CHARACTERISTICS OF FATALITIES IN THE CIREN DATABASE

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Paper Number 09-0253

ABSTRACT

This paper examines whether CIREN fatal cases are representative of crash fatalities in terms of injury patterns and the time to death. To examine the association, CIREN fatalities are compared with those of all motor vehicle crashes. Comparison data sets are derived from FARS data and from records obtained from the Maryland Office of the Chief Medical Examiner. Differences in injury patterns between those who died early-on vs. those who died later are documented. The findings suggest that the CIREN dataset is representative of real-world fatalities in terms of the fraction of deaths occurring within thirty minutes of the crash; and that, as expected, occupants who die early-on in CIREN are observed to have more severe injuries than those who die later. Moreover, injuries among early-on deaths appear to have a slightly different distribution than among those who die later. Also, CIREN has a higher fraction of cases where occupants died after twenty-four hours than in the U.S. population. The results of this study will help to refine methods used to estimate mortality associated with particular injuries by assessing the completeness of injury records for fatal cases.

BACKGROUND

The National Highway Traffic Safety Administration (NHTSA) is responsible for reducing deaths, injuries, and economic losses resulting from motor vehicle crashes in the US. NHTSA's goal of reducing highway traffic fatalities is achieved by establishing safety priorities driven by real-world crash data.

Typically, a NHTSA plan of action focuses on an intervention aimed to mitigate injuries. It is accompanied by a benefits analysis in which costs and lives lost are computed for a given priority area. This involves the identification of a target population to which the benefit is directed. A target population consists of an occupant group sustaining injuries to a particular body region that are associated with high mortality and may be mitigated by a proposed intervention. Unit costs are first established by equating a cost to a given injury type, injury severity, and injured body part. These costs are then applied to a target population to compute benefits associated with interventions aimed at narrow ranges of injuries.

One of the difficulties in using crash data in this type of analysis is that the categorization of motorists by injury type and body region is not usually straightforward. As a result, a given crash victim is typically categorized by selecting the injury associated with the maximum severity score in accordance with the Abbreviated Injury Scale (MAIS). For each occupant injury record, however, there are frequently multiple injuries in multiple body regions. This makes it difficult to judge how likely it is that a life will be saved if a specific injury is mitigated. Nonetheless, it is reasoned that the cost associated with the MAIS injury is the approximate cost incurred by the victim. Thus, the costing methodology is an averaging process: it is understood that most victims suffer multiple injuries, and all injuries contribute to the overall cost. This methodology offers a reasonable means to account for injury costs.

<u>New injury accounting process</u>. A new injury accounting methodology was developed by Martin and Eppinger (ESV 2005) that takes into account multiple injuries. Estimates are made of costs and the number of fatalities attributable to specific types

of injuries. The procedure examines a crash victim's entire injury record in the process. Fatalities attributable to specific injuries are determined by considering the effect that a specific injury or set of injuries has on fatality risk. Attributable costs are estimated in a similar manner. The procedure estimates the risk to life that multiple injuries pose to crash victims. It also estimates the costs borne by and the number of fatalities attributable to specific types of injuries. For example, if one desires to estimate the number of lives saved if a particular injury is mitigated, it may be accomplished directly. This is much harder to accomplish in the context of an MAIS value which represents just one injury from a record of multiple injuries.

Ranking CIREN injuries via optimization. The injury accounting process is based on a ranking of AIS injury codes established using an optimization scheme (see Martin and Eppinger, 2003). Each seven-digit AIS code is placed into one of approximately 60 individual injury groups and each group is assigned a mortality constant ranging from zero to one. Mortality constants were previously derived from Crash Injury Research and Engineering Network (CIREN) data.

For each CIREN case, the mortality constants associated with each of the crash victim's injuries are determined by the overall dataset which makes use of a probability function that predicts mortality. For each case, deviance is computed by comparing the probability of fatality to the case fatality observed (0=nonfatal, 1=fatal). Optimization solvers are then used to assign mortality constants to each of the 60 codes such that the average deviance of all cases is minimized.

The accuracy of the ranking system, and hence, the fatality attribution process is contingent upon complete and accurate injury records in fatal cases. Crash victims entered into the CIREN database are selected based on patient admission into the Trauma Center, vehicle model year, injury severity, crash type, and occupant restraint condition. Also, CIREN enrollees (or next of kin) must consent to enrollment. CIREN is not sampled with the intention of providing a dataset that represents a U.S. population. Exceptions to the consent process are made for "dead on arrival". Nonetheless, CIREN fatalities may be under-represented by those who died at the scene and were never admitted to the trauma center.

Recent studies comparing CIREN data to the nationally representative National Automotive Sampling System – Crashworthiness Data System (CDS) sample have shown that the fatality rates are about the same. Flannagan and Rupp (2009) found that when CDS cases that met the CIREN criteria were compared to CIREN, the two datasets were quite similar in terms of the fatality rate. However, this study only considered the incidence of fatalities, and not the distribution of injuries. A similar study applied the Mahalanobis distance metric methodology to determine similarity between CIREN and CDS cases and found the mortality rate among occupants in the CIREN database to be much lower than those in the CDS (Stitzel et al, 2007). But this likely occurred because MAIS 2 cases (which are almost always non-fatal) were stricken from their CDS dataset.

OBJECTIVE

This paper examines whether CIREN fatal cases are representative of real-world fatalities in terms of injuries and the fraction of early-on deaths. It investigates the extent of any selection bias in CIREN for fatal cases by determining whether early-on fatalities are under-represented. It also investigates whether occupants who die early-on have different injuries than those who die later. Several other data sources are also examined to offer insights into the limitations associated with benefits analyses aimed at mitigating particular injuries and combinations of injuries.

DATA SOURCES

The following data sources were used in this study:

CIREN Database. The CIREN database is maintained by NHTSA as a means to examine injury causation in crashes. This database contains a sample of comprehensive medical records of severely injured occupants admitted to one of eight U.S. Level 1 trauma centers. It consists of 300-400 passenger car crashes per year and the database now includes information on approximately 4,000 drivers and passengers.

The injury ranking methodology described earlier was determined based on CIREN data of adults. For the analysis herein, the CIREN dataset was limited to adult fatalities only. The dataset includes the time-to-death from the crash and all injury information. Based on the findings of this study, the caveats and conditions upon which CIREN data may be used in such a ranking methodology shall be discussed.

Maryland Autopsy Reports – Autopsy reports generated by the Maryland Office of the Chief

Medical Examiner (OCME) are used to provide a dataset for comparison of fatalities with CIREN data. OCME cases for years 2000-2002 for all deaths of passenger car drivers are used. The OCME cases, which include about 900 deaths, represent an unbiased census of fatally injured occupants in Maryland. They include those that died at the scene of the crash early-on and those that died later after hospital treatment.

The autopsies are conducted by medical examiners trained in pathology. Every traffic fatality is accompanied by a police crash report and any related available records. Injuries are identified at the time of the autopsy from either a full investigation by the medical examiner or from a combination of an external investigation and existing medical records.

The cause of death is determined by the medical examiner based on the documented injuries. The time of death from the crash is determined from medical records, if the person is declared dead in the field by a medical doctor, or investigative techniques employed by the medical examiner.

OCME Variables. Injury information takes the form of text descriptions of the findings of a pathologist. OCME reports also include a listing of injuries identified in the examination. Each autopsy report is unique and the final listing of injuries abstracted.

Other variables that typically appear on an OCME report include age, date of birth, gender, vehicle make and model, crash date, crash time, seating location, seatbelt use, airbag use, rollover collision (y/n), alcohol/drug use, date of death, time of death, cause of death, and hospital treatment. Vehicle and crash information are taken from the police crash report; alcohol/drug use are taken from the OCME toxicology testing or hospital record; hospital treatment is determined from medical records.

Fatal Automotive Reporting System (FARS). The FARS – another crash data base maintained by NHTSA – is a census of all fatalities involving motor vehicles on public trafficways in the United States. FARS records only include fatalities occurring within 30 days of the crash. FARS also contains information on the time of death, but has limited injury information. FARS records for 2000-2002 were abstracted into a dataset that contained fatally injured passenger car drivers in the U.S. In order to compare directly with the OCME dataset, the FARS dataset was subdivided into a secondary dataset of crashes occurring in the state of Maryland. The FARS dataset is used to compare the time-to-death from the crash captured in the CIREN and OCME datasets.

METHODS

The first objective is carried out by investigating whether CIREN fatal cases are representative of real-world fatalities in terms of the fraction of early-on deaths. Fatality census counts provided by FARS are compared to CIREN cases. Since FARS is a census of all U.S. fatalities, it represents the baseline for the comparison.

The second objective involves investigating whether occupants who die early-on have different injuries than those who die later. A comparison of CIREN fatalities is carried out comparing the injuries sustained in those two categories of cases. Fatality data abstracted from the Maryland OCME files are compared in the same manner to provide an independent evaluation. The OCME's records constitute a census of all motor vehicle fatalities in Maryland.

Maryland OCME Data Abstraction. Injury data on fatalities were obtained by abstracting autopsy reports at the Office of the Chief Medical Examiner for the State of Maryland. While these reports are quite detailed, for this purpose a summary provided at the end of the report was utilized to abstract the injury descriptions. Given the fact that some of the data required for coding AIS scores, such as duration of loss of consciousness, are obviously not available, it was decided to code the injuries using the more anatomic-based ICD-9 codes.

In applying ICD-9 codes to OCME injury descriptions, severity levels were estimated to be 'moderate' if there was no further qualifying information. These codes were then 'translated' to AIS scores using software that was developed for that purpose. Maximum AIS scores (MAIS) were then determined, based on the highest AIS score for a given individual. For example, if the autopsy report reported 'spleen laceration', in the absence of further detail it was translated to a Grade III spleen laceration.

Therefore, in order to provide consistency in coding, ICD-9 codes were selected to represent the injuries described on the narratives. Those codes were then entered into a software program, ICD-9 MAP (Johns Hopkins, 1997) that converted the ICD-9 codes into AIS codes.

OCME reports from which a detailed set of injury codes could not be abstracted were excluded from the dataset. An example of a case where the OCME file was not coded is where the final list of injuries consisted of the words "brain injuries" or "multiple injuries." Without the full report containing specific observations, these cases were not able to be coded and were excluded.

CIREN and OCME Case Categorization. The CIREN and OCME datasets were broken down by time-to-death from the crash for comparison with the FARS dataset. "Early-on" deaths are defined as those occurring within thirty minutes of the crash. About 95% of early-on fatalities in the CIREN dataset died at the scene of the crash. The remainder died in transport or were pronounced dead soon after arrival to a hospital. "Later" deaths include all others. Furthermore, the CIREN and OCME datasets were examined case-by-case to determine the most severe injury.

Reduced CIREN and OCME Datasets. To judge whether CIREN data is appropriate for establishing mortality constants in accordance with the optimization methodology without bias, the respective CIREN and OCME datasets were reduced to non-deterministic cases. In other words, cases where a non-survivable injury was present were not included in the dataset. Such injuries include all those having an AIS code with a severity score of 6, and a few with a score of 5. These injuries have been observed to always result in a fatality and have an associated mortality constant that results in an estimate of probability of fatality of 100%. All codes with an AIS severity score of 2 were also removed since most have little influence on fatality probability.

RESULTS

OCME Abstracts. Table 1 shows the number of OCME autopsy reports for the period 2000 to 2002. There were a total of 1,044 crash reports involving a fatality, of which 732 (70%) provided abstractable injury information that was fully coded. For reference, Maryland fatalities recorded in FARS are provided to corroborate the OCME crash reports. The slightly higher incidence appearing in the OCME dataset reflects additional OCME cases where the crash may have occurred on a non-public trafficway or where the occupant died over 30 days after the crash.

The OCME and FARS datasets are very similar, which is expected given that FARS statistics are derived in part from the OCME files. The comparison is shown for reference to demonstrate that the autopsy extracts are an accurate representation of all Maryland fatalities and are unbiased by the inclusion criteria.

Time-to-Death Comparison. Table 2 shows the distribution of time intervals between the crash and death for the OCME dataset, the CIREN dataset, and in FARS. Early-on deaths (i.e., those that occurred within thirty minutes of the crash) in CIREN occurred in about the same proportion as in the FARS census data. These represent mostly cases where occupants died before being admitted to a treatment facility.

In comparing the Maryland OCME autopsy data with FARS, it is seen that most of the OCME records that could not be abstracted were early-on deaths where time to death was less than 30 minutes (39% vs. 50%). And among those who died later, Table 2 indicates that CIREN is over-represented by those who survived longer.

Table 1. OCME 2000 to 2002 Driver Fatalities
(Age 16 and over, excluding motorcycle and moped riders)

Year	Md. Fatalities in FARS	OCME Crash Reports	OCME Autopsy Extracts		OCME Autopsy Extracts With Injury Data	
			N	% of Crash Reports	N	% of Crash Reports
2000	297	325	286	88	264	81
2001	352	360	330	92	315	88
2002	349	359	208	58	153	43
Total	998	1,044	824	79	732	70

Table 2. Fatality Counts in OCME, CIREN, and FARS Datasets by time to death from crash.

Time from Crash to Death	CIREN (N=404) %	OCME w/ Injury Data (N=676) %	Md. Fatalities in FARS, (N=935) %	FARS Entire U.S. (N=66,160) %
0 – 30 Minutes	45	39	50	48
31-60 Minutes	9	19	14	15
1 to 2 Hours	6	17	15	17
2 to 24 Hours	15	14	9	10
1 to 5 days	10	5	7	5
6 to 30 days	15	4	6	5
31+ days	-	2	-	

*There are 56 OCME and 63 FARS cases with missing time to death.

Injury Severity Comparison – Full Datasets. Figure 1 and Figure 2 show the distribution of injuries among various body regions for the OCME and CIREN datasets. Each bar represents the percentage of cases in which the injury is present. For example, 148 of the 181 "Died early-on" cases (82%) included a thoracic organ injury of which 47 (32%) had a severity score of AIS 6. Among the 148 cases, the average thoracic organ injury MAIS was 4.8 (typically there were multiple thoracic organ injuries per case). Other injury categories such as deep brain, burns, lumbar spine, knee, and eyes and ears all appeared in less than 8% of deaths and are not shown in Figure 1 and 2.

It is apparent from Figure 1 and Figure 2 that early-on fatalities are generally associated with injuries having a higher threat to life. This is reflected in the higher average AIS scores and the greater number of cases containing unsurvivable injuries.

As expected, the CIREN injury scores are consistently higher than those abstracted from the Maryland OCME reports. As described earlier, the data extraction process, including the use of ICD-9 MAP software, tends to result in conservatively coded injuries. Therefore, the two datasets are only compared for within-dataset trends and not as a case/control comparison.

Figures 1 and 2 also reveal how the frequencies of injuries differ within body regions for early-on deaths vs. those who died later. The biggest differences are seen in the CIREN dataset (Fig. 1) where thorax organ injuries, brain injuries (non diffuse), skull fractures, and cervical spine injuries all occur more often in early-on deaths. Diffuse axonal injuries (DAI), including "Loss of Consciousness" injuries of severity AIS 3+ are notable exceptions. In the OCME dataset, the relative evenness of the bars in Fig. 2 indicates that the fractions of all injuries are about the same.

Injury Severity Comparison – Reduced Datasets. As explained earlier, the optimization routine to determine injury rankings operates on a reduced dataset in which all fatal cases having unsurvivable injuries have been removed. For both the reduced CIREN and OCME datasets, there are only five categories of injuries that occur in more than 15% of deaths. Furthermore, they are the same five categories. Referring to Fig. 3, they are: 1. Thoracic organ injuries; 2. Rib/Sternum; 3. Cortical brain, SDH, SAH; 4; Skull fractures (vault or base); 5. Abdominal organ injuries.

In terms of the frequencies of deaths occurring early vs. later, the reduced OCME and CIREN datasets show similar trends as the full datasets. As shown in Fig. 3, the CIREN frequency bars for early vs. later are more aligned than in the full set.

The overall MAIS scores of both CIREN and OCME reduced datasets are understandably lower than the full dataset. And in CIREN in particular, the severity scores of early-on deaths vs. those who died later begin to converge. This is also understandable given the high fraction (almost half) of early-on deaths that have been removed from the reduced dataset due to the presence of an unsurvivable injury.

The biggest change in going from the full to reduced datasets occurs with OCME rib/sternum injuries. Due to the removal of a high number of AIS 2 codes, their frequency is markedly decreased in the reduced set.

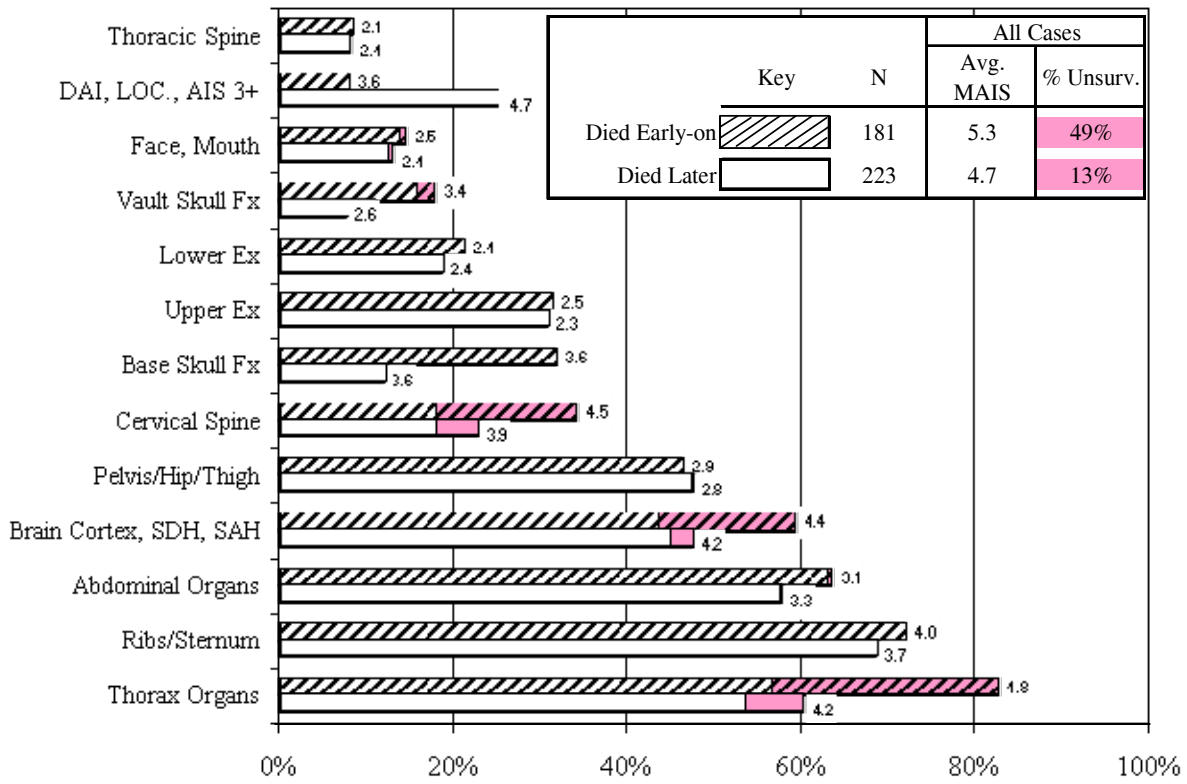

Figure 1. Full CIREN Dataset Comparison. Injury make-up of CIREN dataset by time-to-death. Colored areas represents cases where unsurvivable injuries were present.

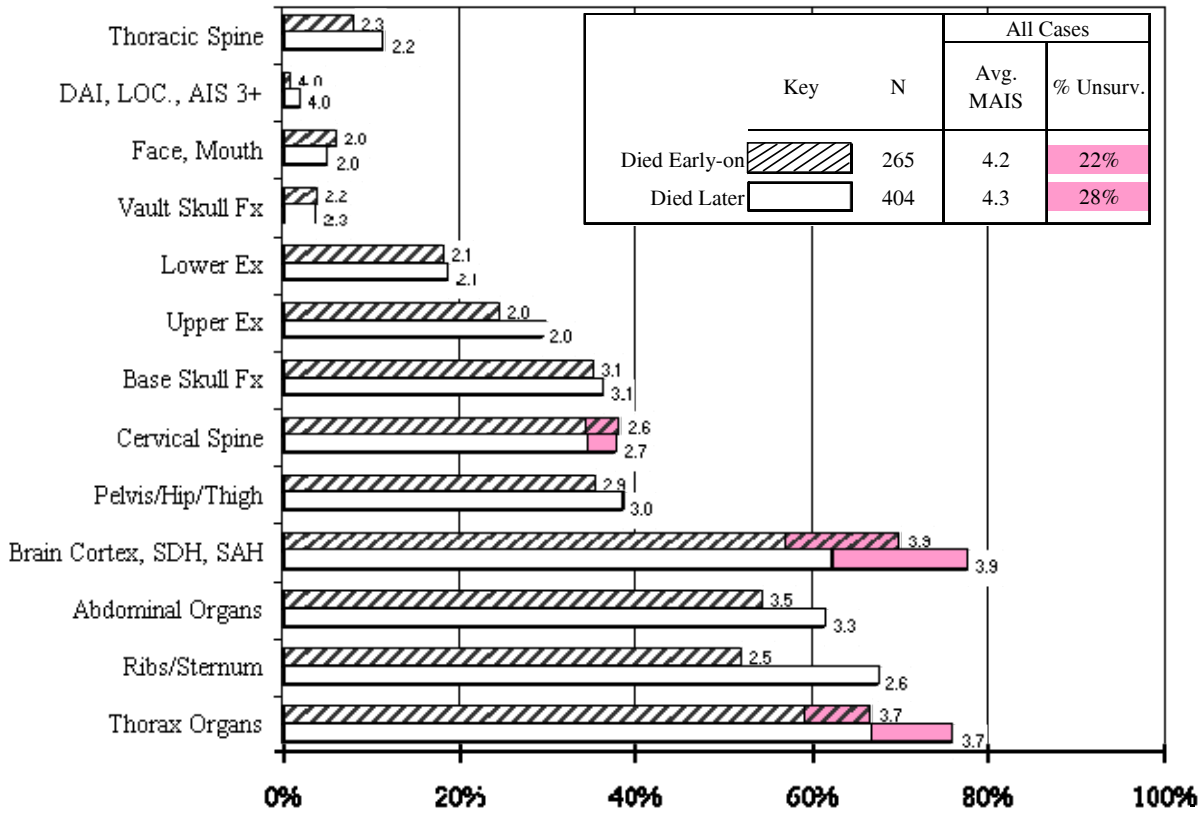

Figure 2. Full OCME Dataset Comparison. Injury make-up of OCME dataset by time-to-death. Colored areas represents cases where unsurvivable injuries were present.

Key	CIREN N	CIREN Avg. MAIS	OCME N	OCME Avg. MAIS
Died Early-on	93	4.6	207	3.7
Died Later	195	4.5	301	3.8

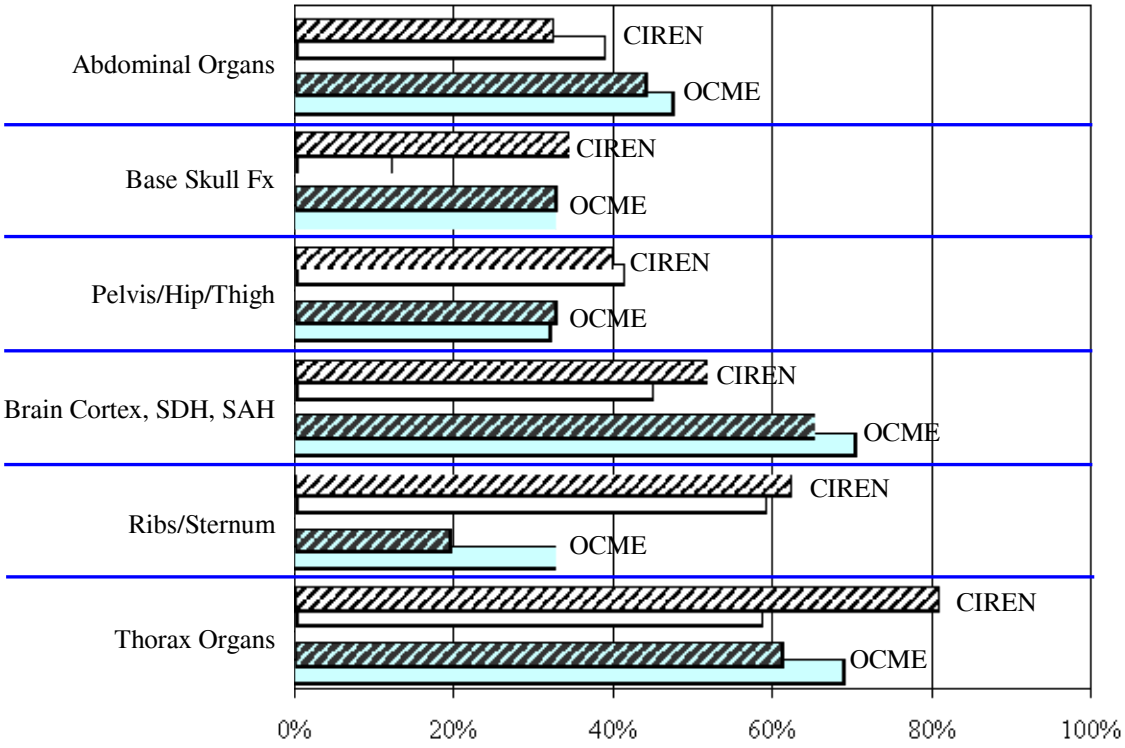

Figure 3. Reduced Dataset Comparison. Injury make-up of CIREN and OCME datasets by time-to-death.

DISCUSSION

Objective 1 – Fraction of early-on deaths in CIREN. In comparison with the FARS and OCME datasets, the CIREN dataset appears to have a similar fraction of early-on deaths. But among those who died later, CIREN contains a greater proportion of those who died several days later (versus died within 24 hours).

This over-representation of deaths after the first day may be explained partly by the contributions of patients transferred from other hospitals. Typically, patients at Level 2 trauma centers that require specialized care (i.e. management of complex spinal and orthopedic injuries) are transferred to Level 1 trauma centers after they become physiologically stable. Since they arrive in a stable condition to the CIREN center, they are unlikely to die within the first 24 hours. Hence, the inclusion of transfers is likely to over-represent those that die after 24 hours.

Also, CIREN's patient recruitment process, in which consent for admitted patients is required, makes it difficult to enroll patients who are admitted and die within two hours (i.e., prevailing events take priority over the enrollment protocol.)

Objective 2 – Differences in injuries for early-on deaths. A within-dataset comparison of CIREN data vs. OCME data shows the two datasets to be slightly at odds over whether early-on injuries are much different than injuries of those who died later (Figs. 1 and 2). As seen earlier, the CIREN dataset indicates that thoracic injuries, skull fractures, and cervical spine injuries appear more often in early-on deaths. The CIREN dataset also shows, as expected, that early-on deaths more often have injuries that are

unsurvivable than in those who die later (49% vs. 13%). In the OCME dataset, unsurvivables are about the same in both (18% vs. 20%). This latter finding within the OCME may be an artifact of the data abstraction process (see below).

Data Origin - OCME vs. CIREN. The differences in injury make-up between the CIREN and OCME datasets prompt further discussion. For early-on deaths in particular, one would expect CIREN and OCME to be very similar. On-scene deaths in CIREN (which include the majority of early-on deaths) represent cases in which occupants receive no hospital treatment. It follows that CIREN early-on deaths should be just like any other early-on deaths, suggesting that the make-up of injuries sustained in CIREN early-on deaths should not differ from those in all Maryland early-on deaths.

Nonetheless, the make-up of injuries in the OCME and CIREN early-on deaths do differ. In the OCME dataset, there is little difference in the MAIS levels per injury (Fig. 2) between early-on vs. later deaths. But this is uncharacteristic, as it seems reasonable to believe that early-on deaths should have more severe injuries than those who died later.

The abstraction process used to code OCME reports probably played a roll in the uncharacteristic data. As stated earlier, those with less information on the injury list appear to be biased by time-to-death. In the OCME dataset, 23% of early-on deaths contain three or fewer AIS 2+ codes on the injury record, compared to 4% in died later cases. On the other hand, only 11% of CIREN cases - for both early-on and later deaths – have three or fewer injuries coded.

The injury severity discrepancy between OCME and CIREN is also related to the process of abstracting injury codes. Often, injury lists are not detailed enough to ascertain injury severity level. The practice of assuming a "moderate" severity level when coding cases has the general affect of undercoding injuries, as many are probably "major" or "complex" injuries with corresponding scores of AIS 4 or 5 given that they occurred in a victim that died. On the other hand, CIREN medical records are coded by AIS directly, resulting in more accurate coding.

The CIREN and OCME are relatively consistent in the frequency of the various injury categories (i.e., the descriptions listed in Figs. 1 and 2). The largest discrepancy is with the greater incidence of brain injuries (non-DAI) in the OCME data. This may be related to the CIREN enrollment criteria, which may under-sample crash scenarios where brain injuries may be particularly prominent, such as crashes involving unbelted occupants and crashes involving vehicles without frontal airbags. This merits further investigation. (The other big difference is with DAI/Level of Consciousness injuries, which will be discussed later.)

Notwithstanding the differences discussed above, the content of predominant injuries (i.e., those occurring in over 50% of deaths) is still fairly similar: thoracic organ injuries, rib injuries, brain injuries (non-DAI), and abdominal injuries.

Maryland vs. U.S Population. Given that trauma care and crash response time in Maryland is very good, the injuries sustained by victims of fatal crashes may vary in other parts of the U.S. The OCME's records constitute a census of all motor vehicle fatalities in Maryland (about 450 per year). However, not all records were retained for this analysis.

Table 3. Characteristics of Fatally Injured Drivers, 2000-2002.

	FARS Entire U.S. (N=66,160) %	FARS Md Only (N=998) %
Male	71	71
Mean Age	42	43
Taken to hospital	41	56
Seat Belt Used	36	53
Rollover Crash	31	18
Ejection	27	19

Table 3 compares the FARS dataset between fatalities occurring in Maryland and those occurring in the United States at large for the years 2000-2002. Maryland fatalities are shown to be aligned with the U.S. population in terms of occupant age, sex, and time-to-death. Although Maryland had a higher percentage of fatally injured drivers taken to the hospital, this may not necessarily reflect more treatable (and less severe) injuries among Maryland deaths. Maryland has been shown to have a very well coordinated trauma system that gets patients to the hospitals efficiently. In fact, the FARS dataset indicates that some drivers who died within 30 minutes – classified as "early-on" deaths herein – were actually brought to the hospital.

In addition, Maryland has one of the highest driver belt use rates in the country (Glassbrenner, 2004). Table 3 also shows that rollover crashes occur less

often in Maryland. These two factors contribute to fewer occupant ejections, and ejections generally produce more severe injuries than other crash modes. This merits further study since the degree to which injuries differ among deaths of those who are belted vs. unbelted and ejected vs. non-ejected was not investigated herein.

Implications for determining mortality rankings. The methodology described in the Introduction to rank injuries provides a relative comparison of the threat-to-life posed by various injuries. As stated earlier, the accuracy of the rankings (and hence, the fatality attribution process) is contingent upon complete and accurate injury records in fatal cases. The effects of biased and incomplete injury records directly affect the rankings.

Prior to this study, the authors were concerned that many CIREN crash victims who die at the scene might have incomplete injury records. The concern was that medical records might be lacking for those who never made it to a hospital, and only a few, easy-to-observe, low-threat injuries would be reported. It would have meant that rankings of injuries undetected in early-on deaths would be too low because the injuries would have been detected (and reported) in a disproportionate share of nonfatal cases. However, the results reported herein have tempered this concern.

The findings of this study do highlight another concern regarding the category of brain injuries that are coded by level of consciousness or as diffuse axonal injuries (DAI, LOC of AIS 3+ in Figs. 1 and 2). According to the AIS coding manual, a level of consciousness code is only applied in the absence of an anatomical description of a brain injury, or when the LOC severity level is greater than the anatomical severity level. And it is never applied to fatalities that occur within 24 hours. Diffuse axonal injuries, observable only from radiographs, are rarely reported in early-on deaths. This coding convention is clearly evident in Figs. 1 and 2.

Similarly, any other injury categories or severity levels that are difficult to observe positively in an autopsy (such as codes which can only be applied if a certain amount of blood loss is observed) may not be coded as heavily in early-on deaths. The end effect on the mortality ranking process is for such injury categories to be ranked relatively low.

Implications for General Studies Biased or miscoded fatal data affects any benefits analysis, such as that described in the Introduction, where a fatally injured occupant is characterized by a single injury. Thus all benefits are directed to the prevention of that injury. Though fatalities are relatively low in number compared to survivors, they have high associated costs. Thus, the underlying data should be correct.

Other limitations. While not examined at this time, the overall fraction of fatal cases within CIREN has been shown to be representative of the U.S. population for crashes that meet the CIREN enrollment criteria for crash type, vehicle model, and injury severity. The use of the methodology is limited to this criteria. However, these cases are generally the ones NHTSA priorities are focused upon.

Future effort: Imputation. As mentioned earlier, certain injury categories may have deflated threat-to-life rankings due in part to the AIS coding convention and the ability to observe certain injuries at autopsy. Given the logistics involved with the disposition of early-on fatalities, there may be no practical way to observe such injuries. A solution may be to impute codes in early-on deaths.

Methods to impute missing data within NHTSA's databases have been developed for certain variables. For example, Rubin et al (1998) describes a method to impute blood alcohol levels that are missing from fatality crash data. It may be possible to develop a method to impute injuries in early-on fatality records using the other variables within the dataset.

CONCLUSIONS

The purpose of this study is to investigate the extent of any selection bias in CIREN for fatal cases. The primary goal is to help refine methods to estimate mortality associated with particular injuries and combinations of injuries. In pursuit of that goal, the following observations were made.

1. The CIREN dataset appears to be representative of crash fatalities in terms of the fraction of early-on deaths. However, CIREN also appears to have a higher fraction of cases where occupants died after twenty-four hours than in the U.S. population.

2. Occupants who die early-on appear to have different injuries than those who die later. Those who died at the scene tend to have more unsurvivable injuries. It follows that they have more severe injuries in terms of MAIS and their probability of fatality. Early-on deaths also tend to have a higher frequency of brain injuries, skull fractures, thorax organ injuries, and cervical spine injuries.

3. The CIREN dataset also appears to be representative of crash fatalities in terms of the frequency of injuries in early-on vs. later deaths, but this could not be confirmed by comparison with the OCME dataset. This issue should be investigated in the future. Also, brain injuries appear to be under-represented within CIREN deaths.

4. When considering a reduced dataset in which all cases with unsurvivable injuries have been removed, a dataset derived from CIREN is similar to that of the OCME in terms of the frequency of the most predominant categories of injuries and the fraction of early-on deaths. However, CIREN cases tend to be more serious.

5. Implications for injury costs/benefits analyses suggest that benefits could be misplaced if injury records of fatalities are not complete.

ACKNOWLEDGEMENT

The OCME autopsy reports, which are confidential, were obtained by the National Study Center for Trauma & EMS, University of Maryland School of Medicine under agreement with the CODES project. The project has been approved by the University IRB, and meets all requirements for HIPAA. This work was funded by NHTSA under Cooperative Agreement number DTNH22-05-H-01001.

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