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Original Contributions

HIT BY A TRAIN: INJURY BURDEN AND CLINICAL OUTCOMES

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☐ **Abstract—Background: Few data exist regarding the train vs. pedestrian (TVP) injury burden and outcomes. Objective: This study aimed to examine the epidemiology and outcomes associated with TVP injuries. Methods: This is a retrospective National Trauma Databank study (January 2007 to July 2012) including trauma patients sustaining TVP injury. Demographics, injury data, interventions, and outcomes were abstracted. Patients injured by a train were compared to patients who sustained an automobile vs. pedestrian (AVP) injury. Results: Of the 152,631 patients struck by ground transportation during the study time frame, 1863 (1.2%) were TVP. Median TVP age was 38 years (interquartile range [IQR] 24–50 years), 81.6% were male, median Injury Severity Score (ISS) was 13 (IQR 6–24). TVP patients were more severely injured (ISS 13 vs. 9; p < 0.001) and required more proximal amputations (13.4% vs. 0.2%; p < 0.001) and cavitary operations (18.2% vs. 2.8%; p < 0.001). TVP patients had higher rates of intensive care unit admission, mechanical ventilation and transfusion, longer length of stay, and higher in-hospital mortality. On multivariable logistical regression, TVP was an independent predictor for higher injury burden, ISS ≥25 (adjusted odds ratio [AOR] 1.650), immediate operative need (AOR 7.535), and complications (AOR 1.317). Conclusions: TVP is associated with a significant injury burden. These patients have a significantly higher need for immediate operation and more complicated hospital course. © 2019 Elsevier Inc. All rights reserved.**

☐ **Keywords—train; trauma; epidemiology; outcomes**

INTRODUCTION

The injury burden that results from being struck by a train remains poorly understood, with most studies based on small retrospective case series or focus on railroad accident data without information beyond the prehospital setting. Very few studies have provided clinical outcomes data and need for interventions that are of immediate relevance to an emergency physician or trauma surgeon anticipating whether a patient may require transfer for higher level of care beyond a primary and secondary survey. Furthermore, the incidence of train vs. pedestrian (TVP) relative to all forms of ground transportation has not been specifically evaluated. Previous studies have demonstrated an association of TVP mechanism with intoxicated pedestrians, as well as high amputation rates (1–7). The cost of injuries in this population is substantial (2,7).

The purpose of this study is to characterize the injury patterns as well as compare TVP to more common injury mechanisms. TVP seems intuitively more destructive than other ground transport vs. pedestrian mechanisms, given the higher velocity and mass of a train; however, this has not been described formally. Because of our poor understanding of this mechanism of injury, we aimed to characterize the epidemiology of this injury and classify the associated operative need in a nationwide patient population. We also sought to compare this mechanism to automobile vs. pedestrian (AVP) in terms of

demographics, interventions, and outcomes. We hypothesized that TVP would have a higher injury burden compared to AVP, with higher need for operation and greater morbidity and mortality.

MATERIALS AND METHODS

Study Population

This is a National Trauma Data Bank (NTDB) (2007–2012) analysis of all patients sustaining an injury due to a pedestrian vs. ground transport mechanism. We excluded patients from the study if they had any of the following criteria: dead in the field or on arrival, transferred from outside hospital, or were struck by a ground transport mechanism other than automobile or train. We divided the population into two study arms: TVP and AVP. The NTDB is de-identified publicly available data that does not constitute human subjects research, as defined in federal regulations and does not require Institutional Review Board review.

Study Design

We abstracted patient age, race, sex, work-related, toxicology status, comorbidities, systolic blood pressure (SBP), heart rate, Glasgow Coma Scale (GCS), head, chest, abdomen, extremity Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), injury type, blood product administration, operative interventions, complications, and outcomes from the database. NTDB values for vital signs and GCS were recorded on arrival.

The primary outcome measured was in-hospital mortality. Secondary outcomes included hospital lengths of stay (LOS), intensive care unit (ICU) LOS, total ventilation days, and complications, which included pneumonia (PNA), acute respiratory distress syndrome (ARDS), deep vein thrombosis (DVT), pulmonary embolism (PE), alcohol withdrawal, sepsis, acute kidney injury (AKI), extremity compartment syndrome, organ space surgical site infection, deep surgical site infection, and superficial surgical site infection.

Statistical Analysis

Continuous variables were dichotomized using well-established clinically relevant cutoff points within the trauma literature: age (<50 years vs. $\geq$ 50 years), SBP (<90 mm Hg vs. $\geq$ 90 mm Hg), GCS ($\leq$8 vs. > 8), heart rate (<100 vs. $\geq$ 100), and ISS (<15 vs. $\geq$ 15 as well as < 25 vs. $\geq$ 25). Differences between TVP and AVP were investigated using χ^2 or Fisher's exact test for categorical variables and independent Student's t-test or Mann-Whitney U test for continuous variables. Mean and median values were reported with standard deviation (SD) and interquartile range (IQR). Multivariate logistic regression adjusted for differences in baseline patient characteristics was used to identify independent predictors of mortality, need for major operation (proximal amputation, thoracotomy, or laparotomy), and complications. Adjusted odds ratio (AOR), 95% confidence intervals, and p values were calculated for independent predictors. Statistical analysis was performed using SPSS, versions 23 and 24 for Mac (IBM Corp., Armonk, NY).

RESULTS

During the 5-year and 7-month study period, 152,631 trauma patients were entered into the NTDB after sustaining a ground transport vs. pedestrian mechanism. Of these, 1863 (1.2%) had a TVP mechanism, 138,763 (90.9%) had an AVP mechanism, and 12,005 (7.9%) suffered other ground transport vs. pedestrian mechanism. These other ground transports included pedal cycle, off-roading vehicle, motorcycle, snowmobile, animal-drawn transport, rolling stock, and streetcar. The most common other ground transport was cyclist (58.5%), followed by off-road vehicle (14.9%), motorcycle (3.3%), and animal-drawn or ridden (2.8%).

Overall, the study population was predominantly male (64.7%), with a median age of 35 years (range to 1–112 years). At admission, TVP patients were more frequently hypotensive, SBP < 90 mm Hg (10.8% vs. 6.3%; $p < 0.001$) with depressed GCS $\leq$ 8 (21.6% vs. 13.7%; $p < 0.001$), and more likely to have ISS $\geq$ 25 (23.2% vs. 15.4%) compared to AVP patients. In TVP patients, median age was 38 years (IQR 24–50 years), 81.6% were male and median ISS was 13 (IQR 6–24). Patients were more likely to have positive toxicology (40.5% vs. 27.9%; $p < 0.001$), with 21.7% positive for alcohol only, 9.9% positive for a single drug, 8.8% positive for both drugs and alcohol, and 1.9% positive for multiple drugs. TVP occurred more frequently at work (14.1% vs. 2.6%; $p < 0.001$) and patients were transferred to a secondary hospital more frequently (17.4% vs. 1.1%; $p < 0.001$) compared to AVP patients. The most common comorbidities in TVP patients were a history of alcoholism (18.4% vs. 8.7%; $p < 0.001$), hypertension (11.3% vs. 12.2%; $p = 0.25$), and smoking (9.3% vs. 7.5%; $p < 0.004$).

TVP had more orthopedic (64.5% vs. 59.5%; $p < 0.001$), spinal (30.8% vs. 20.6%; $p < 0.001$), pulmonary (15.1% vs. 11.9%; $p < 0.001$), solid organ (10.3% vs. 8.7%; $p = 0.017$), vascular (7.2% vs. 5%; $p < 0.001$), genitourinary (5.8% vs. 4.5%; $p < 0.001$), and gastrointestinal (3.2% vs. 1.9%; $p < 0.001$) injuries relative to AVP. Upper extremity fractures were more common in the TVP group

(15.3% vs. 11.6%; $p < 0.001$), while lower extremity fractures were less common (22.0% vs. 36.7%; $p < 0.001$) relative to AVP. Pelvic fractures were similar in the two groups (17.3% vs. 17.4%; $p = 0.913$). Head AIS was similar between the two groups, while chest, abdomen, upper extremity, and lower extremity AIS were higher in TVP patients (Table 1).

TVP patients more frequently underwent an acute operative intervention (31.3% vs. 13.0%; $p < 0.001$) and had higher rates of laparotomy (5.0% vs. 2.4%; $p < 0.001$), thoracotomy (0.9 vs. 0.4%; $p = 0.002$), and amputation (forearm: 0.7% vs. 0.0%, above elbow: 1.4% vs. 0.0%; $p < 0.001$; below knee: 8.1% vs. 0.1%; $p < 0.001$; above knee: 4.7% vs. 0.1%; $p < 0.001$; hip disarticulation: 0.7% vs. 0.0%; $p < 0.001$). Transfusion requirements were higher in TVP for packed red blood cells (10.0% vs. 6.0%; $p < 0.001$), fresh-frozen plasma (3.9% vs. 2.6%; $p < 0.001$), and platelets (2.5% vs. 1.6%; $p < 0.001$) compared to AVP (Table 2).

TVP patients were more likely to develop PNA, ARDS, DVT, PE, alcohol withdrawal, sepsis, AKI, extremity compartment syndrome, organ space surgical site infection, deep surgical site infection, and superficial surgical site infection compared to AVP patients. They were less likely to have a myocardial infarction or cerebrovascular accident compared to AVP patients, despite the higher percentage of patients 50 years and older (44.1% vs. 30.8%; $p = 0.001$). Overall, TVP patients had longer LOS in the hospital and ICU, with higher need for ventilation and higher in-hospital mortality compared to AVP patients on univariate analysis. Good functional outcome defined as unassisted discharge disposition (discharged to home, jail, or psychiatric facility without home health services) was less common in TVP compared to AVP (67.5% vs. 76.7%; $p < 0.001$) (Table 3).

After adjusting for differences in patient characteristics in multivariate regression, TVP was a significant independent predictor of proximal amputation (AOR 93.4; $p < 0.001$), any major operation (AOR 6.1; $p < 0.001$), and complications (AOR 1.4; $p = 0.002$). However, multivariate logistic regression suggested no differences in in-hospital mortality when comparing TVP with AVP (AOR 0.818; $p = 0.091$).

DISCUSSION

Previous series examining clinical outcomes of TVP mechanism of injury consisted primarily of small case series with one larger South African series with 884 patients, making our 1863 patient study the largest TVP

Table 1. Demographics 2007–2012 Train vs. Pedestrian Mechanism

Demographics	TVP (n = 1863)	AVP (n 138,763)	p Value
Age, y, median (IQR)	38 (24–50)	35 (19–53)	<0.001
Sex, male, n (%)	1512 (81.6)	89,072 (64.4)	<0.001
Work-related, n (%)	229 (14.1)	2980 (2.6)	<0.001
Transfer, n (%)	322 (17.4)	1531 (1.1)	<0.001
Toxicology screen, positive, n (%)	754 (40.5)	38,670 (27.9)	<0.001
Alcohol-only positive	405 (21.7)	18,436 (13.3)	<0.001
Drug-only positive	184 (9.9)	12,060 (8.7)	0.071
Alcohol and drug positive	164 (8.8)	7855 (5.7)	<0.001
Comorbidities, n (%)			
Alcoholism	342 (18.4)	12,118 (8.7)	<0.001
Hypertension	211 (11.3)	16,935 (12.2)	0.250
Smoker	174 (9.3)	10,470 (7.5)	0.004
Injuries, n (%)			
Traumatic brain injury	449 (24.1)	34,752 (25.0)	0.360
Vascular	135 (7.2)	6943 (5.0)	<0.001
Bronchopulmonary tree	281 (15.1)	16,532 (11.9)	<0.001
Gastrointestinal	59 (3.2)	2683 (1.9)	<0.001
Genitourinary	108 (5.8)	6220 (4.5)	0.007
Blunt solid organ injury	192 (10.3)	12,121 (8.7)	0.017
Spinal cord or peripheral nerve	574 (30.8)	28,555 (20.6)	<0.001
Orthopedic	1201 (64.5)	82,535 (59.5)	<0.001
Upper extremity fractures	285 (15.3)	16,126 (11.6)	<0.001
Lower extremity fractures	409 (22.0)	50,965 (36.7)	<0.001
Pelvic fractures	322 (17.3)	24,118 (17.4)	0.913
Head AIS, median (IQR)	0 (0–3)	0 (0–2)	0.282
Chest AIS, median (IQR)	0 (0–3)	0 (0–1)	<0.001
Abdomen AIS, median (IQR)	0 (0–0)	0 (0–0)	0.005
Upper extremity AIS, median (IQR)	0 (0–2)	0 (0–1)	<0.001
Lower extremity AIS, median (IQR)	2 (0–3)	2 (0–3)	0.003

AIS = Abbreviated Injury Scale; AVP = automobile vs. pedestrian; GCS = Glasgow Coma Scale; IQR = interquartile range; TVP = train vs. pedestrian.

Table 2. Interventions 2007–2012 Train vs. Pedestrian Mechanism

Variable	TVP, n (%) (n = 1863)	AVP, n (%) (n = 138,763)	p Value
Packed red blood cells, n (%)	186 (10.0)	6283 (6.0)	<0.001
Fresh-frozen plasma, n (%)	73 (3.9)	2736 (2.6)	<0.001
Platelet, n (%)	47 (2.5)	1727 (1.6)	<0.001
Next phase, n (%)			
Operating room	563 (31.3)	17,590 (13.0)	<0.001
Floor	512 (28.5)	49,803 (36.9)	<0.001
Intensive care unit	428 (23.8)	34,706 (25.7)	0.044
Telemetry	90 (5.0)	7911 (5.9)	0.107
Morgue	72 (4.0)	4209 (3.1)	0.038
Home	71 (3.9)	14,476 (10.7)	<0.001
Other	63 (3.5)	6432 (4.8)	0.010
Major operation	325 (18.2)	3836 (2.8)	<0.001
Laparotomy	93 (5.0)	3285 (2.4)	<0.001
Thoracotomy	17 (0.9)	597 (0.4)	0.002
Proximal amputation	240 (13.4)	260 (0.2)	<0.001
Wrist to elbow amputation	13 (0.7)	18 (0.0)	<0.001
Elbow to shoulder amputation	26 (1.4)	26 (0.0)	<0.001
Below-knee amputation	151 (8.1)	116 (0.1)	<0.001
Above-knee amputation	88 (4.7)	128 (0.1)	<0.001
Hip disarticulation	13 (0.7)	3 (0.0)	<0.001

AVP = automobile vs. pedestrian; TVP = train vs. pedestrian.

cohort to date, to the best of our knowledge (1–11). Our population was primarily male, as in other series (3–6). The incidence of pediatric trauma in previous series range from 5% to 22%, consistent with our own series (1,3). Other large studies look specifically at trespassing behavior that results in TVP, but these did not include outcomes or injury data and focused primarily on prehospital crossing behavior. Zhang et al. identified lying or sleeping and running or walking on or near tracks as risky behavior in the context of highway rail–grade crossing and non-crossing areas (12). These papers are instructive when formulating policy changes and railroad safety improvement planning. These studies result in formulated pedestrian protection systems, such as locomotive bumpers and modernized platform stops (13,14). They also identify rail-level crossings less likely to be ignored by pedestrians (eg, visual lights vs. auditory bells), as well as pedestrian characteristics more inclined to rule breaking at pedestrian train crossings (15,16). The focus of our paper was to provide information for

Table 3. Outcomes 2007–2012 Train Versus Pedestrian Mechanism

Outcomes	TVP (n = 1,863)	AVP (n = 138,763)	p Value
Complications, n (%)	147 (7.9)	5744 (4.1)	<0.001
Pneumonia	107 (5.7)	4792 (3.5)	<0.0001
Acute respiratory distress syndrome	54 (2.9)	2462 (1.8)	<0.001
Deep vein thrombosis	37 (2.0)	1776 (1.3)	0.007
Alcohol withdrawal	50 (2.7)	1291 (0.9)	<0.001
Sepsis	32 (1.7)	1071 (0.8)	<0.001
Acute kidney injury	17 (0.9)	1020 (0.7)	0.374
Extremity compartment syndrome	19 (1.0)	832 (0.6)	0.020
Pulmonary embolism	18 (1.0)	621 (0.4)	0.001
Organ space surgical site infection	34 (1.8)	536 (0.4)	<0.001
Superficial surgical site infection	18 (1.0)	401 (0.3)	<0.001
Myocardial infarction	3 (0.2)	256 (0.2)	0.815
Cerebrovascular accident	2 (0.1)	247 (0.2)	0.471
Deep surgical site infection	8 (0.4)	175 (0.1)	<0.001
Non-assisted functional outcome,* n (%)	1022 (67.5)	83,202 (76.7)	<0.001
Hospital LOS, d, median (IQR)	6 (2–15)	3 (1–8)	<0.001
ICU admission, n (%)	809 (43.4)	45,852 (33.0)	<0.001
ICU LOS, d, median (IQR)	4 (2–11)	3 (2–8)	<0.001
Intubated, n (%)	527 (28.3)	23,055 (16.6)	<0.001
Ventilator days, median (IQR)	3 (1–11)	3 (1–10)	0.362
In-hospital mortality, n (%)	182 (9.8)	10,857 (7.8)	0.002

AVP = automobile vs. pedestrian; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; TVP = train vs. pedestrian.
* Home, jail, or psychiatric facility.

emergency physicians and surgeons regarding the anticipated hospital course and injury sequelae associated with this high-energy mechanism.

Alcohol has been associated with TVP victims previously, with positive alcohol level detection ranging from 25% to 80% (1,3–5,9,11). Our study had an alcohol positive rate of 30.5%, falling within the range reported in the previous literature. We also found that the TVP population was toxicology-positive for any substance approximately 40.5% of the time. TVP patients were more likely to be toxicology-positive compared to AVP. They were also more likely to have a history of alcoholism and smoking.

TVP were far more likely to be injured than someone hit by a car, this included vascular injury, bronchopulmonary tree injury, gastrointestinal injury, genitourinary injury, blunt solid organ injury, spinal cord or peripheral nerve injury, and upper extremity fractures. TVP patients were less likely to have a lower extremity fracture compared to AVP patients, however, they were 105 times more likely to require below-knee amputation, 58 times more likely to require above-knee amputation, and 325 times more likely to require disarticulation. This suggests that while lower extremity fracture occurs less frequently in the TVP population compared to AVP, the severity and architecture of these injuries are devastating, as a much higher proportion require proximal amputation. Previous studies have noted the need for multiple operations and multiple amputation revisions to a more proximal level (12). In general, a high amputation rate has been reported in the literature for TVP mechanism, 17–94%, relative to other mechanisms of injury (2,6,7,10). Previous studies noted a higher lower extremity relative to upper extremity amputation rate and our study was consistent with this (12). We also noted a higher need for shoulder to wrist amputations in TVP patients compared to AVP patients.

To our knowledge, this is the first study to compare the mechanism of TVP to the more common and familiar AVP. TVP patients have higher major operative needs compared to AVP patients when they survive to the ED, with higher in-house complications. While TVP has a higher mortality rate than AVP, this relationship did not persist after adjusting for differences in patient characteristics and operative intervention. Therefore, these patients should be transported to major trauma centers, whenever possible. The similar mortality for AVP and TVP after adjustment for covariates despite higher major operative burden may be attributed to appropriate triage and transfer practices by emergency medicine and surgical teams of TVP patients. When the trauma team learns that a pedestrian struck by a train is en route to their hospital, they can anticipate a higher likelihood of immediate operative intervention, as well as a more complicated and prolonged hospital course. Patients that survive the early phase of treatment often have surgically correctable issues, however, they are predictably fraught with postoperative complications.

Limitations

This study is limited by its retrospective nature, as well as its reliance on NTDB data. It is at risk of convenience sampling error. Data regarding national injury incidence and prevalence may be invalid as a disproportionate number of larger hospitals with younger and more severely injured patients may be included. Selection bias may be present when differences in inclusion and exclusion criteria at different trauma centers may alter the calculated "risk-adjusted" mortality of an injury. For example, an isolated hip fracture is a lower-risk injury that is included in some trauma center registries and not in others. Information bias also occurs as different institutions may calculate ISS score differently by different registries or when centers submit incomplete AIS and ISS data. Incomplete data on patient complications may falsely appear as delivery of better care quality or outcomes compared to a hospital that records every complication. Additionally, this 2007–2012 database was the most complete NTDB database available to us at the time the study was performed.

Future Studies

The safety campaign, "*Stop. Trains Can't*" ran February 26, 2018 through April 1, 2018 in English and Spanish as a joint effort by the National Highway Traffic Safety Administration and Federal Railroad Administration (FRA) to address the problem of railroad crossing crashes based on 94% of all railroad fatalities and injuries occurring at railroad crossings or due to trespassing based on railroad accident reports filed with FRA. It will be interesting to see if this campaign impacts railroad injury patterns subsequent to their intervention.

CONCLUSIONS

While TVP is not as common as AVP, the injury burden and need for operation intervention are higher in patients that survive to the ED. This trauma mechanism may warrant transfer to major trauma centers whenever feasible. TVP mechanism morbidity is higher with no difference in mortality compared to AVP.

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ARTICLE SUMMARY

1. Why is this topic important?

Train vs. pedestrian (TVP) is associated with a significant injury burden. These patients have a significantly higher need for immediate operation and more complicated hospital course.

2. What does this study attempt to show?

While TVP is not as common as automobile vs. pedestrian (AVP), the injury burden and need for operative intervention are higher in patients that survive to the emergency department. The morbidity associated with TVP is higher, with no difference in mortality compared to AVP.

3. What are the key findings?

On multivariable logistical regression, TVP was an independent predictor for higher injury burden, Injury Severity Score ≥ 25 (adjusted odds ratio [AOR] 1.650), immediate operative need (AOR 7.535), and complications (AOR 1.317). However, multivariate logistic regression suggested no differences in mortality when comparing TVP with AVP (AOR 0.818; $p = 0.091$).

4. How is patient care impacted?

When the trauma team learns that a pedestrian struck by a train is en route to their hospital, they can anticipate a higher likelihood of immediate operative intervention, as well as a more complicated hospital course.