



# The Association Between Crash Proximity to Level 1 and 2 Trauma Centers and Crash Scene Mortality of Drivers Injured in Fatal Crashes

## Summary

This report models the association between the proximity of a fatal crash to a Level 1 or 2 trauma center and the crash scene mortality of the driver in the fatal crash. It does so by comparing drivers who died at the scene of the crash with other injured drivers who survived the crash and were taken to a hospital. Results show that the further that a fatal crash occurs from a Level 1 or 2 trauma center, the more likely it is that the driver will be listed as “died at scene.” The study shows that a driver within the 45- to 60-minute response time coverage area was 1.13 times as likely to be coded as “died at scene” (DAS) compared to a driver within the a 45-minute-or-less (notated as <45) coverage area. Similarly, a driver in the 60-minute-or-longer (notated as 60+) response time coverage area was 1.23 times as likely to be coded as DAS, compared to a driver in the <45 coverage area. Response time coverage area was determined based on American Trauma Society (ATS) data. ATS defined Level 1 and 2 trauma center coverage areas based on the average time from receipt of a 9-1-1 call to patient arrival at a trauma center.

These results do not state a causal relationship, as this report does not take into account other factors that could affect health outcome, such as the treatment that the crash victims might have received from bystanders or emergency medical services (EMS) personnel. Still, this research displays an association between the location of Level 1 and 2 trauma centers and the health outcome of passenger vehicle drivers in fatal crashes.

## Introduction

This report examined passenger vehicle drivers who were in fatal crashes in 2009 and compared the crash

details of two mutually exclusive groups. One group, referred to in this report as “died at scene,” consisted of drivers who were coded as having died at the scene of the crash and were therefore not taken to a hospital. The other group consisted of drivers who were taken to the hospital from the crash scene by EMS and eventually survived the crash. This group will be referred to as “non-fatally injured, taken to hospital” (NFITH). Drivers in fatal crashes who are neither DAS nor NFITH are not included in this report (see Methodology for details).

The goal of this report was to assess whether the expected travel time to the nearest Level 1 or 2 trauma center was associated with whether the driver was DAS or NFITH, after adjusting for other crash factors. The ATS estimated the magnitude of this expected travel time to map a trauma center coverage area, or buffer zone. This buffer zone variable was categorized by ATS into three levels: <45 minutes, 45 to 60 minutes, and 60+ minutes. This report used the response time categories based on both air and ground ambulance response times, as displayed on the Web site listed in the Reference section.

As shown in the Background section, the task of quantifying the benefits of trauma center coverage has been a leading public health issue for many years. This study is intended to add knowledge to the role that trauma center proximity plays in the crash scene mortality outcome of drivers in passenger vehicle crashes.

## Background

Hospitals can receive trauma center verification by meeting criteria established by the American College of Surgeons. Level 1 is the highest rating, followed by Level 2 and lower levels.

In 2000, Nathens et al. published an article in the *Journal of the American Medical Association* titled “The Effect of Organized Systems of Trauma Care on Motor Vehicle Crash Mortality.” This research used the Fatality Analysis Reporting System (FARS) crash data from 1979 through 1995 and showed that by 15 years following trauma system implementation, motor vehicle crash mortality was reduced by 8 percent (95% confidence interval, 3 to 12%). This model adjusted for many trends in crash types, occupant age, traffic safety laws, and more.

In 2006, MacKenzie et al. published a report in the *New England Journal of Medicine* titled “A National Evaluation of the Effect of Trauma-Center Care on Mortality.” This report collected data on more than 5,000 patients from 14 States who were treated in 18 hospitals with Level 1 trauma centers and in 51 hospitals without trauma centers. After adjusting for many factors, MacKenzie et al. found that after one year, severely injured patients who were treated at Level 1 trauma centers had a 25-percent reduced risk of dying when compared to similar patients treated at non-trauma centers.

In 2009, the ATS modeled air and ground ambulance response time throughout the United States and estimated that 83 percent of the population lived within a 60-minute response time to a Level 1 or 2 trauma center, and this coverage area represented 29 percent of the land area in the United States. Similarly, this ATS mapping model estimated that a 45-minute response time covered 70 percent of the population and 12 percent of the land area. This map of coverage areas was used to help specify what areas of the United States are within certain response times from a Level 1 or 2 trauma center. This ATS mapping model was used to determine that among fatal crashes in 2009 with a known latitude and longitude, 50 percent were within the 45-minute response time, and 70 percent were within the 60-minute response time.

As expected, ATS population coverage and land coverage estimates vary greatly across the United States. Examples of coverage estimates from the ATS model are District of Columbia (100% population, 100% land), New York (97% population, 71% land), Nevada (94% population, 9% land), Hawaii (70% population, 9% land), Alaska (55% population, 1% land), and South Dakota (35% population, 6% land).

## Methodology

Fatal crash data from FARS for 2009 was used for this report. FARS contains data on a census of fatal traffic crashes from the 50 States, the District of Columbia, and Puerto Rico. To be included in FARS, a crash must involve a motor vehicle travelling on a trafficway customarily open to the public and result in the death of a person (occupant of a vehicle or a non-occupant) within 30 days of the crash.

As shown below in Table 1, this study included two groups of passenger vehicle drivers in fatal crashes, and did not include two other groups of drivers. One group the study included was passenger vehicle drivers who died at the scene of the crashes, and thus were not taken to the hospital. This group was coded as DAS = 1 (where DAS was the dependent variable in the logistic regression) and consisted of 9,424 drivers. The second group (NFITH) was passenger vehicle drivers who were non-fatally injured and taken to hospitals. This group was coded as DAS = 0 in the logistic regression, and consisted of 13,620 drivers. The 8,781 drivers who survived and were not taken to the hospital included 1,152 injured drivers, and 7,629 drivers who were not injured. See Table 1.

Table 1  
**Passenger Vehicle Drivers Included and Not Included In Analysis**

	Included	Not Included
Died at Scene of the Crash, Not taken to Hospital (DAS)	9,424	
Taken to Hospital, Died Within 30 Days of the Crash		5,710
Non-Fatally Injured, Taken to Hospital (NFITH)	13,620	
Survived, Not Taken to Hospital		8,781
Died En Route to Hospital		322
<b>Total</b>	<b>23,044</b>	<b>14,813</b>

This study did not examine the 5,710 drivers who were taken to the hospital and died within 30 days of the crash. These drivers were removed in order to improve the clarity of the stratification of the dependent variable, as the DAS and NFITH groups are more distinct. The study also removed the 8,781 surviving drivers who were not taken to the hospital, as the high majority of these drivers were not injured at all. Passengers in the vehicles were not examined due to the fact that blood alcohol concentration (BAC) was a variable in the study and the BAC levels of passengers are not typically recorded in FARS crashes.

There were 322 drivers in whose place of death was coded as en route to the hospital, and these drivers were excluded from the analysis. The seat position variable was not included in the model since only drivers were examined.

Multivariate logistic regression was performed using SAS, with a stepwise selection, and an alpha of .05. The SAS MIAnalyze procedure was used to combine the imputed BAC levels from the FARS database. Exploratory data analysis included many FARS variables that were eventually excluded from the final model. Interaction terms were excluded from the model due to the minimal impact these interactions had on the coefficients in the final model.

The two categories for the dependent variable in the model are shown above in Table 1, where drivers were coded as either DAS (DAS = 1) or NFITH (DAS = 0). Independent variables (and their categories) that remained in the final model include: number of vehicles in the crash (single vehicle, multi-vehicle), number of occupants in the vehicle (single occupant, multiple occupants), ejection status (yes/no), BAC (.00, .01 to .07, .08+), restraint use (yes/no), roadway function class (rural/urban), speed limit of the crash location (55 mph or greater, less than 55 mph), vehicle body type (passenger car, sport utility vehicle, van, pickup), day/night (6 a.m. to 5:59 p.m., 6 p.m. to 5:59 a.m.), occupant age (under 20, 20-29, 30-39, 40-49, 50-59, 60-69, 70+), and expected travel time to the nearest Level 1 or 2 trauma center (less than 45 minutes, 45 to 60 minutes, greater than 60 minutes), which is also referred to as buffer zone in this report. Unless otherwise stated, a category of unknown was included for each independent variable, and these cases were included in the analysis.

A fatality occurring in a crash involving a driver with a BAC of .08 g/dL or higher is considered to be an “alcohol-impaired-driving” fatality.

### *Buffer Zones Around Level 1 or 2 Trauma Centers*

The latitude and longitude data available from FARS fatal crashes, along with map of trauma center coverage areas modeled by ATS, were used to estimate the expected travel time to the nearest Level 1 or 2 trauma center. The buffer zones around the trauma centers were created by ATS for three response time categories: less than 45 minutes, 45 to 60 minutes, or over 60 minutes. ArcGIS software was used to map the crashes in this study and stratify their latitude/longitude locations

into one of the three buffer zone categories included in the ATS model.

## **Results**

The 23,044 drivers examined in this study consisted of two groups: 41 percent (9,424) were DAS, meaning died at the scene of the crash and not taken to the hospital; and 59 percent (13,620) were NFITH, meaning they survived the crash and were non-fatally injured and were taken to the hospital from the crash scene by emergency medical services.

These were the two categories of the dependent variable of the model in this report. See Methodology for details on drivers included in this analysis.

Several crash factors were significantly associated with whether the driver was DAS or NFITH: the number of occupants in the crash, the number of vehicles in the crash, ejection status, restraint use, vehicle type, driver BAC, urban/rural crash location, time of the crash, and speed limit.

Table 2 shows the odds ratio estimate and 95 percent Wald confidence interval for each independent variable from the logistic regression model used in this report. The model shows the impact of each variable on the odds that a passenger vehicle driver was coded as DAS (versus NFITH). Each variable in Table 2 was significant at the alpha = .05 level.

An odds ratio (OR) of 1.31 is displayed in Table 2 for the speed limit parameter (reference category: less than 55 mph). Therefore, in fatal crashes, the odds that the driver was DAS (versus NFITH) was 1.31 times as likely when the speed limit was 55 mph or greater compared to under 55 mph (Table 2), after adjusting for the other variables in the multivariate logistic regression model. This is reasonable since vehicles often travel faster in areas with a higher speed limit, and the thus risk of a fatal injury increases with crashes that occur at higher speeds.

The ejection parameter (reference category: not ejected) had an OR of 1.66. The odds that the driver was DAS was 1.66 times as likely when he or she was ejected from the vehicle, compared to when s/he was not ejected, after adjusting for the other variables in the model.

By comparison, the restraint use parameter (reference category: unrestrained) had an OR of 0.64. Therefore, the odds that the driver was DAS was 0.64 times as likely when the driver was restrained, compared to

when s/he was unrestrained, after adjusting for the other variables in the model. This is a reasonable result since seat belts have been shown to be effective in saving lives in motor vehicle crashes.

The BAC parameter in the model had a reference category of no alcohol (BAC = .00). The OR for a BAC of .08+ (compared to BAC = .00) was 1.64. Therefore, the odds that the driver was DAS was 64 percent higher when the driver had a BAC of .08+ compared to when the driver had a BAC of .00, after adjusting for the other variables in the model. The OR for BAC of .01 to .07 (compared to BAC = .00) was 1.12, showing that a BAC level of .01 to .07 had much less of an effect than a BAC level of .08+.

Refer to Table 2 below for the OR estimates for each parameter in the multivariate logistic regression model, as well as the corresponding 95-percent Wald confidence intervals (95% CI) for these OR estimates.

Table 2  
**Odds Ratio Estimates From Multivariate Logistic Regression Model**

Effect	Odds Ratio Estimate	95% Wald Confidence Limits	
In 45- to 60-Minute Coverage Area (ref: Inside 45-Minute Coverage Area)	1.130	1.044	1.224
Outside 60-Minute Coverage Area (ref: Inside 45-Minute Coverage Area)	1.225	1.139	1.318
Pickup (ref: Passenger Car)	0.717	0.665	0.772
SUV (ref: Passenger Car)	0.672	0.620	0.729
Van (ref: Passenger Car)	0.652	0.572	0.744
BAC = .01 to .07 g/dL (ref: BAC = .00)	1.120	0.931	1.347
BAC = .08+ (ref: BAC = .00)	1.635	1.506	1.776
Rural (ref: Urban)	1.339	1.249	1.436
Night (ref: Day)	1.206	1.128	1.290
Age 0-19 (ref: Age 20-29)	0.862	0.775	0.959
Age 30-39 (ref: Age 20-29)	1.102	1.005	1.210
Age 40-49 (ref: Age 20-29)	1.221	1.112	1.341
Age 50-59 (ref: Age 20-29)	1.218	1.101	1.347
Age 60-69 (ref: Age 20-29)	1.156	1.031	1.297
Age 70+ (ref: Age 20-29)	0.896	0.801	1.001
Speed Limit 55 mph or Greater (ref: Speed Limit Under 55 mph)	1.313	1.232	1.399
Multivehicle Crash (ref: Single-Vehicle Crash)	0.555	0.518	0.595
Restrained (ref: Unrestrained)	0.635	0.594	0.679
Ejected (ref: Not Ejected)	1.659	1.514	1.817
Rollover (ref: No Rollover)	1.153	1.067	1.246
Multiple Occupants (ref: One occupant)	0.451	0.424	0.480

### Buffer Zones Around Level 1 or 2 Trauma Centers

The model shows 1.13 and 1.23 are the OR parameter estimates for a crash occurring in the 45-60 minute coverage area and 60+ minute coverage area respectively, compared to the baseline coverage area of less than 45 minutes response time to a Level 1 or 2 trauma center. Therefore, the study shows that a driver in the 45- to 60-minute response time coverage area was 1.13 times as likely to be coded as DAS (versus NFITH), compared to a driver in the <45 minute coverage area (after adjusting for the other variables in the multivariate logistic regression model). Similarly, a driver in the 60+ minute response time coverage area was 1.23 times as likely to be coded as DAS, compared to a driver in the <45 minute coverage area (after adjusting for the other variables in the model).

For a driver in a crash that met the reference categories of every variable in the model with the exception of the buffer zone variable (specifically: passenger car driver, BAC of .00 g/dL, urban crash, daytime crash, age 20 to 29, speed limit under 55 mph, single-vehicle crash, unrestrained, not ejected, no rollover, one occupant in the vehicle), this model estimates that the probability that this driver was DAS when the crash occurred in the 45-minute buffer zone is 54.5 percent, compared to 57.5 percent in the 45- to 60-minute buffer zone, and 62.4 percent in the 60+ minute buffer zone. These percentage estimates produced by the model are based on the population of DAS or NFITH drivers in this report, and only apply to the specific crash scenario described in this paragraph.

The results in Table 2 show that the following parameters have an *OR below 1.0*. Therefore, drivers in the scenarios below are *LESS LIKELY to be DAS* (versus NFITH):

- Being in a pickup (compared to a passenger car);
- Being in a sport utility vehicle (compared to a passenger car);
- Being in a van (compared to a passenger car);
- Being age 0-19 (compared to age 20-29);
- Being age 70 or older (compared to age 20-29);
- Being restrained (compared to unrestrained);
- Being in a multi-vehicle crash (compared to a single vehicle crash).

- ◆ This is greatly due to the fact that FARS is a database of fatal crashes, and thus the fewer vehicles that are in a crash, the more likely the driver is to have been fatally injured in the crash.
- Being in a vehicle with multiple occupants (compared to being the only occupant).
- ◆ This is greatly due to the fact that FARS is database of fatal crashes, and thus the fewer occupants that are in a crash, the more likely the driver is to have been fatally injured in the crash.

The results in Table 2 show that the following parameters have an *OR above 1.0*. Therefore, drivers in the scenarios below are *MORE LIKELY to be DAS* (versus NFITH):

- Having a BAC of .01 to .07 (compared to a BAC of .00);
- Having a BAC of .08 or higher (compared to a BAC of .00);
- Being in a rural crash (compared to an urban crash);
- Being in a nighttime crash (compared to a daytime crash);
- Being of age 30-39, 40-49, 50-59, or 60-69 (compared to age 20-29);
- Driving where the speed limit is 55 mph or higher (compared to under 55 mph);
- Being ejected from the vehicle (compared to not being ejected);
- Being in a rollover (compared to no rollover);
- Being in a “45- to 60-Minute Coverage Area” (compared to being in an “Inside 45-Minute Coverage Area”); and
- Being in an “Outside 60-Minute Coverage Area” (compared to being in an “Inside 45-Minute Coverage Area”).

## Limitations

Factors beyond those considered in this report could have led to the mortality of the drivers who were DAS. Many details on the factors contributing to the driver’s fatality are not coded in the FARS database. Certain injury types lead to fatality within seconds or minutes of the crash, and in those cases even a near instantane-

ous EMS response would not prevent a fatality from occurring.

For crashes occurring within proximity to a Level 1 or 2 trauma center, issues such as pre-existing activity of air or ground helicopters or ambulances in response to recent crashes, roadway congestion, as well as heterogeneity of EMS expertise, are not accounted for in this analysis.

Level 1 and Level 2 trauma centers were not analyzed separately since the mapping model used in this report, as produced by the ATS, grouped these two levels of trauma centers together. In future studies, it would be beneficial to compare the benefits of crash proximity to Level 1 trauma centers with the benefits of crash proximity to Level 2 trauma centers.

The ATS response time maps are based on average total EMS response times, defined as time from receipt of a 9-1-1 call to patient arrival at a trauma center, which can vary from location to location. These times are ecological data, and not actual response times for each fatal crash. These maps are used as a surrogate for total EMS response time for the crashes in FARS.

Among drivers taken to hospitals after the crashes, specific information about which hospital each driver was taken to is not available in the FARS database. Therefore, hospital details for each crash are not available.

There is a difference between where a driver dies and where the driver is declared dead. The practice of who has the authority to declare a death and where this declaration occurs varies between localities. Variations in EMS system Do Not Resuscitate (DNR) protocols are an important component of the issues discussed in this report.

## Conclusion

This report analyzed passenger vehicle drivers involved in fatal crashes in 2009 who were coded as DAS or NFITH. Results showed many crash factors that contribute to the likelihood that a driver was DAS versus NFITH.

The model in this report shows that, after adjusting for other crash factors, the probability that a driver was DAS increased as the time to the nearest Level 1 or 2 trauma center increased. The odds that a driver was DAS was 1.13 times as likely in the 45- to 60-minute response time coverage area compared to the less-than-

45-minute response time coverage area. Similarly, the odds that a driver was DAS was 1.23 times as likely as in the 60+ minute buffer zone compared to the less-than-45-minute buffer zone.

Factors such as the crash occurring in the daytime versus nighttime and having the driver restrained contributed significantly to reducing the likelihood that the passenger vehicle driver was DAS. By comparison, factors such as the driver having a positive BAC, traveling in a passenger car (versus SUV, pickup, or van), having the crash occur where the speed limit was 55 mph or higher, and the driver being ejected from the vehicle, contributed significantly to increasing the likelihood that the driver was DAS.

The statistical association found in this analysis between the location of Level 1 or 2 trauma centers and the health outcome of drivers who died at the scene and drivers who were not fatally injured and taken to a hospital highlights the need for further study of several factors. Areas of study may include the real-world environmental and emergency care factors that affect the circle of mortality in outlying areas of trauma centers. The study reinforces the need to provide effective medical response and care in outlying areas.

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