# Demographics and Incident Location of Traumatic Injuries at a Single Level I Trauma Center

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## ABSTRACT

**Introduction.** Traumatic injuries are preventable and understanding determinants of injury, such as socio-economic and environmental factors, is vital. This study evaluated traumatic injuries and identified areas of high trauma incidence.

**Methods.** A retrospective review was conducted of all patients 14 years or older who were admitted with a traumatic injury to a Level I trauma center between 2016 and 2017. Descriptive analyses were presented and maps of high injury areas were generated.

**Results.** The most frequent mechanisms of injury were falls (58.3%), motor vehicle crashes (22.3%), and motorcycle crashes (5.7%). Fall patients were more likely to be female (59.6%) and were the oldest age group (72.1 ± 17.2) compared to motor vehicle and motorcycle crash patients. Severe head (22.1%, p = 0.007) and extremity (35.7%, p = 0.001) injuries were most frequent among fall patients, however, more motorcycle crash patients required mechanical ventilation (16.1%, p < 0.001) and experienced the longest intensive care unit length of stay (5.3 ± 6.8 days, p < 0.001) and mechanical ventilation days (6.6 ± 8.5, p < 0.036). Motorcycle crash patients also had the greatest number of deaths (7.5%, p < 0.001). The generated maps of all traumas suggested that most injuries occur near our hospital and are located in several of the most population-dense zip codes.

**Conclusion.** Patient demographics, injury severity, and hospital outcomes varied by mechanisms of injury. Traumatic injuries occurred near our hospital and were located in several of the most population-dense zip codes. Injury prevention efforts should target high incident areas. ***Kans J Med 2021;14:5-11***

## INTRODUCTION

Traumatic injuries play a significant role in healthcare. In 2015, 27.6 million people in the U.S. were treated in emergency departments for injuries, and 2.8 million were hospitalized.[1] Unintentional injuries are the fourth leading cause of death in the U.S., with fall and motor vehicle crash injuries accounting for the most significant number of deaths.[1,2] Numerous studies have demonstrated that the incidence of traumatic injuries is influenced by a combination of demographic, socioeconomic, and environmental factors.[3-16] Understanding how these factors are associated with the incidents of traumatic injuries is essential for trauma prevention efforts.[6,8]

In 2011, the American Association for the Surgery of Trauma Prevention Committee released a publication addressing three resources for injury prevention and research.[5] These resources included the National Trauma Data Bank (NTDB), geographic information systems (GIS), and teaching injury prevention. The NTDB provides an aggregate of U.S. trauma information which can be used to identify the incidence and frequency of mortality and provide injury characteristics on a national level.[2]

Geographic information systems take trauma information one step further by adding geospatial maps of traumatic injuries.[3] With the use of GIS specific neighborhood characteristics and socio-economic factors that might increase or decrease an individual's risk of sustaining a traumatic injury can be explored further.[3] Several previous studies highlighted the effectiveness of GIS analysis in trauma research and demonstrated that there are spatial patterns of injuries.[3-6] As an example, Newgard and associates noted that injury location is not random and that major traumas tend to cluster in census tracts with distinct population characteristics, such as higher rates of unemployment and lower education levels.[4] Another study using GIS to describe motor vehicle crashes (MVC), indicated that environmental factors, such as inadequate traffic engineering and lighting, can lead to increased MVCs.[12]

The purpose of this study was to describe the demographics of our trauma population, identify the frequency of types of injuries, and establish where these injuries occur.

## METHODS

Kansas is a predominantly rural state and is served by three American College of Surgeons Committee on Trauma (ACS COT)-verified Level 1 trauma centers. Two of these centers, Wesley Medical Center and Ascension Via Christi St. Francis, located in Sedgwick County, are within 2.3 miles of one another. The dividing line for patient trauma destination is determined by Interstate 135 (I-135), which runs north-south through the city (Figure 1). Those injured East of I-135 go to Wesley Medical Center and those injured West of I-135 go to Ascension Via Christi St. Francis. Among traumas that occur outside of the county line, patient trauma destination is either determined by the responding Emergency Medical Unit or the transferring facility.

A retrospective chart review was conducted of all patients aged 14 years or older who presented with a traumatic injury to Ascension Via Christi St. Francis from January 1, 2016 and December 31, 2017. Patients were excluded if the incident occurred outside of Kansas, there was no documentation of mechanism of injury or incident location, the injury involved a firearm, or the injury was intentionally self-inflicted.
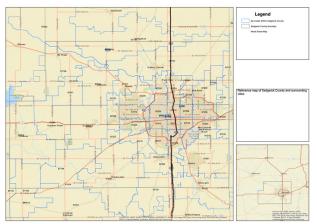
Figure 1. Sedgwick County reference map indicating I-135 dividing line for trauma patient destination.

Data were retrieved from the trauma registry and patient medical records. Abstracted patient data included demographics (age, gender, race/ethnicity, type of insurance), mechanism of injury and injury details, injury location (street address and zip code), injury severity (Injury Severity Score [ISS], Glasgow Coma Scale [GCS], Abbreviated Injury Score [AIS], use of personal protection or restrains), blood alcohol level (BAC), drug test results, hospital parameters (surgical procedures, intensive care unit [ICU] admission and length of stay, mechanical ventilation use and duration of use, hospital length of stay), hospital disposition destination, and mortality.

Descriptive analyses were presented as frequencies with percentages for categorical variables and means with standard deviations for continuous variables. Before comparative analysis was performed, patients were grouped by the top three mechanisms of injury which included falls, motor vehicle crash (MVC), and motorcycle crash (MCC). Pearson's chi-square, likelihood ratio chi-square, and Fisher`s exact tests were used to test the significant association between two nominal or categorical variables in contingency tables. Shapiro-Wilk variables also were used.

For non-normal distributions with appropriate transformation operations, the rank transform approach to nonparametric methods was used as a combination of PROC RANK and PROC GLM. Least-squares means (to estimate the marginal means over a balanced population) were used for pairwise comparisons of groups by Tukey test using Kramer adjustment.

Kernel Density Estimation (KDE) was used to create maps of injury location. KDE is a nonparametric technique for estimating the probability density function of a random variable. Using ArcGIS Desktop version 10.4.1 (ESRI, Redlands, CA), KDE was used to estimate risk zones by calculating the density of trauma injury locations around individual output raster cells as a function of the frequency and proximity of known trauma injury locations.[17] The final output is displayed as a smoothly tapered raster image. The value of the smoothly tapered surface is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point. The following equation was used to determine the search radius: $SearchRadius = 0.9 \times min(SD, \sqrt{(1/ln^2)} \times D_m) \times n^{-0.2}$.

All statistical tests were two-sided, and analyses were considered significant when the resultant was at $p \leq 0.05$. Descriptive statistics for nominal, categorical, and continuous variables were conducted by using PROC FREQ and PROC UNIVARIATE in SAS version 9.4 (SAS Int. Inc., Carry, NC). This study was approved by the Institutional Review Board at Via Christi Hospitals Wichita, Inc. and the Human Subjects Committee at the University of Kansas School of Medicine-Wichita.

## RESULTS

Of 4,176 patients admitted for a traumatic injury during the study period, a total of 1,112 were excluded. Exclusions were due to missing incident location (20.7%, n = 864), involvement of a firearm (3.2%, n = 134), intentional self-inflicted injury (2.0%, n = 82), incident location outside of Kansas (0.7%, n = 30), or unknown mechanism of injury (0.1%, n = 2). The final sample consisted of 3,064 patients, most of whom were male (52.6%, n = 1,612) and Caucasian (86.0%, n = 2,634) with an average age of 60.3 ± 22.7 years. The three most frequent mechanisms of injury were falls (58.3%, n = 1,786), motor vehicle crashes (MVC; 22.3%, n = 684), and motorcycle crashes (MCC; 5.7%, n = 174; Table 1).

Significant differences were noted between the three-main mechanisms of injury regarding gender, age, race, and insurance status (Table 1). Patients who sustained a fall were more likely to be female (59.6%, n = 1,064), while males accounted for most MVC (62.1%, n = 425), and MCC (87.4%, n = 152, p < 0.001) patients. Fall patients accounted for the oldest group (72.1 ± 17.2) and most MVC (45.6%, n = 312) and MCC (52.3%, n = 91, p < 0.001) patients were between the ages of 19-44 years. Compared to the other mechanisms of injury, fall patients had the highest number of patients with Medicare/ Medicaid (78.6%, n = 1,403, p < 0.001).

Comparisons of injury severity and hospital outcomes based on mechanism of injury are presented in Table 2. Severe head (22.1%, n = 394, p = 0.007) and extremity (35.7%, n = 638, p = 0.001) injuries were most frequent among fall patients, however, more motorcycle crash patients had an ISS > 15 (24.1%, n = 42, p < 0.001). Motorcycle crash patients also were more likely to require mechanical ventilation (16.1%, n = 28, p < 0.001) and experienced the longest ICU length of stay (5.3 ± 6.8 days, p < 0.001) and mechanical ventilation days (6.6 ± 8.5, p < 0.036) as compared to fall and MVC patients. Fall injury patients were most likely to be discharged to a nursing home (46.4%, n = 828, p < 0.001) and motorcycle crash patients experienced the highest rate of mortality (7.5%, n = 13, p < 0.001).

Injury details are broken down further for the three-main mechanisms of injury (Table 3). Patients who fell were most likely to do so while standing, sitting, or lying (76.3%, n = 1,362). Those admitted due to MVC were most likely the driver (68.3%, n = 467), and were restrained during the crash (59.1%, n = 385). Among MCC patients, 67.8% (n = 118) did not use protective equipment. Fourteen percent of MVC (n = 100) and 19.5% of MCC (n = 34) patients had BAC above the legal limit (≥ 0.08).

**Table 1. Demographics for patients with a traumatic injury by mechanism of injury.**

| Parameter* | Total | Fall | Motor Vehicle Crash | Motorcycle Crash | p value |
|---|---|---|---|---|---|
| Number of Patients | 3,064 (100%) | 1,786 (58.3%) | 684 (22.3%) | 174 (5.7%) | |
| Gender | | | | | < 0.001 |
| Male | 1,612 (52.6%) | 722 (40.4%) | 425 (62.1%) | 152 (87.4%) | |
| Female | 1,452 (47.4%) | 1,064 (59.6%) | 259 (37.9%) | 22 (12.6%) | |
| Age (years) | 60.3 ± 22.7 | 72.1 ± 17.2 | 44.3 ± 20.2 | 41.3 ± 14.6 | < 0.001 |
| Age groups | | | | | < 0.001 |
| 14-18 | 103 (3.4%) | 16 (0.9%) | 59 (8.6%) | 6 (3.4%) | |
| 19-44 | 735 (24.0%) | 137 (7.7%) | 312 (45.6%) | 91 (52.3%) | |
| 45-54 | 330 (10.8%) | 121 (6.8%) | 81 (11.8%) | 45 (25.9%) | |
| 55-64 | 406 (13.3%) | 214 (12.0%) | 109 (15.9%) | 23 (13.2%) | |
| 65-74 | 413 (13.5%) | 308 (17.2%) | 67 (9.8%) | 7 (4.0%) | |
| ≥ 75 | 1077 (35.2%) | 990 (55.4%) | 56 (8.2%) | 2 (1.1%) | |
| Race/ethnicity | | | | | < 0.001 |
| Caucasian | 2,634 (86.0%) | 1,632 (91.4%) | 524 (76.6%) | 148 (85.1%) | |
| African American | 174 (5.7%) | 57 (3.2%) | 66 (9.6%) | 13 (7.5%) | |
| Hispanic/ Latino | 189 (6.2%) | 68 (3.8%) | 70 (10.2%) | 8 (4.6%) | |
| Asian American | 36 (1.1%) | 14 (0.8%) | 18 (2.6%) | 1 (0.6%) | |
| Other | 31 (1.0%) | 15 (0.8%) | 6 (0.9%) | 4 (2.3%) | |
| Insurance | | | | | < 0.001 |
| Private | 1,328 (43.3%) | 330 (18.5%) | 575 (84.1%) | 154 (88.5%) | |
| Medicare/Medicaid | 1,634 (53.3%) | 1,403 (78.6%) | 95 (13.9%) | 15 (8.6%) | |
| Other | 102 (3.3%) | 53 (2.9%) | 14 (2.1%) | 5 (2.9) | |

*Values presented as n (%) or mean ± standard deviation.

**Table 2. Injury severity and hospital outcomes for patients with a traumatic injury by mechanism of injury.**

| Parameter* | Fall | Motor Vehicle Crash | Motorcycle Crash | p value |
|---|---|---|---|---|
| Number of Patients | 1,786 (58.3%) | 684 (22.3%) | 174 (5.7%) | |
| Injury severity score > 15 | 183 (10.2%) | 130 (19.0%) | 42 (24.1%) | < 0.001 |
| Head AIS ≥ 3 | 394 (22.1%) | 91 (13.3%) | 28 (16.1%) | 0.007 |
| Chest AIS ≥ 3 | 96 (5.4%) | 102 (14.9%) | 34 (19.5%) | 0.054 |
| Abdominal AIS ≥ 3 | 32 (1.8%) | 34 (5.0%) | 9 (5.2%) | 0.454 |
| Extremity AIS ≥ 3 | 638 (35.7%) | 57 (8.3%) | 30 (17.2%) | 0.001 |
| ICU admission | 744 (41.7%) | 250 (36.5%) | 69 (39.7%) | 0.068 |
| ICU days | 3.5 ± 3.7 | 5.0 ± 6.6 | 5.3 ± 6.8 | < 0.001 |
| Mechanical ventilation | 100 (5.6%) | 85 (12.4%) | 28 (16.1%) | < 0.001 |
| Ventilator days | 3.8 ± 4.4 | 5.8 ± 7.8 | 6.6 ± 8.5 | 0.036 |
| Surgery | 788 (44.2%) | 166 (24.3%) | 63 (36.2%) | < 0.001 |
| Hospital length of stay | 4.4 ± 4.7 | 4.0 ± 6.3 | 4.8 ± 9.4 | 0.092 |
| Disposition | | | | < 0.001 |
| Home | 619 (34.7%) | 464 (67.8%) | 115 (76.9%) | |
| Nursing home | 828 (46.4%) | 49 (7.2%) | 9 (5.2%) | |
| Rehabilitation | 194 (10.8%) | 67 (9.8%) | 19 (10.9%) | |
| Hospice | 30 (1.7%) | 2 (0.3%) | 0 (0.0%) | |
| Mortality | 76 (4.4%) | 35 (5.1%) | 13 (7.5%) | |

*Values presented as n (%) or mean ± standard deviation.

**Table 3. Injury details for patients with a traumatic injury.**

| Parameter | Number (%) |
|---|---|
| Fall | |
| Standing, sitting, lying | 1,362 (76.3%) |
| Stairs | 182 (10.2%) |
| Height | 83 (4.6%) |
| Ladder | 78 (4.4%) |
| Motor Vehicle Crash | |
| Driver | 467 (68.3%) |
| Passenger | 134 (19.6%) |
| Pedestrian or pedal cyclist | 83 (12.1%) |
| Restraint, Yes | 385 (59.1%) |
| Restraint, No | 266 (40.9%) |
| Blood alcohol above legal limit (≥ 0.08) | 100 (14.6%) |
| Motorcycle crash | |
| Protective equipment, No | 118 (67.8%) |
| Protective equipment, Yes | 56 (32.2%) |
| Blood alcohol above legal limit (≥ 0.08) | 34 (19.5%) |

Most traumatic injuries were located slightly southwest of the hospital and included zip codes 67202, 67203, 67213, and 67211 (Figure 2). Figures 3, 4, and 5 represent the distribution of incident locations by each of the top three mechanisms of injury. Most fall injuries occurred west of the hospital in zip codes 67202, 67203, and 67213 (Figure 3). Both MVC and MCC were predominantly located in zip code 67202 (Figures 4 and 5, respectively). The highest number of outlying high-density injury locations occurred among MCCs. Although patient socioeconomic factors were not collected, Figure 6 displays residents within our study area living below the federal poverty line (FPL) by zip code.[18]

## DISCUSSION

This was the first study to combine trauma registry data and incident location information to describe our study population. Study findings demonstrated that falls, motor vehicle crashes, and motorcycles crashes accounted for the highest frequency of traumatic injuries in our area. These trends were similar to national trends reported by the U.S. Department of Health and Human Services and the National Trauma Data Bank.[2]

Falls accounted for most of injuries and were most frequent among those 75 years or older. Those who suffered a fall injury also were more likely to be discharged to a nursing home or skilled nursing facility more frequently than any other mechanism of injury. A previous study found that among elderly fall injury patients who lived at home or independently before hospital admission, 37.3% were discharged to a nursing home or skilled nursing facility, suggesting that fall injuries can be harmful and debilitating for those 65 years or older.[19]

An overwhelming majority of patients who fell did so while standing, sitting, or lying. This finding suggested that daily tasks such as getting out of bed or standing up in the bathtub may be factors in fall injuries. Although fall injuries were less frequently severe than MVC and MCC injuries, these cases were most likely to have a severe extremity or head injury. Surgical intervention was required most frequently among fall injuries, further suggesting that these injuries are a significant source of morbidity among our trauma patients.

Motor vehicle crashes were the second most frequent mechanism of injury in the study and occurred most frequently among those aged 19 to 44 years. Road traffic injuries, including those by motor vehicle crashes, were a leading cause of mortality among those aged 15 to 49 years, further highlighting the need for more research and interventions into this issue.[20] In Kansas, 14 years of age is the youngest age a person can obtain a learner's driving permit and legally start driving.[21] A driver's education course is required for those aged 14 to 16 years but is not required for those 17 and older. Therefore, the lack of driving experience and a driver's education course could play a role in the high frequency of motor vehicle crash injuries among the younger trauma population.

In the current study, restraints were used in less than two-thirds of motor vehicle crash injuries, despite there being a state law requiring the use of seatbelts. Additionally, concerning is that more than one out of ten patients injured by a motor vehicle crash were identified as legally impaired by alcohol. Previous studies have demonstrated that lack of restraint use and impairment by alcohol are associated with worse outcomes, such as high frequency of severe injuries and mortality, in motor vehicle crashes.[22-25]

Motorcycle crash injuries occurred less frequently than both fall and motor vehicle crash injuries but accounted for the highest frequency of severe injuries and the second-highest frequency of surgical intervention. Potential contributing factors to the higher incidence of severe injury and mortality among our motorcycle crash population included lack of protective equipment use and alcohol impairment, as other studies have suggested that these are associated with worse patient outcomes.[24,26-28]

The generated maps of all traumatic for the current study suggested that most injuries occurred near our hospital and were located in several of the most population-dense zip codes.[29] These findings were similar to what other studies have demonstrated.[10,14-16] Injury locations in our study area also corresponded to locations popular for dining, shopping, and nightlife. These areas also have a large number of alcohol-serving establishments. Walker and associates noted that traumatic injury hotspots also had a high concentration of alcohol-serving establishments.[10]

The high injury areas for each mechanism of injury were different, although the areas had some overlap. For instance, both MVC and MCC were located near the hospital and seemed to occur along or near a major highway (U.S. 54). These findings were similar to Dezman et al.[14] who studied MVC in Baltimore, Maryland. They noted that crash sites were predominately in the high-density center of the city and followed main access roads and avenues. However, among our population, MCCs were centered north and south of U.S. 54, while more MVCs occurred west along U.S. 54. In addition, more MCCs appeared to

occur at interactions in surrounding areas, and one hotspot of MCC corresponded to a local motocross track (near zip code 67101). Fall injuries were more spread-out compared to MVC and MCC, however, these injuries still had a high number located central to our hospital.
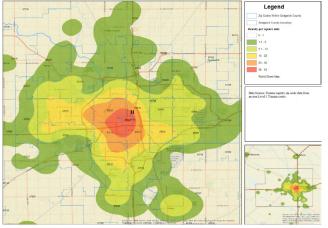


Figure 2. Geographic distribution of traumatic injuries by incident zip code between January 2016 and December 2017.
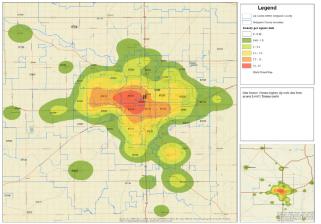


Figure 3. Geographic distribution of fall-related injuries by incident zip code between January 2016 and December 2017.
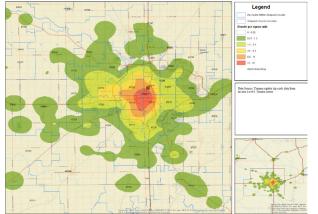


Figure 4. Geographic distribution of motor vehicle crash-related injuries by incident zip code between January 2016 and December 2017.
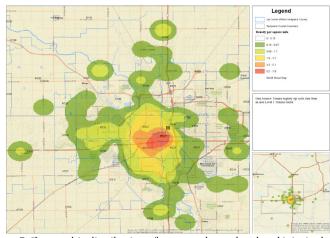


Figure 5. Geographic distribution of motorcycle crash-related injuries by incident zip code between January 2016 and December 2017.
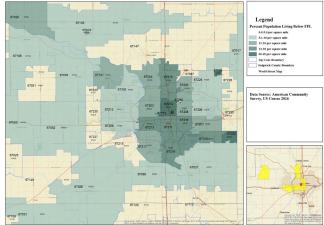


Figure 6. Residents within our study area living below the federal poverty line (FPL) by zip code.

**Implications**. Traumatic injuries are frequently preventable, yet remain a leading cause of death in the U.S. To reduce traumatic injuries and promote safety, injury prevention strategies should be implemented at the population level. States with more injury prevention policies in place have lower rates of death from injury.[30] GIS can be used to identify high incidence and high-risk areas for traumatic injuries.[5] Once these areas have been identified, guided interventions can be developed and tailored to specific characteristics of the area, such as lowering speeds of streets in areas of high pediatric pedestrian injuries.[31] The use of geospatial analysis to guide injury prevention strategies is a clear benefit to communities that are trying to reduce traumatic injuries and should become a staple of any injury prevention initiative.[4-6]

Through the mapping of fall injuries, it is possible to identify areas more densely populated with people over the age of 65, specifically outside of nursing homes, with the goal of targeting community gathering spots to implement educational interventions regarding fall risks and hazards. Since our finding suggested that falls occur most often during daily activities providing information on common household fall risks and techniques on how to limit these risks should be included in any fall prevention effort directed at our patients. With the use of our GIS maps, these prevention programs can be targeted to the high incident locations.

Among our MVC and MCC patients, lack of seatbelt use and driving under the influence (DUI) were common. With our generated maps for MVC and MCC locations, police can increase traffic enforcement, such as enforcement of seatbelt laws and DUI checkpoints, in these high injury locations. Unfortunately, due to the nature of our study we were unable to investigate any environmental factors that may play a role in the high number of MVC and MCC locations displayed in our maps.

**Future Research**. Future studies can use this information to aid in the development of targeted injury prevention strategies. Another avenue for future research involves comparing socioeconomic factors within the area and identifying trends among traumatic injuries. The use of GIS could highlight these areas further and identify their spatial relation to socioeconomic trends within the area. In addition, future studies may involve a more detailed investigation at the neighborhood level to establish risk factors of significant injuries for our hospital population catchment areas. This may include investigating the influence of the built environment, neighborhood demographics, and risk-taking behaviors.

**Limitations**. There are limitations to our study. First, not all trauma injuries in our area were represented in the study findings due to including only one of two local Level 1 trauma centers and by not including those who died at the scene. Second, the lack of data in patient charts made looking at patient socioeconomic factors impossible. Census data were used to characterize zip codes according to the federal poverty level. However, these data did not reflect the study population necessarily as trauma injuries did not always occur in or near a patient's home; this was likely to be seen with motor vehicle and motorcycle crashes. Additionally, more detailed information regarding incident locations such as the characteristic of the built environment and environmental factors were not available due to the retrospective nature of the study.

## CONCLUSIONS

Falls, motor vehicle crashes, and motorcycle crashes were the most common mechanisms of injury among the study population. Although the mechanisms of injury differed in frequency, morbidity, and mortality, they each represented a significant hazard to the community. The use of GIS aided in the identification of the areas of highest incidence, showing that the most traumatic injury cases per square mile were concentrated in certain regions. With these findings, it is possible to implement injury reduction strategies aimed at areas of high injury prevalence, with the goal of reducing preventable trauma injuries.

## ACKNOWLEDGMENTS

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