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Original Research

Trends of Hospitalizations and In-Hospital Outcomes for Traumatic Cardiac Injury in United States

Harsh Mehta, MBBS[1,2], Zaid Gheith, M.D.[1,3], Saad Amin, M.D.[4,5], Prakash Acharya, M.D.[1,2], Emmanuel Daon, M.D.[1,6], Peter Downey, M.D.[1,6], Eric Hockstad, M.D.[1,2], Mark Wiley, M.D.[1,2], Gregory Muehlebach, M.D.[1,6], George Zorn III, M.D.[1,6], Matthew Danter, M.D.[1,6], Kamal Gupta, M.D.[1,2]

[1]University of Kansas School of Medicine-Kansas City, Kansas City, KS
[2]Department of Cardiovascular Medicine
[3]Department of Internal Medicine
[4]University of Texas Medical Branch, Galveston, TX
[5]Department of Internal Medicine
[6]Department of Cardiothoracic Surgery

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ABSTRACT

Introduction. Traumatic cardiac injury (TCI) poses a significant risk of morbidity and mortality, yet there is a lack of population-based outcomes data for these patients.

Methods. The authors examined national yearly trends, demographics, and in-hospital outcomes of TCI using the National Inpatient Sample from 2007 to 2014. We focused on adult patients with a primary discharge diagnosis of TCI, categorizing them into blunt (BTCI) and penetrating (PTCI) cardiac injury.

Results. A total of 11,510 cases of TCI were identified, with 7,155 (62.2%) classified as BTCI and 4,355 (37.8%) as PTCI. BTCI was predominantly caused by motor vehicle collisions (66.7%), while PTCI was mostly caused by piercing injuries (67.4%). The overall mortality rate was 11.3%, significantly higher in PTCI compared to BTCI (20.3% vs. 5.9%, $\chi^2(1, N = 11{,}185) = 94.9$, $p < 0.001$). Additionally, 21.5% required blood transfusion, 19.6% developed hemopericardium, and 15.9% suffered from respiratory failure. Procedures such as heart and pericardial repair were more common in PTCI patients. Length of hospitalization and cost of care were also significantly higher for PTCI patients, $W(1, N = 11{,}015) = 88.9$, $p < 0.001$).

Conclusions. Patients with PTCI experienced higher mortality rates than those with BTCI. Within the PTCI group, young men from minority racial groups and low-income households had poorer outcomes. This highlights the need for early and specialized attention from emergency and cardiothoracic providers for patients in these demographic groups.
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INTRODUCTION

The 2015 National Trauma Data Bank (NTDB) annual report indicates that falls and motor vehicle collisions are the primary causes of traumatic injuries, with chest trauma reported in 23% of cases.[1] Chest trauma ranks as the second leading cause of death in vehicle collisions, second only to head injuries.[2] Traumatic cardiac injuries (TCI) are common in chest and polytrauma patients and are often fatal.[3-8]

TCIs can be classified into two categories based on the mechanism of injury: blunt traumatic cardiac injury (BTCI) and penetrating traumatic cardiac injury (PTCI). BTCI often is caused by a direct blow to the chest, compression of the heart between the sternum and the spine, shearing injury due to sudden deceleration, or a combination of these factors.[9] On the other hand, PTCI results from a direct stab wound, firearm/gunshot wound, or blast injuring the heart.[10,11] These injuries can range in severity from benign dysrhythmias to chamber contusions or rupture, valvular leaflet tears, and injuries to the great vessels or coronary arteries.[4-6,12,13] Despite the high mortality associated with TCI, there is a lack of data to adequately identify risk factors for poorer outcomes and guide early treatment strategies for these higher-risk patients. Therefore, this study aimed to assess temporal trends, demographic characteristics, and in-hospital outcomes of patients with TCI using a U.S.-based national population database.

METHODS

We utilized the National Inpatient Sample (NIS) from 2007 to 2014, a database maintained by the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality. The NIS represents a 20% sample of over 97% of inpatient discharges from non-federal hospitals in the U.S., stratified by hospital size, location, region, and teaching status. It excludes discharges from the emergency department and all patient information is deidentified. The database includes diagnoses and procedures reported using International Classification of Diseases, 9th Edition (ICD-9-CM) codes, as well as outcomes such as mortality and length of hospital stay. HCUP conducts numerous quality checks to ensure data accuracy, including cross-checking with the National Hospital Discharge Survey.[14]

The study included all adults (aged 18 and older) with a primary discharge diagnosis of TCI, categorized using ICD-9-CM codes. Comorbid conditions, complications, and associated trauma were extracted as secondary diagnoses, with associated trauma further categorized into thoracic, abdominal/pelvic, and back/spine. Modes of injury were defined using external causes of injury codes (ECODES) and grouped into four categories: any vehicle injury, falls, firearm injury, and piercing injury, as per Centers for Disease Control and Prevention (CDC) recommendations (Table 1).[15]

We identified patient demographics (age, gender, race, median household income) and hospital characteristics (region, bed-size, location, teaching status). Patients who died in the hospital were excluded, and the length of hospital stay was estimated in days using the length of stay variable. Total charges for each hospitalization were obtained from the NIS database and converted to hospitalization cost using cost-to-charge ratios (CCR) from HCUP. The total hospitalization cost was adjusted for inflation using consumer price index data from the U.S. Bureau of Labor Statistics to calculate an adjusted cost as of December 2014.[16]

Table 1. Patient characteristics in traumatic cardiac injury.

Measures	TCI (N=11,510)	BTCI (N=7,155)	PTCI (N=4,355)	p Value
Age, mean (SE), y	49.3 ± 0.6	58.4 ± 0.6	34.5 ± 0.5	<0.001
Gender (%)				
Male	71.2	58.5	92.0	<0.001
Female	28.8	41.5	8	
Age groups (%)				<0.001
18-45 years	46.6	27.5	77.1	
46-65 years	26.4	31.1	18.7	
66 years and above	27	41.4	3.2	
Race (%)				<0.001
White	55.4	70.0	32.0	
Black	20.6	11.3	35.6	
Hispanic	16.0	10.7	24.4	
Asian or Pacific Islander	2.6	2.8	2.2	
Native American	1.2	1.0	1.6	
Other	4.2	4.2	4.2	
Primary expected payer (%)				<0.001
Medicare	17.3	23.5	7.0	
Medicaid	15.6	6.4	30.6	
Private insurance	39.4	52.0	18.8	
Self-pay	15.2	8.8	25.8	
No charge	2.1	0.8	4.2	
Other	10.4	8.5	13.6	
Hospital bed-size (%)				<0.001
Small	5.9	7.8	2.8	
Medium	18.0	18.5	17.1	
Large	76.1	73.7	80.1	
Hospital location and teaching status (%)				<0.001
Rural	7.7	11.0	2.2	
Urban, non-teaching	23.5	28.7	14.8	
Urban, teaching	68.8	60.3	83.0	
Hospital region (%)				0.33
Northeast	22.1	22.8	21.1	
Midwest	19.5	20.7	17.4	
South	34.8	34.4	35.5	
West	23.6	22.1	26.0	
Median household income national quartile for patient ZIP code (%)				<0.001
0-25th percentile	35.0	28.2	46.6	
26-50th percentile	24.8	25.3	23.9	
51-75th percentile	22.8	24.7	19.9	
76-100th percentile	17.4	21.8	9.6	
Comorbidities (%)				
Chronic ischemic heart disease	13.6	20.8	1.7	<0.001
Hypertension	32.9	46.2	11.0	<0.001
Diabetes mellitus	11.8	17.0	3.2	<0.001
Heart failure	7.7	11.0	2.3	<0.001
Dyslipidemia	14.9	23.2	1.4	<0.001
Obesity	4.8	6.1	2.7	<0.001
Chronic kidney disease	4.7	7.4	0.2	<0.001
Atrial fibrillation/flutter	11.1	13.9	6.4	<0.001
Chronic liver disease	1.4	1.8	0.8	0.05
Chronic lung disease	8.8	11.7	4.0	<0.001
Mental disorders (psychotic/mood)	5.3	2.7	9.7	<0.001
Alcohol use disorder	7.2	5.7	9.6	<0.001
Smoking use disorder	17.2	18.8	14.6	0.01

BTCI: blunt traumatic cardiac injury; PTCI: penetrating traumatic cardiac injury; TCI: traumatic cardiac injury.

Weights from the variables "TRENDWT" (up to 2011) and "DISCWT" (from 2012 onward) in the NIS database were used in weighting and stratification methods to produce national estimates. Descriptive statistics were calculated for all study variables, with continuous variables presented as means ± standard error (SE) and compared between blunt and penetrating injury groups using appropriate statistical tests. Categorical variables were presented as frequencies (percentage) and analyzed using the two-way Chi-square test. Trend analysis for continuous and categorical variables was performed using the t-test and two-way Chi-square test, respectively. A p-value of <0.05 was considered statistically significant. Data analysis was conducted using STATA 13.0 SE Software package.

RESULTS

A total of 11,510 weighted discharges with a primary diagnosis of TCI were identified over the eight-year period. Among these, 7,155 (62.2%) patients had BTCI, and 4,355 (37.8%) patients had PTCI. Figure 1 illustrates that although there was a non-statistically significant declining trend in overall TCI admissions, the proportion of PTCI cases increased over the years.

Figure 1. Trends of traumatic cardiac injury.

Demographic information and underlying comorbidities in the study population are summarized in Table 1. The patients were generally young (mean age 49.3 years), mostly male (71.2%), and tended to come from lower-income households. The majority were admitted to large (76.1%) and urban-teaching (68.8%) hospitals. Significant differences were observed between the BTCI and PTCI groups. Patients with PTCI were younger (mean age 34.5 years vs. 58.4 years), predominantly male (92% vs. 58.5%), of non-Caucasian races, and more likely to be from the lowest income quartile (46.6% vs. 28.2%). The PTCI group had fewer comorbidities overall, except for higher rates of mental disorders (psychotic/mood; 9.7% vs. 2.7%) and alcohol use disorder (9.6% vs. 5.7%).

Motor vehicle collisions were the most common cause of BTCI (66.7%), while PTCI were primarily caused by piercing injuries (67.4%) and firearm-related injuries (21.2%; Table 2). Additionally, most patients had associated non-cardiac thoracic injuries, with a minority also experiencing abdominal/pelvic or spine injuries.

Table 2. Traumatic cardiac injury, in-hospital complications, and procedures.

Measures	TCI (N=11,510)	BTCI (N=7,155)	PTCI (N=4,355)	p Value
External cause of injury (%)				
Motor vehicle collision	42.0	66.7	1.3	<0.001
Falls	6.7	10.0	1.2	<0.001
Firearms	8.3	0.5	21.2	<0.001
Piercing or cutting injury	26.9	2.3	67.4	<0.001
Associated injury (%)				
Extra cardiac thoracic injury	61	53.2	73.9	<0.001
Abdominal or pelvic injury	16.1	9.4	27.0	<0.001
Spine or back injury	8.4	10.8	4.6	<0.001
In-hospital clinical events (%)				
Need for blood transfusion	21.5	8.6	42.8	<0.001
Shock	13.9	5.9	27.1	<0.001
Myocardial infarction	3.4	4.0	2.5	0.07
Hemopericardium	19.6	6.4	41.4	<0.001
Ventricular arrhythmias	5.8	4.7	7.5	0.006
Acute kidney injury	7.6	7.1	8.6	0.21
Acute respiratory failure	15.9	9.4	26.6	<0.001
Sudden cardiac arrest	8.8	3.7	17.2	<0.001
Procedures (%)				
Endotracheal intubation	26.6	12.4	49.9	<0.001
Thoracentesis/chest tube	19.8	6.6	41.6	<0.001
Thoracotomy	10.3	2.7	22.9	<0.001
Median sternotomy	1.0	0.3	2.2	<0.001
Heart or pericardial repair	35.5	7.1	82.3	<0.001
Pericardiocentesis	2.5	1.4	4.4	<0.001
Pericardial window	15.6	4.1	34.4	<0.001
Coronary angiography	5.9	8.5	1.5	<0.001
Coronary angioplasty	0.2	0.3	0.0	0.13
Coronary artery bypass grafting	0.7	0.5	1.2	0.07
Valve surgery	1.2	0.9	1.9	0.05

BTCI: blunt traumatic cardiac injury; PTCI: penetrating traumatic cardiac injury; TCI: traumatic cardiac injury.

Table 2 presents in-hospital clinical events and procedures during TCI-related hospitalizations. Overall, 21.5% of patients required blood transfusion, 19.6% developed hemopericardium, and 15.9% experienced respiratory failure. The incidence of most complications was higher in PTCI patients compared to BTCI patients, with more PTCI patients undergoing operative management, including heart or pericardial repair (82.3%), pericardial window (34.4%), and thoracotomy (22.9%).

The overall mortality rate for TCI patients was 11.3%, with a mean length of stay of 7.9 days. Patients with PTCI had significantly higher mortality, longer hospital stays, and higher hospitalization costs compared to those with BTCI (Table 3). There were no significant changes observed in mortality, length of stay, or inflation-adjusted cost of hospitalization over the study period (Figure 2).

Table 3. In-hospital outcomes in traumatic cardiac injuries.

Measures	TCI (N=11,510)	BTCI (N=7,155)	PTCI (N=4,355)	p Value
Mortality (%)	11.3	5.9	20.3	<0.001
Mean Length of Stay (days)	7.9 ± 0.4	5.0 ± 0.2	13.4 ± 0.9	<0.001
Inflation adjusted hospitalization cost ($)	27,924.1 ± 1,280	17,717.6 ± 905.7	47,175.5 ± 2,843	<0.001
Disposition after live discharge (%)				0.27
Routine	71.5	70.8	72.8	
Transfer to short-term hospital	3.9	3.9	4.0	
Transfer other: SNF, ICF, other facility	15.3	15.1	15.8	
Home health care	7.8	8.8	5.9	
Against medical advice	0.1	0.01	0.2	

BTCI: blunt traumatic cardiac injury; PTCI: penetrating traumatic cardiac injury; TCI: traumatic cardiac injury.

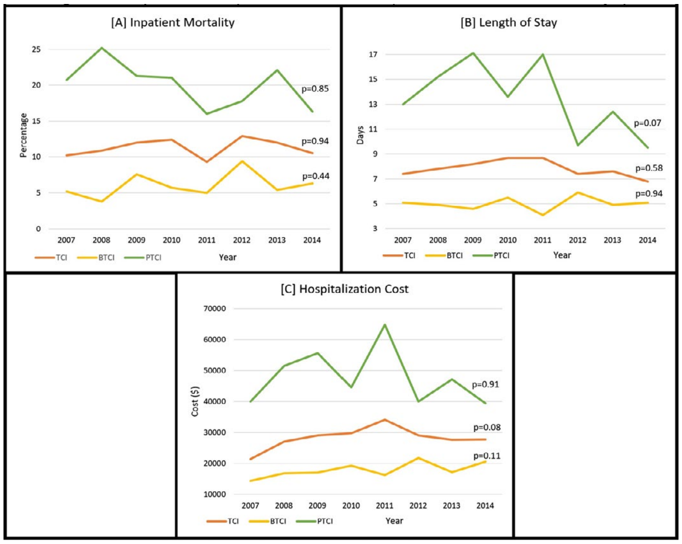

Figure 2. Yearly trends of hospitalization outcomes in patients with TCI.

DISCUSSION

This study represents the first nationwide, population-based analysis of TCI-related hospitalizations in the U.S. Our findings shed light on key aspects including demographics, in-hospital outcomes, cost of care, and national trends over an eight-year period.

Our analysis revealed that over 60% of patients had BTCI, with the remainder having PTCI. While previous studies, such as that by Asensio et al.,[7] have focused on outcomes associated with PTCI, limited attention has been given to BTCI. Unlike PTCI, BTCI can be challenging to confirm, particularly in cases of polytrauma, and can manifest as anything from minor myocardial contusions to dysrhythmias to cardiac rupture, with most cases likely involving non-life-threatening cardiac damage.[11,17] Due to the lack of standardized reporting criteria, the reported incidence of BTCI in chest trauma has varied widely, from 8% to 76%.[18] For example, a report from the Oklahoma trauma registry found that BTCI accounted for 62% of all TCI hospitalizations, a figure similar to our national findings.[13]

While our analysis did not identify a significant increase in overall TCI cases over the eight-year period studied, we did observe a rising trend in the proportion of PTCI cases. This increasing proportion of PTCI cases aligns with findings from the Oklahoma registry, suggesting a shifting landscape in traumatic cardiac injuries.[13]

Our findings support previous research from single-center and regional studies indicating that TCI patients are typically younger and predominantly male. We also observed that compared to those with BTCI, patients with PTCI tended to be younger, overwhelmingly male, and the majority were in the lower income category. For instance, Morse et al.[5] reported in their 36-year single-center study of PTCI that 86% of patients were male with a mean age of 32 years. These results closely resemble ours, where the mean age for PTCI patients was 34 years and 92% were male. Because PTCI patients were much younger, they also had a significantly lower prevalence of most co-morbidities, except for mental disorders and alcohol use, which were higher.

The differences in demographics and co-morbidities between BTCI and PTCI patients likely can be attributed to the causes of these injuries. Most BTCIs result from vehicular collisions, whereas PTCIs are more often related to stabbings or firearm injuries. We also noted significant racial differences, with Caucasians constituting the majority of BTCI patients, while non-Caucasians made up more than two-thirds of the PTCI group. This aligns with the findings of Mikhail et al.[19] in their study of a single trauma center population (not limited to TCI), where they observed that African American patients more frequently belonged to lower socio-economic strata, experienced penetrating injuries more often, and had a higher in-patient mortality compared to Caucasians.

Examining eight-year trends, we discovered that although the overall hospitalization rate for TCI remained stable, there was a rise in the percentage of TCIs resulting from piercing injuries. This trend likely signifies an increase in violent injuries from stabbings or gunshots. However, it also may be linked to enhancements in emergency medical services (EMS) delivery and the increased availability of specialty ground and air EMS vehicles, facilitating the rapid transport of these patients to hospitals.[20]

In a condition like TCI, which can be immediately fatal after occurrence and where survival depends on rapid triage to a major trauma center, one must be cautious when drawing conclusions based on hospital mortality data. Local EMS capabilities, trauma protocols, and ease of access to trauma centers directly impact in-hospital outcomes. For example, over a 36-year study period at Grady Memorial Hospital, overall mortality consistently increased from 1975-1985 to 2000-2010 (27% vs. 42%),[5] despite improvements in local EMS and institutional trauma protocols. The authors suggested that contributing factors were an improved survival rate to hospital arrival due to a better community ambulance system and a significant increase in gunshot wound-related TCI, which have a higher mortality rate. Similarly, the Oklahoma registry report found a significant 10-year trend toward increased mortality related to TCI, paralleling a significant increase in the proportion of PTCI.[13] They reported a mortality rate of 51.2% with PTCI and 26.3% with BTCI. Additionally, utilizing the NTDB databases, Teixeira et al.[7] reported a mortality rate of 67.6% for blunt cardiac ruptures, and Asensio et al.[8] reported a mortality rate of 66% for penetrating cardiac injuries. We found a significantly lower in-hospital mortality for both BTCI (5.9%) and PTCI (20.3%). Several factors could explain these differences, such as the inclusion of a wide variety of hospitals, regional or state-level differences, and the fact that we used the primary discharge diagnosis of TCI as an inclusion criterion. This might have resulted in the exclusion of patients who may have had other major associated trauma that resulted in a different primary diagnostic code.

Regarding major procedures performed, our findings were similar to those previously reported by Tran et al.,[13] who showed that patients with PTCI underwent significantly more procedures, including heart or pericardial repair in 82%. This likely explains the increased hospitalization cost in PTCI patients.

We observed a low mortality rate in BTCI patients and a non-significant downward trend in mortality over the study period. This trend may be related to the fact that most of these patients were involved in vehicular collisions, which aligns with a report from the Insurance Institute of Highway Safety showing a 15% decline in deaths related to motor vehicle collisions between 2007 and 2015.[21] However, since motor-vehicle collision-related injuries were the most common cause of BTCI, our study aims to encourage discussions around more robust compliance with motor vehicle safety and seatbelt laws.

Myocardial infarction was the only complication that occurred more frequently in the BTCI group. Although rare, myocardial infarction has been reported after blunt chest trauma, with Demerouti et al.[22] reporting 189 such cases, where they found coronary artery dissection to be the major mechanism and the left anterior descending artery the most involved artery. In our study population, this also could be possible due to the finding that patients in the BTCI group were significantly older, with a higher burden of established risk factors for atherosclerotic cardiovascular disease, such as hypertension, diabetes mellitus, dyslipidemia, obesity, and smoking, as well as a higher burden of established chronic ischemic heart disease and heart failure.

The presence of these risk factors, combined with trauma, might have led to electrocardiographic abnormalities and cardiac enzyme elevations in patients, prompting clinicians to perform a coronary angiography, which was done in 8.5% of cases in our study. However, only 0.3% of patients required a coronary angioplasty, which could possibly indicate that myocardial contusion or a demand-supply mismatch could have contributed to these abnormalities.

Limitations. Our study has several limitations. Firstly, since all the data were obtained from the NIS database, the identification of the study cohort and the variables used in the study depend heavily on the accuracy of coding procedures. However, the NIS has been extensively validated over the years, and any misclassification occurring from inaccuracies in ICD-9-CM codes (including ECODES) would likely be distributed uniformly, allowing for the generalizability of the data.[23,24]

Another limitation is that we selected a population of only discharges with a primary discharge diagnosis of TCI. Many patients with TCI would have other significant diagnoses, which could have been coded as a primary discharge diagnosis, with TCI being coded as a secondary diagnosis. Additionally, the NIS does not incorporate discharges from the emergency department. Thus, our study likely underestimates the prevalence of TCI and the associated mortality. However, our reasoning behind including only those discharges with a primary diagnosis of TCI was to improve the accuracy of our study by eliminating those patients who could have been misclassified as having TCI.

It is important to note that NIS databases from 2007 to 2009 were not capable of excluding transfers to another facility, so there is a possibility that some discharges might have been double-counted, which is an inherent limitation of a large population-based database. Furthermore, while the NIS is available through 2019, we limited our study through 2014 because ICD-10-CM codes were adopted in the fourth quarter of 2015, and a direct conversion from ICD-9-CM to ICD-10-CM was not available for certain codes utilized in our study.

Additionally, higher Injury Severity Scores (ISS), which have been reported by studies utilizing trauma registries, seem to correlate with mortality. However, due to the nature of the administrative database used, we were unable to report ISS, which is another limitation of our study. Lastly, due to the cross-sectional nature of the database of hospitalization records, we do not have data on follow-ups or subsequent readmissions. Despite these limitations, we believe that our study offers the first look at national data on TCI and adds significantly to the literature on cardiac trauma.

CONCLUSIONS

In conclusion, our descriptive study outlines trends and in-hospital outcomes of TCI in the U.S. population. We found that compared to patients with BTCI, those with PTCI had significantly higher mortality rates. Young male patients from minority racial groups, who belonged to low-income households, were identified as being at higher risk for poorer outcomes. Therefore, emergency medicine and cardiothoracic providers should pay special attention when caring for patients from these demographic groups.

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