLOGY

The optimization, for finding the mortality rate values, was carried out using the 2058 cases obtained from CIREN and using the condensed two/three-digit injury codes. The problem set up and details are shown below:

Transformed CIREN Dataset

The original CIREN dataset (with seven-digit injury codes) was transformed based on the injury coding scheme to obtain the transformed CIREN dataset in terms of the two/three digit injury codes. This dataset was further analyzed and the 50 unique injury codes used in the entire dataset were identified. Of these 50 injury codes, 41 had an incidence of 10 or more and were optimized and the remaining 9 with incidence of less than 10 were hard coded (Appendix A).

Constraints

The following constraints were then applied on the injury codes (Figure 3):

- All the injury codes sharing the same base code followed the hierarchy rule. For example, $2.2 \leq 2.3 \leq 2.4 \leq 2.5 \leq 2.6$ (which shows the codes sharing the same base code of 2) means that the mortality rate value of the lower severity codes will always be less than or equal to the mortality rate value of the higher severity codes.
- No constraints were applied on the injury codes having different base codes. For example 2.3 < ? > 3.4 which share a different base code had no constraints, either one could end up higher than the other.
- The mortality rate (MR) values of the injury codes were constrained as $0.0001 \leq MR \leq 0.9999$. MR values of 0 and 1 were not used in order to avoid computational problems during the calculation of log likelihood function.
- No restrictions were applied on the NFS 7 codes. Since injuries with AIS score of 7 are of unknown severity, they cannot be related to the injuries having AIS score from 1-6. Thus, no hierarchy rule or other constraints were applied on the mortality rate value of such codes.

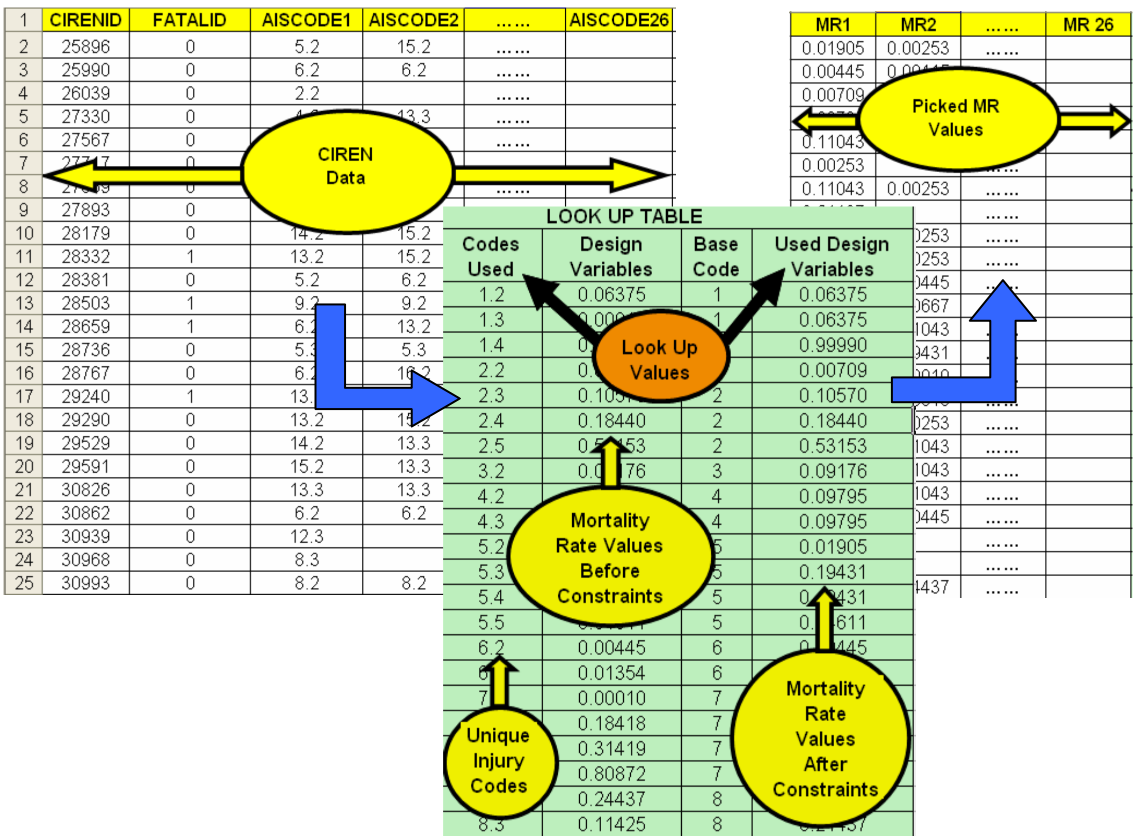

Figure 3: Optimization Problem Set Up-I.

Initial Guess MR values

The initial guess used for the mortality rate values of the injury codes for the optimization process was obtained according to Equation 1:

$$Initial\ Guess = \frac{Number\ of\ times\ the\ code\ is\ fatal}{Number\ of\ times\ the\ code\ is\ used} \qquad (1)$$

It was found that using this initial guess always produced the lowest starting and final deviance values. After applying the constraints and initial guess, the mortality rate values were picked up for each case and for each injury listed for that case (Figure 3).

Injury Profile

Studies were carried out for the top, top two, top three, and top five injuries to find the number of injuries sufficient to compute probability of fatality for the crash victim. Deviance statistics were used for comparison. Since the analysis with three injuries gave the lowest final deviance value (Table 2), the crash victim's injury profile was characterized by the top three injuries.

Table 2. Injury Characterization Study.

No. of Injuries	Deviance
Top Injury	673.36
Top 2 Injuries	626.72
Top 3 Injuries	**624.76**
Top 5 Injuries	632.17

Once the mortality rate values were picked up for each injury and each case, the top three injuries were selected for each case (Figure 4). These top three injuries were used further to calculate the probability of fatality for the crash victim (Figure 4).

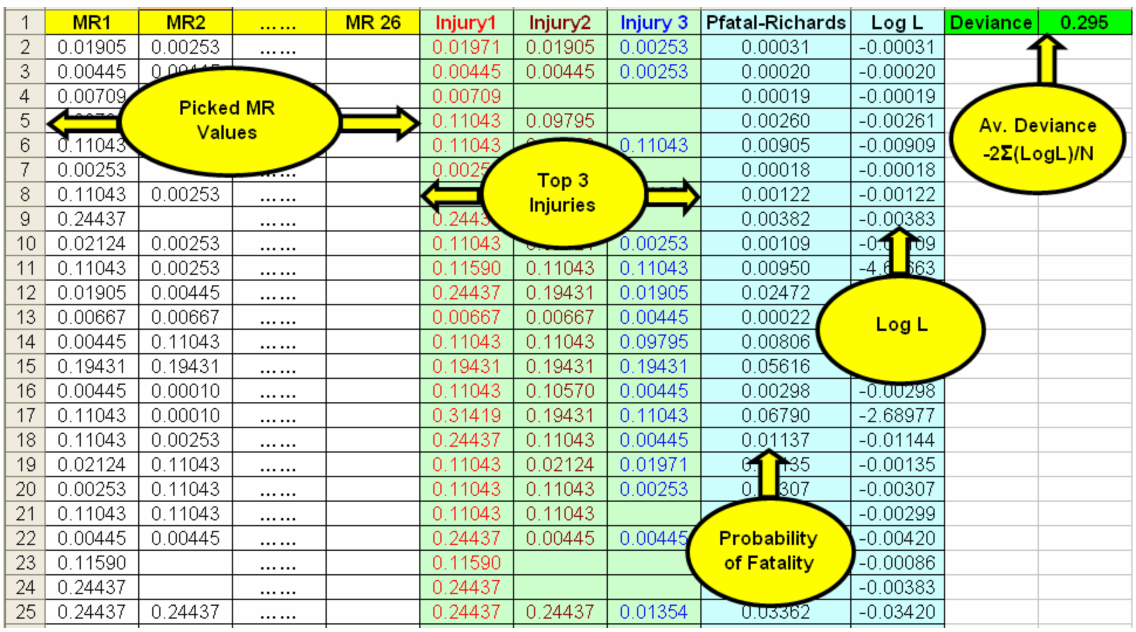

Figure 4: Optimization problem set up-II.

Probability of Fatality Function

Since the FATAL-ID listed in CIREN is a dichotomous variable (0-non-fatal, 1-fatal), three different sigmoid functions were evaluated as possible candidates for computing probability of fatality using the top three injuries. These were:

1. Gompertz Function

$$a * e^{-e^{-\frac{(x-xo)}{b}}} \qquad (2)$$

2. Logistic Function

$$\frac{1}{1+\exp(-(a0+a1*x))} \quad (3)$$

3. Richards Function

$$\frac{1}{[1+\exp(-(a0+a1*x))]^{1/d}} \quad (4)$$

where *a*, *x0*, *b*, *a0*, *a1* and *d* are function parameters and *x* represents the average of the mortality rate values of the top three injuries. The averaging was done as the Gompertz function does not have a form that takes into account the top three injuries separately as the other two functions. It seemed acceptable to compare the functions this way as the same averaging scheme was used for all the three functions.

Studies were carried out with these three functions to find out the function which a) gave the lowest deviance and b) was the most flexible. First part was evaluated by using a CIREN dataset and using deviance statistics for comparison purposes. The initial guess for the functions parameters were chosen in such a way so as to have the same starting form for all the three functions (Figure 5).

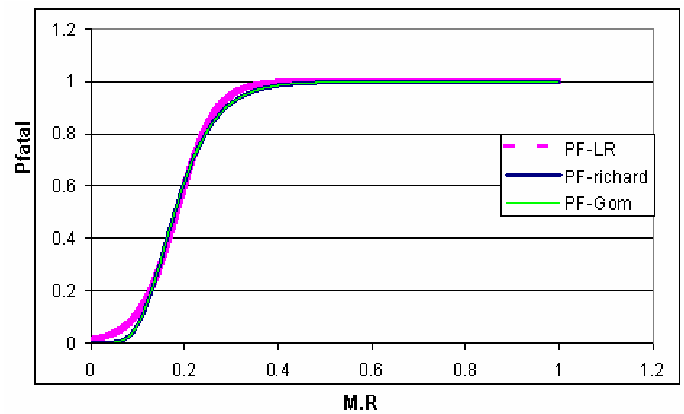

Figure 5: Initial Form of The Three Functions.

The final deviance value obtained from the three functions was compared. The Richards function was found to give the lowest deviance value (Table 3).

Table 3. Function Comparison-Deviance Value.

Function	**Deviance**
Gompertz Function	732.369
Logistic Function	754.167
Richards Function	**731.707**

The Gompertz and Richards functions converged to the same final form but the logistic function converged to a different final form (Figure 6).

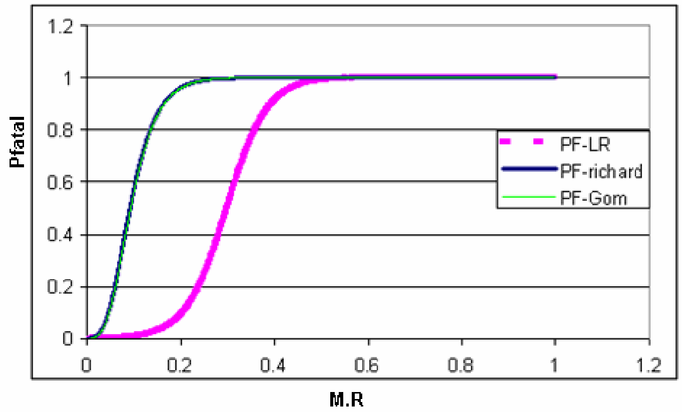

Figure 6: Final Form of The Three Functions.

The flexibility of the three functions was evaluated by fitting them among each other and identifying the function that provided the best fit to the other two functions for any given set of function parameters. Fitting the Gompertz function to logistic function and vice-versa for any given set of function parameters always showed some error (Figure 7). The Richards function was the only function that provided a good fit to both logistic and Gompertz functions (Figure 8).

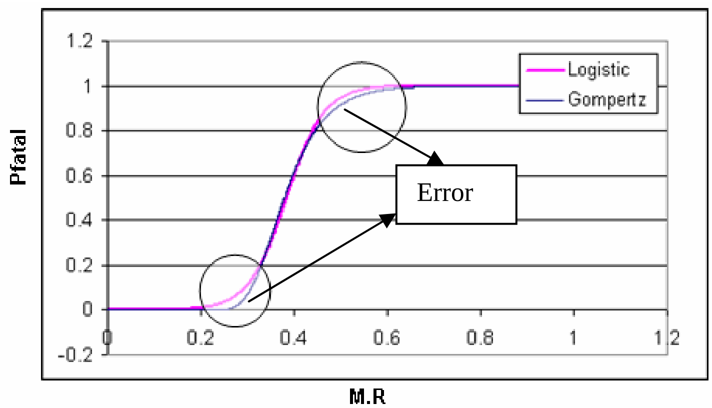

Figure 7: Logistic-Gompertz Fit

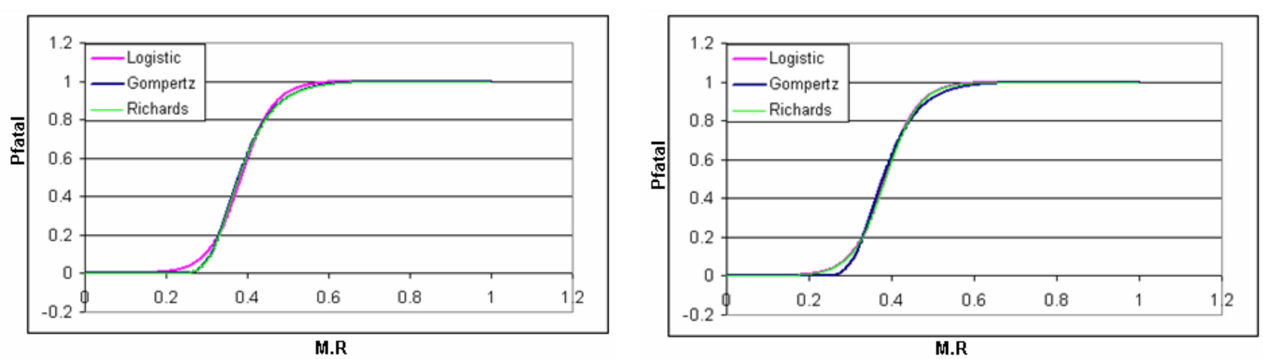

Figure 8: (a) Richards- Gompertz Fit; (b) Richards- Logistic Fit.

Since the Richards function provided the lowest deviance value and also showed good flexibility, it was chosen as the function for computing the probability of fatality. Hence, the final function form used for computing the probability of fatality was:

$$Pfatal = \frac{1}{[1 + \exp(-(a0 + a1 \times I1 + a2 \times I2 + a3 \times I3))]^{1/d}} \qquad (5)$$

where

- *a0*,*a1*,*a2*,*a3* and *d* are function parameters which were optimized
- *I1*, *I2* and *I3* were the mortality rate values corresponding to the top three injuries respectively.

Constraints on Pfatal Function Parameters

Since the function parameters were also optimized, constraints were applied on these as shown in Equation 6.

$$\begin{aligned} &0 \le a0 \le 6 \\ &0 \le a1, a2, a3 \le 6 \\ &0.001 \ge d \ge 0.1 \end{aligned} \qquad (6)$$

These constraints were chosen in such a way so that the Pfatal function could take a wide range of forms from the dark blue curve to the light blue curve (Figure 9). The dark and the light blue curve show the extremes within which the function can take many forms, with some of the forms shown by the pink and yellow curves.

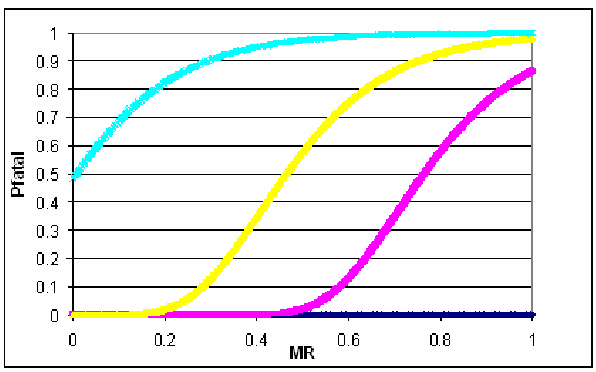

Figure 9: Pfatal Function Range.

Objective Function

After computing the probability of fatality using Richards function for each case, Log likelihood was calculated (Figure 4) using Equation 7.

$$LogL = (1 - Fatal) \times \ln(1 - Pfatal) + (Fatal) \times \ln(Pfatal) \qquad (7)$$

where *Fatal* = 1 (if case is fatal)
Fatal = 0 (if case is non-fatal).

This was further used to calculate the average deviance (Figure 4) using Equation 8.

$$D = -2(\sum_{i=1}^{N} LogL_i) / N \quad ; N\text{=Number of CIREN cases} \qquad (8)$$

Minimization of the deviance -- the error between the CIREN listed outcome and model predictions -- was defined as the objective for this problem.

Optimization

Once the problem was defined and set up as shown by Figures 3 and 4, optimization was carried out using the Generalized Reduced Gradient (GRG) solver available in Microsoft Excel to compute the mortality rate values of the injury codes which were then used to rank the injury codes. This problem had a total of 46 design variables (those that were optimized) of which 41 were injury code design variables and 5 were function related design variables.

The predictive capability of this model was also compared against the Maximum AIS (MAIS) approach, Injury Severity Score (ISS) approach and the "Cause" approach used in the past (Martin and Eppinger, 2003b).

Comparative studies were carried out between CIREN and CDS dataset to show that even though CIREN dataset is not a nationally representative sample, it is closer to the weighted CDS dataset thus justifying the use of CIREN dataset for this analysis

RESULTS

Predictive Capability

The "top three injuries" model's predictive capability was compared with the ISS and MAIS approach (Table 4). It was found that this model showed much lower average deviance than the other two methods.

Table 4. Predictive Capability of Different Models.

Model	**Pfatal function**	**Average Deviance**
MAIS	$\frac{1}{[1+\exp(-(a0+a1\times MAIS))]^{1/d}}$	0.370
ISS	$\frac{1}{[1+\exp(-(a0+a1\times ISS))]^{1/d}}$	0.383
TOP THREE INJURIES	$\frac{1}{[1+\exp(-(a0+a1\times I1+a2\times I2+a3\times I3))]^{1/d}}$	**0.295**

The predictive capability of the "top three injuries" model was also compared with the "Cause" approach. For this comparison the mortality rate values of the injury codes present in the CIREN dataset were computed using the "Cause of death" approach (Martin and Eppinger, 2003b) instead of optimization approach. The results (Table 5) showed better predictability with the optimization approach.

Table 5. "Optimization" Approach vs. "Cause" Approach.

Approach	**Average Deviance**
CIREN –"Cause Based Approach"	0.328
CIREN- " Optimization Approach"	**0.295**

For the same order of the injury codes around the periphery (Figure 10), the ranks obtained for the injury codes from the two approaches showed a lot of differences.

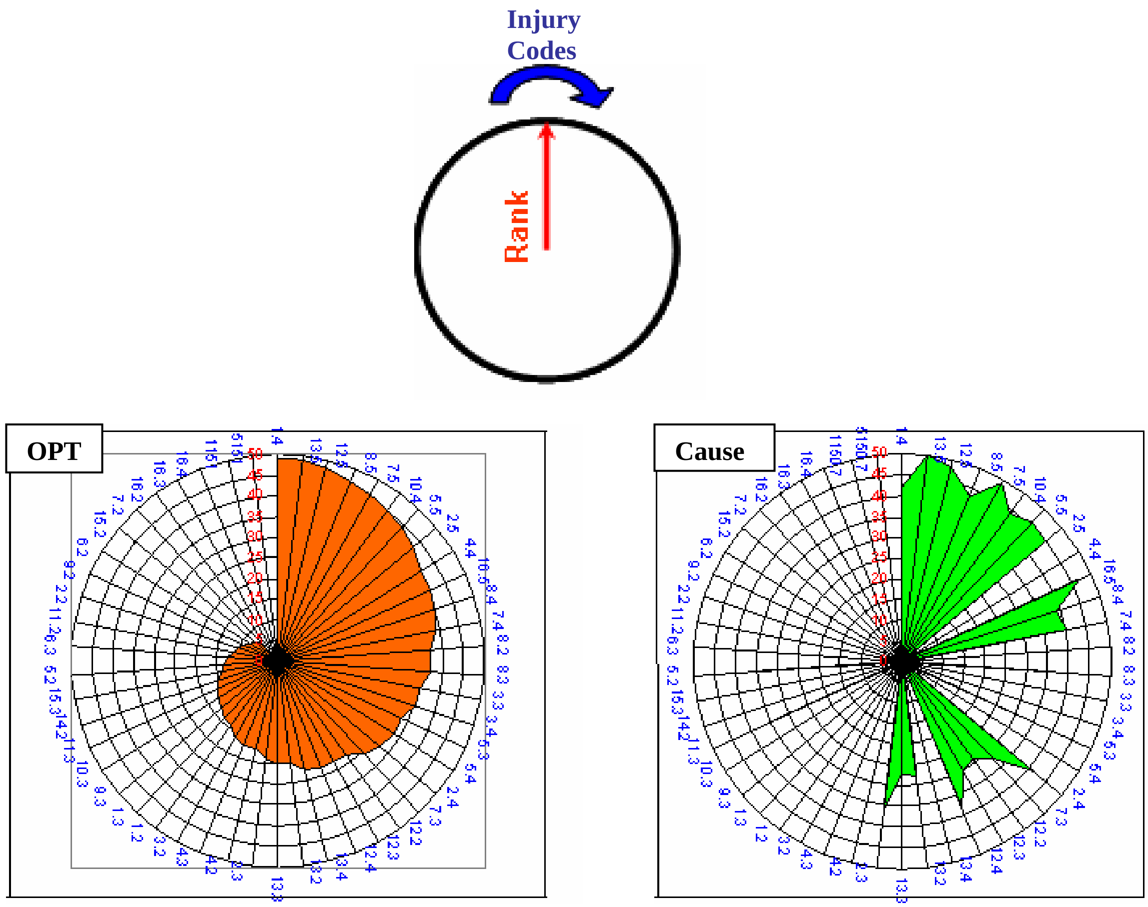

Figure 10: “Optimization” vs. “Cause” Approach.

“Cause” refers to the cause of death as determined by the physician. Using the “Cause” approach, the mortality rate values could only be computed for the injuries listed as the cause of death. For the other injuries, mortality rate value could not be computed. The optimization methodology, on the other hand, allowed mortality rate values to be computed for injuries that contributed to fatalities, but were not necessarily the direct cause of fatality as defined by the “cause” variable. Hence, optimization approach proved better for computing the mortality rate values and ranking the injury codes. For example, Injury code 4.4 had a rank of 0 based on “Cause approach” but had a rank of 40 based on “Optimization approach”. Since 4.4 was never listed as the cause of death, it was impossible to compute its mortality rate value using the “Cause approach”. This shows another advantage of using the “Optimization approach”.

Injury Codes Ranking

The optimization approach using “top three injuries” followed in this paper showed better predictability than the other methods used in the past. Optimization of the CIREN dataset provided the mortality rate values of the injury codes which were then used to rank the injury codes (Figure 11). The AIS level 5 skull and pelvis injuries were ranked the highest and the burns and NFS 7 codes were ranked the lowest. Not all the AIS level 5 injuries were ranked higher than AIS level 4 injuries. For example, AIS level 4 Trunk injury was ranked higher than the AIS level 5 cervical spine injury. Also some AIS levels 2 and 3 injuries were ranked higher than AIS level 4 injuries compared across different body regions. Eppinger (1987) had found that the threat to life posed by injuries of same AIS level was not the same. This could be seen in the injury rankings obtained. For example, an AIS level 2 rib/sternum injury was ranked much higher than an AIS level 2 cervical spine injury.

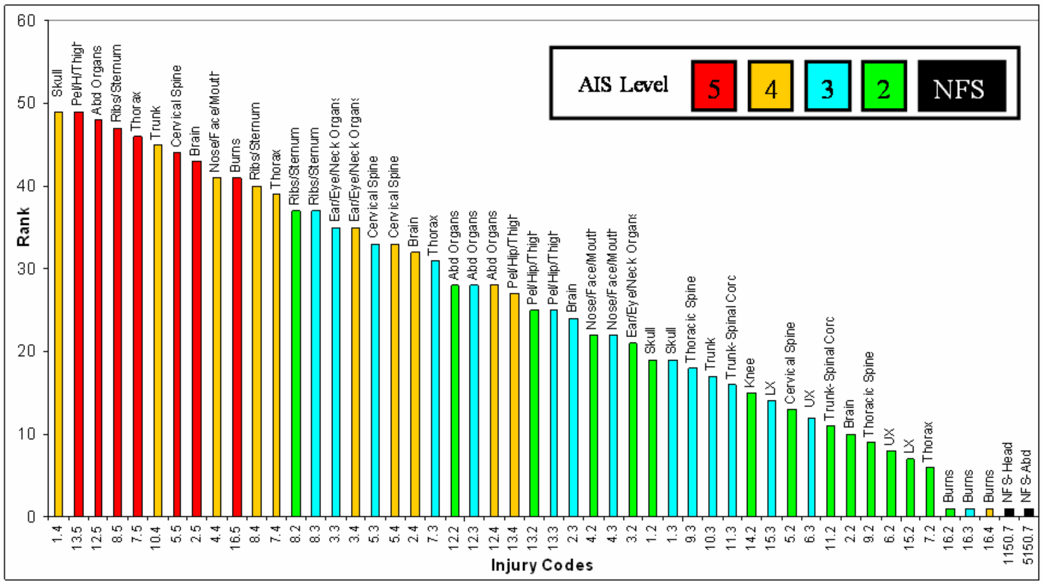

Figure 11: Injury Codes Ranking Obtained From CIREN.

The injury codes grouped by body regions are shown in Figure 12.

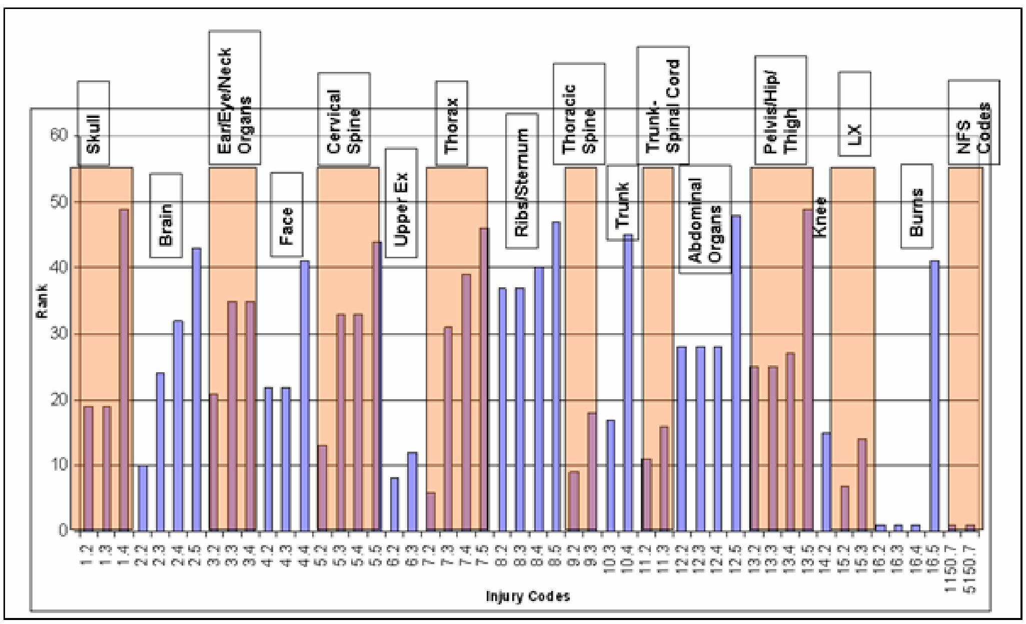

Figure 12: Injury Codes Grouped by Body Regions.

CIREN vs. CDS

CDS dataset used for comparison was conditioned in the same way as the CIREN dataset. The same inclusion/exclusion criteria, injury coding scheme and constraints were applied. The same top three injuries scheme and Pfatal function were used. After conditioning, the CDS dataset had a total of 25,563 cases of which 3115 were fatal.

Since CDS had more cases than CIREN, 68 unique injury codes were found in CDS dataset as compared to 50 for CIREN. For making the comparison, all the injury codes in CDS that were common with CIREN were assigned the optimized mortality rate values obtained from CIREN. Since the same Pfatal function was used, the optimized function parameter values obtained from CIREN were used for the CDS dataset also. For the remaining injury codes, the mortality rate values were hardcoded (Figure 2) based on the CDS data. Both the unweighted and the weighted average deviance values were then computed for the CDS dataset using Equations 9 and 10, respectively.

$$D_{unwgt} = -2(\sum_{i=1}^{N} LogL_i)/N \text{ ; } N \text{ is number of CDS cases} \qquad (9)$$

$$D_{wgt} = -2(\sum_{i=1}^{N} LogL \times RATWGT)_i / N_{wgt}$$

where (10)

$$N_{wgt} = \sum_{i=1}^{N} (RATWGT)_i \text{ , } N \text{ is number of CDS cases}$$

and *RATWGT* is a weighing factor that represents an estimate of the number of like-mannered cases that occurred during the sample year.

When using the unweighted CDS dataset, it is assumed that the "Cause/incidence" ratio is the same across all sampling strata in CDS. But these ratios are known to vary across the sampling strata (Martin et al., 2000). As a result, the mortality rates of the injury codes might not be represented correctly within the unweighted dataset. Thus, using a weighted CDS dataset would be a logical choice for computing correct mortality rates of the injury codes. But due to limitations of the CDS dataset with regard to availability of detailed injury data, comparison was made between CDS and CIREN to see if CIREN dataset was closer to the weighted CDS dataset so that it could be used for this injury analysis as it has much detailed injury data. Comparison of the average deviance value between CIREN and CDS (Table 6) showed that the CIREN dataset was closer to the weighted CDS dataset. The unweighted CDS dataset showed much higher deviance than CIREN and weighted CDS datasets.

Table 6. CIREN vs. CDS.

Dataset	Average Deviance
CIREN	**0.295**
CDS (unwgt)	0.59
CDS (wgt)	**0.29**

Since CIREN has a richer dataset and was found to be closer to the weighted CDS dataset, it justified the use of CIREN dataset for the injury analysis presented in this paper.

Case Study

In order to show the utility of the scheme, a case study was carried out.

Situation: Consider the risk factors associated with pulmonary contusions sustained in motor vehicle collisions. A pulmonary contusion is a parenchymal injury and is the most common lung injury identified in the setting of blunt chest trauma. In a previous study (O'Connor, 2006), a total of 2184 CIREN case occupants were analyzed to evaluate the epidemiological and biomechanical risk factors associated with pulmonary contusions. Only occupants with age 15 yrs or more involved in frontal and lateral crashes were considered. A multivariate analysis as shown by Table 7 was carried out.

Table 7. Multivariate Analysis Details.

Outcome	Independent Variable	Covariates (AIS 3 +)	Stratification Levels
Incidence of Mortality	Pulmonary Contusion	Head Injuries	No other AIS 3+ thoracic injury
		Spinal Injuries	
		Abdominal Injuries	At least 1 other AIS 3+ thoracic injury
		Upper Extremity Injuries	
		Lower Extremity Injuries	

From this analysis it was found that *pulmonary contusion* is not a risk factor for mortality when controlling for other AIS 3+ injuries.

Problem: In order to check the effectiveness of the "top three injuries" optimization approach, the above mentioned situation was analyzed using the CIREN dataset gathered in this paper. The aim was to analyze the CIREN dataset to find the mortality rate values of pulmonary contusion injury codes and check if they get ranked as the primary injury when other AIS 3+ thoracic injuries are present.

Analysis: The CIREN dataset was reorganized. Pulmonary contusion codes (4414023, 4414063 and 4414104) were segregated from the rest of thoracic injuries. It was found after segregation that each of these codes and the other thoracic injury codes were used more than 10 times, and thus no hard coding was carried out. The pulmonary contusion codes were treated as design variables for optimization. The rest of the problem set up was the same. Optimization was carried out using the entire dataset to obtain the mortality rate values. It was noticed that pulmonary contusions had a much lower mortality rate than the other thoracic injuries (Table 8). Three different initial guesses were used to analyze this situation, with all three pointing to the same conclusion.

Table 8. Mortality rate value comparison.

Other Thoracic Injuries				**Pulmonary Contusions**			
Injury Codes	Run1	Run2	Run3	Injury Codes	Run1	Run2	Run3
7.2	33.13%	32.58%	39.61%	4414023	0.13%	0.61%	3.16%
7.3	33.13%	32.58%	39.61%	4414063	1.43%	1.56%	0.01%
7.4	33.13%	33.35%	40.99%	4414104	11.15%	0.01%	14.72%
7.5	63.02%	63.72%	71.51%				

After optimization, only cases having both pulmonary contusions and other thoracic injuries (base code 7) were selected. Primary, secondary and tertiary injuries were than identified for these cases (Figure13) and it was found that pulmonary contusions were never the primary injury when other thoracic injuries were present.

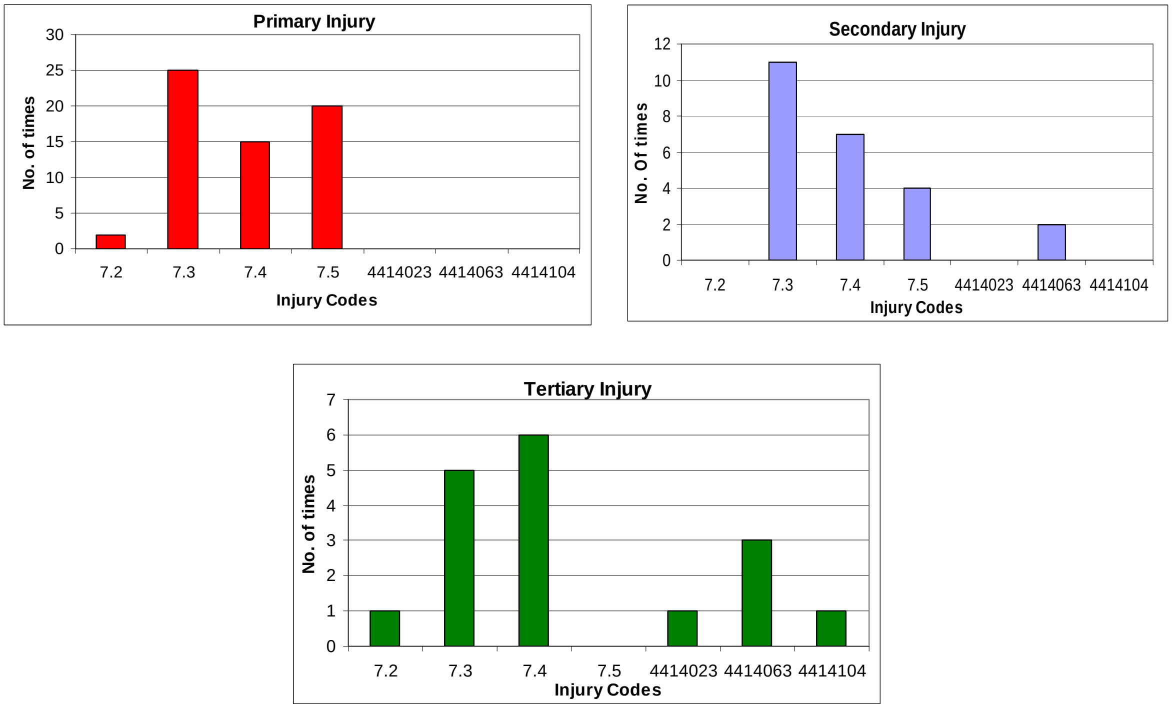

Figure 13: Pulmonary Contusions as Primary, Secondary, and Tertiary Injuries.

The optimization approach works by selecting top three injuries and since some cases only had a total of two/three injuries, the pulmonary contusions showed up as secondary and tertiary injuries.

Conclusion: This analysis does lend support to the original finding and shows the effectiveness and utility of the scheme.

CONCLUSION

This paper presents an alternate approach using optimization methodology for predicting fatality and ranking the injury codes. The methodology shows better predictive capabilities over the ISS approach, MAIS approach, and the "Cause" approach that have been used in the past.

It is a data driven approach, provides outcome based on multiple injuries, and helps discriminate among injuries within and across body regions.

The ability to calculate mortality rate values provides the means of ranking the injury codes based on threat to life and helps determine the injuries which are critical and should be prevented. This information can be used to identify dummy capabilities and can be used to project lives saved and cost benefit obtained by mitigating a specific injury.

LIMITATIONS

- Age was not used in this analysis and can certainly have effect on the results.
- Uniqueness of the result (ranking of the injury codes) may be a problem that requires further investigation as different initial guesses converged to different results.
- A local gradient based solver was used for optimization which has its limitations with regard to spanning the solution space.

FUTURE WORK

- Show that CIREN data is appropriate: i.e., Pfatal = F {injuries} and does not depend on CDS Stratum or on whether the case resides in CIREN or CDS.
- Use age in the analysis and study the effects on the injury codes ranking.
- Identify more suitable functions for computing *Pfatal*.
- Determine standard errors of Pfatal estimates.
- Carry out more case studies to demonstrate the utility of the scheme.
- Investigate the uniqueness issue.
- Consult with medical community on injury rankings.
- Use global solvers for optimization.

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APPENDIX A

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
150000.2	Skull fracture			
150400.2	Vault skull fx	1.2	0.0638	56
150402.2	Vault skull fx			
150200.3	Basilar fracture			
150202.3	Basilar fracture	1.3	0.0638	129
150204.3	Basilar fracture			
150404.3	Vault skull fx			
150206.4	Basilar fracture			
150406.4	Vault skull fx	1.4	0.9999	40
150408.4	Vault skull fx			
130606.2	Optic nerve			
130699.2	Optic nerve			
130899.2	Oculomotor nerve			
131402.2	Abducens nerve			
131499.2	Abducens nerve			
131602.2	Facial nerve			
131604.2	Facial nerve			
131699.2	Facial nerve			
132699.2	Hypoglossal nerve	2.2	0.0071	470
160202.2	LOC			
160404.2	Awake at scene			
160406.2	Awake at scene			
160410.2	Awake at scene			
160414.2	Awake at scene			
160602.2	Lethargic, Stuporous			
160606.2	Lethargic, Stuporous			
160610.2	Lethargic, Stuporous			
161000.2	Cerebral Concussion			
121006.3	Internal carotid			
121406.3	Middle cerebral			
140402.3	Cerebellum contusion			
140403.3	Cerebellum contusion			
140450.3	Cerebellum			
140466.3	Cerebellum subarachnoid			
140602.3	Cerebrum contusion			
140604.3	Cerebrum contusion			
140606.3	Cerebrum contusion			
140611.3	Cerebrum contusion	2.3	0.1057	492
140612.3	Cerebrum contusion			
140614.3	Cerebrum contusion			
140620.3	Cerebrum contusion			
140622.3	Cerebrum contusion			
140660.3	Cerebrum			
140662.3	Cerebrum			
140668.3	Cerebrum edema			
140670.3	Cerebrum edema			
140206.5	Brain stem			
140210.5	Brain stem			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
140676.3	Cerebrum infarction			
140680.3	Cerebrum ischemia			
140682.3	Pneumocephalus			
140684.3	Subarachnoid			
140699.3	Cerebrum NFS			
160204.3	LOC			
160206.3	LOC			
160408.3	Awake at scene			
160412.3	Awake at scene			
160614.3	Lethargic, Stuporous			
160802.3	Unconscious			
160806.3	Unconscious			
160810.3	Unconscious			
160899.3	Unconscious			
120602.4	Carotid fistula			
121004.4	Internal carotid			
121202.4	Intracranial vessel			
140404.4	Cerebellum contusion			
140410.4	Cerebellum hematoma			
140418.4	Cerebellum hematoma			
140430.4	Cerebellum hematoma			
140438.4	Cerebellum hematoma			
140442.4	Cerebellum hematoma			
140474.4	Cerebellum laceration			
140608.4	Cerebrum contusion			
140616.4	Cerebrum contusion			
140624.4	Cerebrum contusion			
140629.4	Cerebrum hematoma	2.4	0.1844	256
140630.4	Cerebrum hematoma			
140632.4	Cerebrum hematoma			
140638.4	Cerebrum hematoma			
140640.4	Cerebrum hematoma			
140642.4	Cerebrum hematoma			
140644.4	Cerebrum hematoma			
140650.4	Cerebrum hematoma			
140652.4	Cerebrum hematoma			
140664.4	Cerebrum			
140678.4	Cerebrum intraventric			
140688.4	Cerebrum laceration			
160208.4	LOC			
160210.4	LOC			
160814.4	Unconscious			
121402.5	Middle cerebral			
122404.5	Superior longitudinal			
140202.5	Brain stem			
140204.5	Brain stem			
251200.2	Orbit fracture			
251202.2	Orbit fracture			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level	Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
140406.5	Cerebellum diffuse				251604.2	TMandibular joint			
140422.5	Cerebellum epidural				251800.2	Zygoma fracture			
140610.5	Cerebrum contusion				350200.2	Hyoid fracture			
140626.5	Cerebrum contusion				250808.3	Maxilla fracture	4.3	0.098	64
140628.5	Cerebrum diffuse				251204.3	Orbit fracture			
140634.5	Cerebrum hematoma	2.5	0.5315	174	250810.4	Maxilla fracture	4.4	0.5	2
140636.5	Cerebrum hematoma				630202.2	Cervical Spine			
140646.5	Cerebrum hematoma				630210.2	Cervical Spine			
140648.5	Cerebrum hematoma				630212.2	Cervical Spine			
140654.5	Cerebrum hematoma				630299.2	Cervical Spine			
140656.5	Cerebrum hematoma				650200.2	Cervical Spine			
140666.5	Cerebrum				650202.2	Cervical Spine			
140674.5	Cerebrum edema				650204.2	Cervical Spine			
160212.5	LOC				650208.2	Cervical Spine	5.2	0.019	158
160214.5	LOC				650209.2	Cervical Spine			
160818.5	Unconscious				650216.2	Cervical Spine			
160824.5	Unconscious				650218.2	Cervical Spine			
230202.2	Optic nerve				650220.2	Cervical Spine			
230204.2	Optic nerve				650230.2	Cervical Spine			
240402.2	Eye avulsion				650232.2	Cervical Spine			
241202.2	Sclera laceration				650299.2	Cervical Spine			
320499.2	Carotid (external)	3.2	0.0918	15	630226.3	Cervical Spine			
321002.2	Vertebral artery				640200.3	Cervical Spine			
340202.2	Larynx contusion				640201.3	Cervical Spine			
340204.2	Larynx laceration				640202.3	Cervical Spine			
341802.2	Vocal cord				640204.3	Cervical Spine			
320202.3	Carotid (common)				640206.3	Cervical Spine			
320206.3	Carotid (common)				640208.3	Cervical Spine			
321010.3	Vertebral artery	3.3	0.2001	5	650203.3	Cervical Spine			
321018.3	Vertebral artery				650206.3	Cervical Spine	5.3	0.1943	198
340208.3	Larynx laceration				650210.3	Cervical Spine			
320210.4	Carotid (common)				650212.3	Cervical Spine			
340210.4	Larynx laceration	3.4	0.2001	2	650222.3	Cervical Spine			
243404.2	Tongue laceration				650224.3	Cervical Spine			
250200.2	Alveolar ridge				650226.3	Cervical Spine			
250608.2	Mandible fracture				650228.3	Cervical Spine			
250610.2	Mandible fracture				650234.3	Cervical Spine			
250612.2	Mandible fracture				640210.4	Cervical Spine			
250614.2	Mandible fracture	4.2	0.098	284	640212.4	Cervical Spine			
250616.2	Mandible fracture				640214.4	Cervical Spine			
250800.2	Maxilla fracture				640216.4	Cervical Spine	5.4	0.1943	16
250802.2	Maxilla fracture,				640218.4	Cervical Spine			
250804.2	Maxilla fracture				640414.4	Thoracic Spine			
250806.2	Maxilla fracture				640614.4	Lumbar Spine			
251004.2	Nose fracture				640224.5	Cervical Spine			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level	Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
640228.5	Cervical Spine				421006.3	Pulmonary artery			
640246.5	Cervical Spine				421202.3	Pulmonary vein			
640266.5	Cervical Spine	5.5	0.5461	14	421204.3	Pulmonary vein			
640464.5	Thoracic Spine				421402.3	Subclavian artery			
640468.5	Thoracic Spine				421404.3	Subclavian artery			
640668.5	Lumbar Spine				421604.3	Subclavian vein			
730430.2	Median, radial,				421804.3	Vena Cava			
730450.2	Median, radial,				422008.3	Chest vessel			
740400.2	Upper Ext muscle				440208.3	Bronchus distal			
740600.2	Upper Ext joint				440604.3	Diaphragm laceration			
750230.2	Acromioclavicular				441002.3	Heart			
750642.2	Elbow joint				441004.3	Heart	7.3	0.1842	442
751030.2	Shoulder joint				441008.3	Heart			
751230.2	Sternoclavicular joint				441010.3	Heart			
751430.2	Carpus joint				441402.3	Lung contusion			
751440.2	Carpus joint				441406.3	Lung contusion			
751600.2	Acromion fracture				441414.3	Lung laceration			
751800.2	Arm/wrist fx	6.2	0.0045	672	441416.3	Lung laceration			
752000.2	Carpus fx				441430.3	Lung laceration			
752002.2	Carpus fx				441432.3	Lung laceration			
752004.2	Metacarpal bone				441499.3	Lung NFS			
752200.2	Clavicle fracture				441604.3	Pericardium injury			
752402.2	Finger amputation				441802.3	Pleura laceration			
752600.2	Humerus fracture				442202.3	Thoracic cavity			
752602.2	Humerus fracture				442204.3	Thoracic cavity			
752800.2	Radius fracture				420202.4	Aorta, thoracic			
752802.2	Radius fracture				420206.4	Aorta, thoracic			
753000.2	Scapula fracture				420208.4	Aorta, thoracic			
753200.2	Ulna fracture				420299.4	Aorta, thoracic			
753202.2	Ulna fracture				420408.4	Brachiocephalic			
711000.3	Upper Extremity				420606.4	Brachiocephalic			
720608.3	Brachial artery				421008.4	Pulmonary artery			
721008.3	Upper ext vessel				421206.4	Pulmonary vein			
752604.3	Humerus fracture				421408.4	Subclavian artery			
752606.3	Humerus fracture	6.3	0.0135	403	421806.4	Vena Cava			
752804.3	Radius fracture				440210.4	Bronchus distal	7.4	0.3142	198
752806.3	Radius fracture				440606.4	Diaphragm rupture			
753204.3	Ulna fracture				441006.4	Heart			
753206.3	Ulna fracture				441410.4	Lung contusion			
422099.2	Chest vessel				441418.4	Lung laceration			
440602.2	Diaphragm contusion				441420.4	Lung laceration			
440802.2	Esophagus contusion				441434.4	Lung laceration			
441602.2	Pericardium laceration	7.2	0.0001	23	441436.4	Lung laceration			
441699.2	Pericardium NFS				441450.4	Lung laceration			
441800.2	Pleura laceration				441452.4	Lung laceration			
441804.2	Pleura contusion				442206.4	Thoracic cavity			
420406.3	Brachiocephalic				442208.4	Thoracic cavity			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level	Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
420204.5	Aorta, thoracic				520699.3	Iliac artery			
420210.5	Aorta, thoracic				520802.3	Iliac vein			
420212.5	Aorta, thoracic				521402.3	Abdominal vessel	10.3	0.0421	39
420216.5	Aorta, thoracic				521404.3	Abdominal vessel			
441012.5	Heart	7.5	0.8087	71	521406.3	Abdominal vessel			
441300.5	Intraventricular				521499.3	Abdominal vessel			
441422.5	Lung laceration				521602.3	Abdominal vessel			
441438.5	Lung laceration				521604.3	Abdominal vessel			
441458.5	Lung laceration				520202.4	Aorta, abdominal			
442210.5	Thoracic cavity				520406.4	Celiac Artery			
450210.2	Rib cage				520608.4	Iliac artery			
450220.2	Rib cage	8.2	0.2444	254	521206.4	Vena cava	10.4	0.6642	13
450804.2	Sternum fracture				521408.4	Abdominal vessel			
450211.3	Rib cage				521606.4	Abdominal vessel			
450214.3	Rib cage				650600.2	Lumbar Spine			
450222.3	Rib cage				650604.2	Lumbar Spine			
450230.3	Rib cage	8.3	0.2444	254	650616.2	Lumbar Spine			
450250.3	Rib cage				650618.2	Lumbar Spine	11.2	0.0113	249
450262.3	Rib cage				650620.2	Lumbar Spine			
450232.4	Rib cage				650630.2	Lumbar Spine			
450240.4	Rib cage				650632.2	Lumbar Spine			
450252.4	Rib cage	8.4	0.418	205	630606.3	Lumbar Spine			
450260.4	Rib cage				630628.3	Lumbar Spine			
450264.4	Rib cage				630672.3	Lumbar Spine			
450242.5	Rib cage	8.5	0.8138	59	640604.3	Lumbar Spine			
450266.5	Rib cage				650622.3	Lumbar Spine	11.3	0.0217	42
650404.2	Thoracic Spine				650624.3	Lumbar Spine			
650409.2	Thoracic Spine				650626.3	Lumbar Spine			
650416.2	Thoracic Spine				650634.3	Lumbar Spine			
650418.2	Thoracic Spine				540214.2	Adrenal gland			
650420.2	Thoracic Spine	9.2	0.0067	174	540610.2	Bladder contusion			
650430.2	Thoracic Spine				540620.2	Bladder laceration			
650432.2	Thoracic Spine				540810.2	Colon contusion			
650499.2	Thoracic Spine				540820.2	Colon laceration			
640400.3	Thoracic Spine				540822.2	Colon laceration			
640401.3	Thoracic Spine				541010.2	Duodenum contusion			
640402.3	Thoracic Spine				541222.2	Gallbladder laceration			
640404.3	Thoracic Spine				541410.2	Jejunum contusion			
640408.3	Thoracic Spine	9.3	0.0596	53	541420.2	Jejunum laceration			
650410.3	Thoracic Spine				541422.2	Jejunum laceration			
650422.3	Thoracic Spine				541610.2	Kidney contusion			
650424.3	Thoracic Spine				541612.2	Kidney contusion			
650426.3	Thoracic Spine				541620.2	Kidney laceration			
650434.3	Thoracic Spine				541622.2	Kidney laceration			
520402.3	Celiac Artery				541810.2	Liver contusion			
520602.3	Iliac artery				541812.2	Liver contusion			
520606.3	Iliac artery				541820.2	Liver laceration			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level	Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
541822.2	Liver laceration				540626.4	Bladder laceration			
542010.2	Mesentery contusion				540826.4	Colon laceration			
542020.2	Mesentery laceration				541024.4	Duodenum laceration			
542022.2	Mesentery laceration				541226.4	Gallbladder laceration			
542210.2	Omentum contusion				541426.4	Jejunum laceration			
542222.2	Omentum laceration	12.2	0.1159	523	541626.4	Kidney laceration	12.4	0.1159	129
542810.2	Pancreas contusion				541640.4	Kidney rupture			
542812.2	Pancreas contusion				541826.4	Liver laceration			
542822.2	Pancreas laceration				542026.4	Mesentery laceration			
542899.2	Pancreas NFS				542828.4	Pancreas laceration			
543224.2	Perineum laceration				543402.4	Placenta abruption			
543610.2	Rectum contusion				544226.4	Spleen laceration			
543620.2	Rectum laceration				544426.4	Stomach laceration			
544024.2	Scrotum laceration				541628.5	Kidney hilum			
544210.2	Spleen contusion				541828.5	Liver laceration	12.5	0.937	33
544212.2	Spleen contusion				542832.5	Pancreas laceration			
544220.2	Spleen laceration				544228.5	Spleen laceration			
544222.2	Spleen laceration				820404.2	Femoral vein			
544410.2	Stomach contusion				830402.2	Sciatic nerve			
544420.2	Stomach laceration				850610.2	Hip dislocation			
544422.2	Stomach laceration				850614.2	Hip dislocation	13.2	0.1104	702
545022.2	Urethra laceration				850618.2	Hip dislocation			
545210.2	Uterus contusion				852600.2	Pelvis fracture			
545424.2	Vagina laceration				852602.2	Pelvis fracture			
540424.3	Anus laceration				813004.3	Crush knee			
540640.3	Bladder rupture				820204.3	Femoral artery			
540824.3	Colon laceration				820608.3	Popliteal artery			
541022.3	Duodenum laceration				851800.3	Femur fracture			
541023.3	Duodenum laceration				851801.3	Femur fracture			
541224.3	Gallbladder laceration				851804.3	Femur fracture			
541424.3	Jejunum laceration				851808.3	Femur fracture			
541614.3	Kidney contusion				851810.3	Femur fracture	13.3	0.1104	1063
541624.3	Kidney laceration				851812.3	Femur fracture			
541814.3	Liver contusion				851814.3	Femur fracture			
541824.3	Liver laceration	12.3	0.1159	254	851818.3	Femur fracture			
542024.3	Mesentery laceration				851822.3	Femur fracture			
542814.3	Pancreas contusion				852604.3	Pelvis fracture			
542824.3	Pancreas laceration				852800.3	Sacroilium fracture			
543400.3	Placenta abruption				853000.3	Symphysis pubis			
543800.3	Retroperitoneum				852606.4	Pelvis crush			
544214.3	Spleen contusion				852608.4	Pelvis crush	13.4	0.1112	9
544224.3	Spleen laceration				852610.5	Pelvis crush	13.5	0.9999	1
544240.3	Spleen rupture				820602.2	Popliteal artery			
544424.3	Stomach laceration				820804.2	Popliteal vein			
544826.3	Ureter laceration				841002.2	Patellar tendon			
545226.3	Uterus laceration				841004.2	Patellar tendon			
540624.4	Bladder laceration				850806.2	Knee dislocation			

Full Code	Nomenclature	Abbr. Code	Optimized MR Value	Inc. Level
850810.2	Knee dislocation			
850814.2	Knee dislocation			
850818.2	Knee laceration	14.2	0.0212	199
850822.2	Knee meniscus			
850826.2	Knee sprain			
852400.2	Patella fracture			
815000.2	Lower Extremity			
830602.2	Femoral/tibal nerve			
830604.2	Femoral/tibal nerve			
830606.2	Femoral/tibal nerve			
830699.2	Femoral/tibal nerve			
840200.2	Achilles tendon			
840204.2	Achilles tendon			
840402.2	Collateral ankle			
840404.2	Collateral knee			
840600.2	Lower Ext muscle			
840802.2	Lower Ext tendon			
840804.2	Lower Ext tendon			
850210.2	Tarsus disloc			
850214.2	Tarsus disloc			
850218.2	Tarsus disloc			
850222.2	Tarsus disloc			
851400.2	Calcaneus fracture	15.2	0.0025	1425
851605.2	Fibula fracture			
851606.2	Fibula fracture			
851608.2	Fibula fracture			
851610.2	Fibula fracture			
851612.2	Fibula fracture			
852000.2	Foot/ankle fx			
852002.2	Leg/ankle fx			
852200.2	Metatarsal fx			
853200.2	Talus fracture			
853404.2	Tibia fracture			
853406.2	Tibia fracture			
853410.2	Tibia fracture			
853412.2	Tibia fracture			
853414.2	Tibia fracture			
853416.2	Tibia fracture			
853420.2	Tibia fracture			
853604.2	Toe amputation			
811002.3	Leg Amputation			
821008.3	Low ext vessel			
821206.3	Low ext vessel			
840406.3	Posterior cruciate			
851614.3	Fibula fracture	15.3	0.0197	309
853405.3	Tibia fracture			
853408.3	Tibia fracture			
853418.3	Tibia fracture			
853422.3	Tibia fracture			
190604.2	Scalp laceration			
190804.2	Scalp avulsion			
290604.2	Facial Skin			
290804.2	Facial Skin			
390604.2	Neck/Throat Skin			
411000.2	Breast avulsion			
490604.2	Chest Skin			
490804.2	Chest Skin			
590604.2	Abdomen Skin			
590804.2	Abdomen Skin			
790604.2	Upper ext skin	16.2	0.0001	175
790804.2	Upper ext skin			
792012.2	Upper ext burn			
794002.2	Degloving injury			
794004.2	Degloving injury			
890604.2	Lower ext skin			
890804.2	Lower ext skin			
892008.2	Lower ext burn			
892012.2	Lower ext burn			
919201.2	Inhalation Injury			
190606.3	Scalp laceration			
190806.3	Scalp avulsion			
590806.3	Abdomen Skin			
790806.3	Upper ext skin			
792010.3	Upper ext burn	16.3	0.0001	17
794006.3	Degloving injury			
890606.3	Lower ext skin			
890806.3	Lower ext skin			
894006.3	Degloving injury			
992022.4	Burn 2nd deg	16.4	0.0001	2
992028.5	Burn 2nd deg			
992030.5	Burn 2nd deg	16.5	0.5	2
115099.7	Closed head	1150.7	0.0001	3
515099.7	Blunt abdominal	5150.7	0.0001	2

DISCUSSION

PAPER: **Ranking Injury Codes Using Optimization Methodology**

PRESENTER: ***Vikas Hasija, Gesac, Inc.***

QUESTION: *Guy Nusholtz, Daimler Chrysler*
On one of your graphs, it appeared that the sternum ribs were the most—That one: Ribs sternum. And that's the highest risk of injury? Is this fatal injuries? Sternum risks—sternum ribs are the highest risk? That's a new piece of information for us.

ANSWER: Yeah. That's part is actually coming out of the data so we want to consult the medical community and see if the ranking makes sense. So, that's what it showed: That the events actually having the higher mortality rate.

Q: I see. I see the brains.

A: But consider that fact that these are average rankings.

Q: I see the brains down there.

A: Yeah, if you see this, you can see the skull actually has the highest ranking. So that is just the average ranking.

Q: Okay. So the ribs and sternum are it. Okay. Thank you.

Q: *Richard Kent, UVA*
It's a good point because that's usually considered to not have a lot of clinical significance so it would be interesting to try and resolve that. That actually sort of leads to my question: That I think there's—Did you make an attempt to control for cofactors, like age?

A: No. We didn't do that.

Q: Because that may be dominating what you see there. And in particular, I think you've also introduced a bias by eliminating the MAIS 2 injury because there is a finite probably of death associated with those.

A: There are only three instances with MAIS 2.

Q: I'm sorry?

A: There are only three cases with MAIS 2.

Q: There are only three cases with MAIS 2 in the CIREN database?

A: [inaudible]

Q: In row 3? Okay. Oh yeah. Okay. Okay. You may want to look at that because that is age bias because there are older folks who die of MAIS 2 injuries and in fact, they're often associated with complications, as well. So by excluding 2's and excluding complications, you're introducing an age bias. But then, you seem to sort of have an overrepresentation of older folks by having ribs and sternum be a fatal injury. So, I'm sort of wondering how that works out? I don't quite understand it.

A: That's a part of our future work, so we've created a new balance from that.

Q: Okay. Thanks.