ORIGINAL ARTICLE

Accident Mechanisms and Demographic Distribution of Train-related Accidents in the United States

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Resumen

Introducción: Hay poca información en la literatura sobre los patrones demográficos más críticos en los accidentes de tren. Intentamos evaluar patrones demográficos asociados con lesiones ferroviarias en los Estados Unidos.

Materiales y métodos: Utilizando el Banco Nacional de Datos de Trauma (NTDB) de 2017, identificamos a los adultos que sufrieron lesiones relacionadas con el tren. Datos recogidos incluidos edad, sexo, etnia, dispositivos de sujeción, signos vitales prehospitalarios y del departamento de emergencias (ED) y escala de coma de Glasgow (GCS), tiempo de respuesta y transporte, paro cardíaco prehospitalario, mecanismo de lesión, muerte en accidente y en el servicio de urgencias, embarazo de más de 20 semanas cuando corresponda, lesiones por quemaduras, oxígeno suplementario, altura, peso, disposición al alta del servicio de urgencias, antecedentes de alcoholismo y abuso de drogas, necesidad de unidad de cuidados intensivos (UCI), duración de la estadía (LOS) en la UCI y el hospital, uso de ventilador en días, cirugía de control de hemorragia, hemoderivados recibidos y Abreviado Puntuación de la escala de lesiones (AIS). Para todos los análisis estadísticos, se consideró significativo un valor de p <0,05.

Resultados: Identificamos 4.545 pacientes de los cuales el 68% eran varones, y la edad media fue de 37 ± 16,5 años. La distribución racial fue 64% Blanca, 19% Negro, 12% hispano, 11% hispano y 6% otros. Los mecanismos más comunes de lesión fueron las autolesiones intencionales al saltar o acostarse en frente al tren (30 %), seguido del peatón atropellado por el tren (26 %), la colisión intencional de un vehículo motorizado con el tren (19 %) y el choque accidental del motor. colisión de vehículo con tren (14%). En comparación con las mujeres, los hombres tenían GCS más bajo 12 vs 12,7 (p = 0,005). La intoxicación por alcohol estuvo presente en el 13% de pacientes que tenían LOS más largos 13,4 vs 10 días (p = 0,001). La participación del fármaco estuvo presente en el 19 % de los pacientes que tenían una GCS más baja 11,9 frente a 12,6 (p = 0,001). La mortalidad global fue del 17% y fue mayor en intentos de suicidio (19%) y atropello de peatones (35%). Mortalidad de ocupantes de automóviles lesionados por colisión de tren vs colisión intencional de vehículo de motor fue de 5,9 vs 3,4%.

Conclusión: Las lesiones más frecuentes relacionadas con el tren son secundarias a intentos de suicidio. Los segundos incidentes más comunes ocurren en el ferrocarril. cruces de peatones y ocupantes de vehículos de motor. Se necesita más investigación sobre la atención pública para mejorar las medidas de seguridad y la conciencia pública. asociado a los cruces de ferrocarril.

Palabras clave: Suicidio, Trenes, Lesiones traumáticas.

Abstract

Introduction: There is little information in the literature about the most critical demographic patterns on train accidents. We attempt to assess demographic patterns associated with railway injuries in the US.

Materials and Methods: Using the 2017 National Trauma Data Bank (NTDB), we identified adults who suffered train-related injuries. Data collected included age, sex, ethnicity, restraint devices, prehospital and emergency department (ED) vital signs and Glasgow Coma Scale (GCS), time of response and transportation, prehospital cardiac arrest, mechanism of injury, death in crash and in ED, pregnancy more than 20 weeks when applicable, burn injuries, supplemental oxygen, height, weight, ED discharge disposition, history of alcoholism and drug abuse, need of intensive care unit (ICU), length of stay (LOS) at the ICU and hospital, ventilator use in days, hemorrhage control surgery, blood products received, and Abbreviated Injury Scale (AIS) score. For all statistical analyses, a p-value of <0.05 was considered significant.

Results: We identified 4,545 patients, of whom 68% were male, and the mean age was 37 ± 16.5 years. The racial distribution was 64% White, 19% Black, 12% Hispanic, 11% Hispanic, and 6% others. The most common mechanisms of injury were intentional self-harm by jumping or lying in front of the train (30%), followed by pedestrian struck by train (26%), intentional collision of motor vehicle with train (19%), and accidental motor vehicle collision with train (14%). Compared to females, males had lower GCS 12 vs 12.7 (p = 0.005). Alcohol intoxication was present in 13% of patients who had longer LOS 13.4 vs 10 days (p = 0.001). Drug involvement was present in 19% of patients who had lower GCS 11.9 vs 12.6 (p = 0.001). Overall mortality was 17% and was greater in suicide attempts (19%) and pedestrian struck (35%). Mortality for car occupants injured by train collision vs intentional collision of motor vehicle was 5.9 vs 3.4%.

Conclusion: The most frequent train-related injuries are secondary to suicide attempts. The second most common incidents occur on railway crossings with pedestrians and motor vehicle occupants. Further public care research is needed to improve safety measures and public awareness associated with railway crossings.

Keywords: Suicide, Trains, Traumatic injuries.

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Introduction

Railroads in the United States are frequently used for commerce and personal transportation. Nevertheless, railway-related accidents continue to occur throughout the world.[1] The mass of a train combined with the velocity results in an enormous amount of kinetic energy being transferred to the body of a person when struck, resulting in potentially life-threatening injuries.[2] Globally, the number of railway disasters, nonfatal injuries, and people killed has increased throughout the last hundred years—particularly during the last 4 decades (1970–2009), when 88% of all incidents occurred.[3] The reason is that railway transportation has been growing at a noninterrupted pace, and despite remarkable improvements in safety systems, train-related injuries continue to happen frequently.[3]

Factors such as high speed and increase in passenger traffic contribute to the latent risk of railway accidents. In the United States, railway collisions vs motor vehicles or pedestrians occur as frequently as every 120 minutes.[4] In the absence of a case history, it has been difficult to distinguish between accidents, suicide, or criminal violence; since these events associated with railways mostly occur when tracks are used as a convenient route for walking or crossing.[5] Furthermore, substance abuse has played an important role in train-related accidents, as trespasser fatalities have been related to alcohol abuse in up to 80% of the events.[6]

Research data about train-related injuries remain limited, despite having a significant impact, often resulting in morbid, debilitating, or even fatal injuries.[4] Extensive injury patterns and associated long-term disabilities are often devastating for the patients and are associated with significant health care expenses.[7] Developing data on prevalence, demographics, risk factors, and injury patterns is essential for accident prevention programs.[3,8]

Our objective is to assess demographic patterns, accident circumstances, and injury burden in railway accidents across the United States. This information will give insight about the importance to follow safety measures and the critical need for management strategies to prevent the consequences from these injuries.

Materials and Methods

We performed a retrospective cohort analysis based on the NTDB from the years 2017 to 2019. Patients who suffered injuries from train-related accidents were included in this analysis. Demographic variables collected were age, sex, and race. Trauma-related variables were mechanism of injury, trauma center criteria (TCC) type of injuries, traumatic brain injury (TBI), and injury severity score (ISS). Mechanism of injury categories were derived from ICD-10 code system. We used the mechanism of injury codes V05, V15, V25, V35, V45, V55, V65, V75, X81, X82, and Y02 to determine diagnostic inclusion in the analysis.

Our analyses also included inpatient care variables such as prehospital and ED vital signs, GCS, time to response, mode of transportation, prehospital cardiac arrest, death at the scene and in ED, injury type, ISS, AIS, use of supplemental oxygen, ED discharge disposition, hospital discharge disposition, evidence of alcohol intoxication, substance abuse, active mental conditions, need of ICU admission, LOS at the ICU, total hospital LOS, ventilator days, type of surgery for hemorrhage control, blood products received in first 4 hours, and primary payment method.

Categorical variables are presented as frequencies and continuous variables as means ± standard deviation. We used chi-square test for statistical correlation with a p-value of <0.05 for statistical significance.

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Results

We collected data from 4,545 patients with train-related injuries from years 2017, 2018, and 2019 using the NTDB. Our population was predominantly male (68%). Mean age was 37 ± 16.5 years with a range from 1 to 89 years. Race in majority was White (64%), followed by Black (19%), and Hispanic (11%), see Table 1.

Mean age for self-harm-related injuries was 32 years, which is younger than the total population. The highest prevalence in self-harm-related injuries was found in the White race ($p < 0.01$). Moreover, among African Americans unintentional pedestrians hit by train were overproportioned compared to the other racial groups ($p = 0.03$).

Alcohol intoxication was seen in 75% of our total patient population. This condition was predominant in patients who had intentional self-harm by jumping or lying in front of the train (80%) or by motor vehicle crash (87%) ($p < 0.01$). Additionally, 13% of the patients had a positive screening test for substance abuse. Active psychiatric disorder history was characteristically found in 22% of the total population. Finally, among the patients who committed suicide, 42% of them suffered from previously diagnosed mental disorders ($p = 0.05$) (Fig. 1).

Data from restraint devices showed that only 39% motorcycle drivers wore a helmet in collisions with railway. Similarly, only 30% of pedal cyclists injured were wearing a helmet. Furthermore, 50% of motor vehicle occupants were wearing a seatbelt at the time

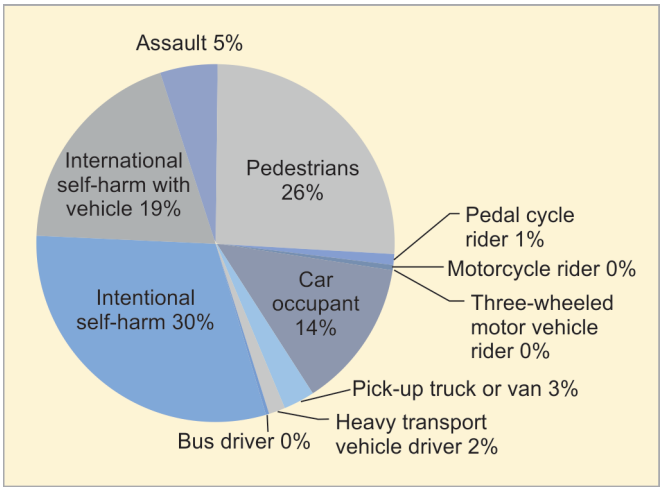

Fig. 1: Mechanism of injury

of collision with a railway train, and airbag deployment occurred only in 44% of crashes. Among the patients committing suicide by motor vehicle crash, only 35% of them were wearing a seat belt.

Injury Severity Score levels were defined according to the "*Nicole Van Der Heyden* and *Thomas B. Cox classification*".[4] Minor ISS level refers to 1-to-8-point score, moderate ISS level to 9–15, severe ISS level 16–25, and very severe ISS more than 25-point score. The most frequent ISS level was minor (32%), followed by moderate (28%), severe (19.3%), and very severe (19.4%).

Pedestrians primarily presented lower ISS (32%) vs motor vehicle occupants who had higher prevalence in moderate ISS (30%). Additionally, a correlation was found between higher ISS scores and ICU admissions ($p = 0.048$). Surprisingly, ISS scores did not show statistical significance with blood transfusions within the first 4 hours of admission ($p = 0.09$).

The most common type of injury was crushed, degloved, or mangled extremity (21%), just followed by long bone fracture (19%) and amputation (16%). Long bone fractures and amputations were seen more frequently in pedestrians (65%) compared to vehicle occupants (44%) ($p = 0.05$). Skull fractures were mostly reported in suicidal patients (41%) and pedestrians (47%) ($p < 0.01$), see Table 2.

Traumatic brain injury was divided based on GCS level. Mild TBI (GCS 14–15) had a frequency of 72%, moderate TBI (GCS 9–13) 5%, and severe TBI (GCS 3–8) 21%. Suicidal patients were more likely to have a severe level of TBI (52%) compared to pedestrians (40%) and car occupant injury patients (10%) ($p < 0.01$).

Among the patients with hypotensive shock or signs of hypoperfusion, 20.3% of them required surgery. The mortality in ED shock patients was 1.5 times higher compared to those who had vital signs within normal limits ($p = 0.020$). The most common injury types related to shock were long bone (33.3%), skull (30%), and (upper or lower) extremity fractures (27%), although *p*-value showed to be nonsignificant ($p = 0.560$). Moreover, in patients who suffered prehospital cardiac arrest, 48% of them died in ED, and the remaining were rushed to the operating room (OR) or ICU ($p = 0.008$).

Mean time of emergency medical services response was 11.73 minutes, while the most common mode of transportation to the ED was ground ambulance (80%) followed by air transport (16%).

Almost a quarter of the patients required direct transfer from the ED to the OR. Of those, 22% required ICU care, and 18% had a general surgical floor admission. Intensive care unit admission was required for 45% of patients with a mean LOS of 7 ± 9 days. The most frequent surgeries performed were exploratory laparotomies (22%), followed by mangled extremity salvage or amputation (16%).

Total patient mortality rate was 17%. Of which, 70% of them died in the ED, 27% expired during hospitalization, and 3% were reported dead at the scene. Intentional self-harm injury had the highest mortality rate (35%), followed by pedestrians (19%) and drivers (5%). As to be expected, in-hospital mortality showed correlation with severe ISS scores ($p < 0.01$).

During hospital stay, most patients were discharged home or self-care (24%), followed by admission to ICU (16%), and transfer to a third-level hospital (16%). Private insurance (37%) and Medicaid (28%) were the most common payment methods, followed by self-pay (19%), see Table 3.

Table 1: Demographics and mechanism of injury

	N = 4,545
Sex	
Male (*n*, %)	3,095 (68%)
Female (*n*, %)	1,450 (32%)
Age, years	
Mean	37 ± 16.5
Race	
White (*n*, %)	2,905 (64%)
Black (*n*, %)	850 (19%)
Hispanic (*n*, %)	513 (11%)
Unknown (*n*, %)	126 (3%)
Asians (*n*, %)	96 (2%)
American Indian (*n*, %)	55 (1%)
Mechanism of injury	
Intentional self-harm (*n*, %)	1,376 (30%)
Pedestrians (*n*, %)	1,180 (26%)
Intentional self-harm with vehicle (*n*, %)	876 (19%)
Car occupant (*n*, %)	614 (14%)
Assault (*n*, %)	226 (5%)
Pick-up truck or van (*n*, %)	125 (5%)
Heavy transport vehicle driver (*n*, %)	72 (2%)
Pedal cycle rider (*n*, %)	44 (1%)
Motorcycle rider (*n*, %)	16 (0%)
Bus driver (*n*, %)	11 (0%)
Three-wheeled motor vehicle rider (*n*, %)	5 (0%)

Table 2: Trauma-related outcomes

	N = 4,545
ISS levels	
Minor (*n*, %)	1,453 (32%)
Moderate (*n*, %)	1,249 (30%)
Severe (*n*, %)	878 (19%)
Very severe (*n*, %)	882 (19%)
TCC type of injury	
Crushed, mangled, extremity (*n*, %)	106 (21%)
Long bone fracture (*n*, %)	96 (19%)
Amputation (*n*, %)	79 (16%)
Skull fracture (*n*, %)	76 (15%)
Pelvic fracture (*n*, %)	54 (11%)
Penetrating injury (*n*, %)	45 (8%)
Chest injury (*n*, %)	35 (7%)
Paralysis (*n*, %)	17 (3.3%)
TBI level	
Mild (*n*, %)	3,238 (72%)
Severe (*n*, %)	965 (21%)
Moderate (*n*, %)	245 (5%)
Unknown (*n*, %)	97 (2%)
TBI with midline shift	
Unknown	2,555 (56%)
No	1,059 (23%)
Yes	931 (21%)

Discussion

Our retrospective study shows a comprehensive approach for the understanding of train-related trauma injuries. This is the biggest sample size study evaluating train-related injuries in the US. Demographic findings regarding sex, age, and race were similar to ones from previous studies,[7,6] being White middle-aged men the most commonly affected population. However, racial distribution can be affected by different regions in the US and further studies focusing on geographic patterns should be done.[9]

Table 3: Hospital-related outcomes

	N = 4,545
Time of response	12 ± 23 min
LOS at ICU	7 ± 9 days
Length of hospital stay	10 ± 15 days
Length of ventilator use	6 ± 9 days
Mode of transportation	
Ground ambulance (*n*, %)	3,615 (80%)
Air transportation (*n*, %)	743 (16%)
Private vehicle (*n*, %)	88 (2%)
Police (*n*, %)	47 (1%)
Other (*n*, %)	36 (1%)
ED disposition	
Deceased (*n*, %)	547 (12%)
Hospital admission (*n*, %)	799 (18%)
Home with services (*n*, %)	103 (2%)
Home without services (*n*, %)	137 (3%)
ICU (*n*, %)	979 (22%)
Left against medical advice (*n*, %)	50 (1%)
Observation (<24 hours) (*n*, %)	342 (8%)
OR (*n*, %)	1,016 (22%)
Jail/mental health (*n*, %)	161 (4%)
Stepdown unit (*n*, %)	204 (5%)
Transferred to another hospital (*n*, %)	136 (3%)
Unknown (*n*, %)	71 (2%)
Hospital discharge disposition	
Discharged home or self-care (*n*, %)	1,069 (24%)
Transferred to a third-level hospital (*n*, %)	731 (16%)
Unknown (*n*, %)	672 (15%)
Transferred to psychiatric unit (*n*, %)	532 (12%)
Left against medical advice (*n*, %)	317 (7%)
Transferred to rehab (*n*, %)	306 (7%)
Deceased (*n*, %)	209 (5%)
Transferred to long-term care hospital (*n*, %)	195 (4%)
Transferred to skill nursing facility (*n*, %)	183 (4%)
Discharged home with home health orders (*n*, %)	102 (2%)
Transferred to intermediate care facility (*n*, %)	100 (2%)
Transferred to short-care hospital	95 (2%)
Discharged to jail	23 (<1%)
Transferred to hospice care	11 (<1%)
Payment method	
Private insurance (*n*, %)	1,667 (37%)
Medicaid (*n*, %)	1,261 (28%)
Self-pay (*n*, %)	859 (19%)
Medicare (*n*, %)	355 (8%)
Other (*n*, %)	258 (6%)
Not billed (*n*, %)	39 (1%)

Remarkably, alcohol intoxication was present in 75% of patients of the total population. This finding differs from other studies that did not find such high percentage of alcoholism in their population. Previous studies described alcoholism in 51%[12] and 58%[7] of the study population. This *variable* was also highly correlated to the group of intentional self-harm, since alcohol causes physical and mental dysfunction which increases the risk for trespassers to be struck by a train or commit suicide. Since alcoholism is a major contributor to suicide attempts, there is an opportunity for campaigns that informs the community about the dangers of ingesting drugs and alcohol near railways, as well as improvement in law enforcement by making higher efforts to prevent act of suicide itself with heavier penalties and increased vigilance along the railways.[2]

In addition, active mental disorder in our population was not as high as previously reported.[7] Donnally et al. reported 52% of their population to have any kind of psychiatric history, although their geographic location was not as wide as ours. Still, being an existing relation between mental disorders and suicide rates, this is also a crucial parameter needed to be considered in interventions for train-related accident prevention.[1] Physical barriers have been implemented before such as fencing program and platform screen doors that showed to be effective,[7] but mental health preventive plans are still pending, and higher quality of psychiatric therapeutic plans are needed, which more effectively should be done in a multilevel approach across the healthcare system.[13,14]

Suicide attempts were reported in almost half of all train-related injuries, which is surprisingly high. Suicide rate is related to severe TBI outcomes and needs long-term care and extensive rehabilitation. Traumatic brain injury can cause permanent cognitive dysfunction and physical impairment which increases the public health expenses since 36% of these patients used a government health insurance. This also is a source of work loss time as majority of the cohort was young and potentially could have contributed to society over many more years. Traumatic brain injury can cause important dysfunction of frontal lobes and frontal-subcortical circuits that can ultimately lead to violence, cognitive impairment, and impulsivity, which can decrease the possibility of social reintegration of these patients[10] and potentially increase cost to the justice system.

Although it is not uncommon to find violent crimes around the train system, intentional harm and homicide rate were also significant and unexpected. Apparently, there is a surge of these cases since 2015 from 0.97 violent crime per 1 million rides to 5.89 in 2020.[11] This increasing issue needs to be addressed urgently since railway systems serve as an important mode of transportation in all our communities. Safety measures are required to be implemented to assure commuter's integrity.

As expected, the most common TCC-defined type of injury was crushed, degloved, mangled, or pulseless extremity followed by amputation and skull fractures. This scenario demonstrates how railway accidents can be truly devastating for a patient since high-level traumatic injuries, such as amputation of extremity, can be highly debilitating for that person posing a social burden after discharge.[3]

We found that a quarter of patients required immediate surgery, which points out the importance of trauma center care to assess and manage these complex patients appropriately. Trauma center care offers rapid and high-level multidisciplinary trauma care for these

critically injured patients. Frequently, these polytrauma patients require extensive rehabilitation and psychological support available in tertiary centers.[1]

Our total mortality rate was similar to previously reported rates.[7,14] Although mortality percentages varied based on mechanism of injury related to train accident. For instance, some studies did not include motor vehicle-related injuries, which tend to cause more fatalities among patients.[9] As expected, higher mortality rate was seen in the suicidal patients, since they have more severe injuries than any other mechanism of trauma, such as severe TBI. Furthermore, we included mortality at scene and ED, which brings more reliability to our data in comparison to other studies that did not include this information in their reports.[9]

Limitations of our research study were related to lack of randomization (prone to selection bias), data quality issues (missing data), and recording or coding errors that may be present in the NTDB. At the same time our team experienced technical difficulties with gathering information of more years due to technical NTDB limitations. Differentiation between intentional vs accidental cause for the collision of motor vehicles against train was part of the ICD coding from the database. Our project relies on proper documentation by hospital institutions. Nevertheless, our findings are outstanding and showed that there is a clear trend regarding these types of injuries.

Our findings provide insightful information about train-related injuries in the United States. However, the information gathered shows that tighter controls and safety measures are needed to reduce rate of train accidents and suicide attempts. Being this population characterized as a high-risk group, further studies are needed to focus on preventive approaches, reducing the number of train-associated suicide attempts and accidents.

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