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Authors

Laytin, Adam D
Kumar, Vineet
Sarang, Bhakti
[et al.](#)

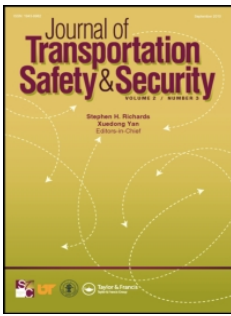
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Patterns of injury mechanism at a tertiary trauma center in Mumbai, India: Opportunities for injury prevention

Adam D. Laytin^{a,b}, Vineet Kumar^c, Bhakti Sarang^d, Nobhojit Roy^d,
Rochelle A. Dicker^a, and Catherine J. Juillard^a

^aCenter for Global Surgical Studies, Department of Surgery, University of California—San Francisco, San Francisco, California, USA; ^bDepartment of Emergency Medicine, Oregon Health & Science University, Portland, Oregon, USA; ^cDepartment of Surgery, Lokmanya Tilak Municipal Medical College, Mumbai, India; ^dDepartment of Surgery, BARC Hospital, Government of India, Mumbai, India

ABSTRACT

This study aims to describe patterns of injury mechanism among patients treated at a tertiary trauma center in Mumbai to identify opportunities for targeted injury prevention strategies. Data were collected from an institutional trauma registry, and all patients presenting with life- or limb-threatening injuries over a 16-month period were included. Univariate and bivariate analyses were performed for demographic characteristics, injury mechanisms, and clinical outcomes. A total of 1,115 patients were treated during the study period, and the in-hospital mortality rate was 32% in this severely injured cohort. More than one half of patients were suffered transportation injuries (58%). Of victims of transportation injuries, 45% were victims of railway injuries and 28% were pedestrians struck by motor vehicles. Mortality was highest among victims of railway injuries (42%) and pedestrians struck by automobiles (38%). Although injury prevention is a major public health concern worldwide, it is important to understand local patterns of injury to guide targeted prevention strategies. This study highlights the utility of trauma registries in collecting crucial injury surveillance data. In this context, a focus on pedestrian safety and railway injury prevention is warranted.

KEYWORDS

injury prevention; traffic injury; railway; pedestrian; India

1. Introduction

Injury accounts for at least 10% of deaths worldwide, and low- and middle-income countries are disproportionately affected (World Health Organization [WHO], 2010). As these countries industrialize, the burden of injury continues to grow (Mock, Kobusingye, Anh, Afukaar, & Arreola-Risa, 2005; World Health Organization Department of Violence and Injury Prevention and Disability, 2009). Many injury-related deaths can be avoided with established injury prevention strategies and improvements in trauma care, but robust injury surveillance is crucial to

CONTACT Catherine J. Juillard  catherine.juillard@ucsf.edu  San Francisco General Hospital, 1001 Potrero Ave, Campus Box 0807, San Francisco, CA 94110, USA.

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inform context-appropriate interventions (Mock, Joshipura, Arreola-Risa, & Quansah, 2012; Mock, Quansah, Krishnan, Arreola-Risa, & Rivara, 2004). Trauma registries are invaluable surveillance tools that elucidate patterns of injury and their public health implications (Chichom Mefire, Etoundi Mballa, Azabji Kenfack, Juillard, & Stevens, 2013; Kobusingye & Lett, 2000).

The WHO (2009) estimates that 10% of deaths and 13% of disability-adjusted life years lost in India are due to injury. Road traffic injuries (RTIs) comprise the majority of India's injury-related deaths; the National Crime Records Bureau (2013) reported 440,000 RTIs resulting in 140,000 deaths in 2013. Multiple hospital-based studies have shown that the majority of victims of RTI are pedestrians or on two-wheeled vehicles at the time of injury (Deshmukh, Ketkar, & Bharucha, 2012; Radjou, Balliga, Pal, & Mahajan, 2012; Uthkarsh et al., 2012). Patterns of injuries among children differ, with falls outnumbering RTIs (Sharma et al., 2011; Verma, Lal, Lodha, & Murmu, 2009).

Despite the burden of injury, trauma systems in India are still in the early development phase and are hampered by resource limitations and lack of coordination (Joshipura, 2008; Roy et al., 2010). Studies have shown that injury-related mortality is twice the expected rate in multiple Indian hospitals (Deshmukh et al., 2012; Murlidhar & Roy, 2004). Trauma quality improvement programs that rely on trauma registries have been shown to be effective in improving care, decreasing mortality, and reducing cost (Juillard, Mock, Goosen, Joshipura, & Civil, 2009).

The purpose of this study is to use data from an institutional trauma registry in Mumbai to describe the epidemiology of trauma patients presenting to a tertiary trauma center to identify opportunities for targeted injury prevention measures in this context and elucidate needs for further research.

2. Method

2.1. Study setting

This retrospective review was conducted using data from the institutional trauma registry of Lokmanya Tilak Municipal General Hospital (LTMGH), a busy, urban, public tertiary trauma center in Mumbai, India. Because LTMGH provides government-subsidized care, 70% of its patients come from the slums in and around Mumbai. It is one of the four tertiary trauma centers in the city to receive patients transferred from peripheral public and private hospitals with inadequate infrastructure or resources to provide appropriate care for patients who are severely injured. LTMGH receives the bulk of patients with road traffic injuries from the outskirts of the city due to its proximity to a major highway into Mumbai. LTMGH has an institutional trauma registry in operation since 1998 (Gerdin et al., 2014; Murlidhar & Roy, 2004).

There is no organized prehospital ambulance or emergency medical response system in Mumbai or the surrounding area. Prehospital care is minimal, and there is no system of prehospital triage. Patients transferred to LTMGH from other health care facilities may have received some resuscitative interventions prior to transfer, though these are not standardized.

2.2. Methodology

All trauma patients who are severely injured are cared for by the trauma service, which is always staffed by registrars. The registrar in surgery with the trauma service routinely completes an intake form, which includes information regarding the patient's age, gender, mechanism of injury, transfer status, vital signs, and Glasgow Coma Score on arrival, as well as interventions performed following arrival in the Emergency Department and disposition from the Emergency Department. Additional data regarding hospital course and mortality are collected during the hospital stay, then compiled by an independent research officer.

Although the LTMGH collects data to quantify injury severity with Injury Severity Score (ISS), a recent report demonstrated poor correlation between ISS and in-hospital mortality at LTMGH, raising concerns about the accuracy of ISS in this setting (Laytin et al., 2015). For this analysis, injury severity was instead quantified retrospectively using the GAP score, a simple physiologic injury severity scoring system based on Glasgow Coma Scale (Teasdale & Jennett, 1974), Age and (Systolic Blood) Pressure (Kondo et al., 2011). The GAP score assigns a value from 3 to 24, with injuries classified as mild (19–23), moderate (11–18) and severe (3–10). The GAP score has been shown to have a high correlation with in-hospital mortality at LTMGH (Laytin et al., 2015).

All patients presenting to LTMGH with life- or limb-threatening injuries according to the criteria of the WHO Trauma Checklist (Laytin et al., 2015) study over a 16-month period between October 2010 and February 2012 were included. Patients with minor or isolated limb injuries were not included in this analysis, nor were those with burn injuries and those presenting after near drowning. Gunshot wounds, stab wounds, and lacerations were classified as penetrating, whereas all other injury mechanisms were classified as blunt.

Trauma registry data were entered into the EpiInfo 6 software (CDC Statistical package; Centers for Disease Control and Prevention, Atlanta, GA), transferred to Microsoft Excel (Microsoft, Redmond, WA) for cleaning, and then imported to Stata 13 statistical software (StateCorp, College Station, TX) for analysis. Anonymous, deidentified data were shared with authors at the Center for Global Surgical Studies, Department of Surgery, University of California San Francisco for analysis.

2.3. Statistical analysis

Univariate and bivariate analyses were performed for all demographic characteristics, transfer status, and mechanisms. Subanalyses of genders, age groups, transfer status, and mechanisms of injury were performed. Bivariate analyses were done using the chi-squared test for categorical variables when all group contained at least five elements and Fisher's exact test otherwise, and the Student's *t*-test for continuous variables. Logistic regression models were created to evaluate predictors of in-hospital mortality, using demographic factors, injury mechanisms, and transfer status as independent variables and

in-hospital mortality as the dependent variable. A p value of less than 0.05 was determined to be statistically significant.

2.4. Ethical approval

This study was approved by the LTMGH institutional ethics committee, the World Health Organization Ethics Review Committee, and the University of California San Francisco Committee on Human Research.

3. Results

3.1. Demographics

A total of 1,115 patients treated in the Lokmanya Tilak Municipal General Hospital Trauma Ward between October 2010 and February 2012 met inclusion criteria. The mean age of patients who were injured was 30.8 years ($SD = 17.1$), and 88% were male. On average, female patients were younger than males (mean age 27.9 vs. 31.2, t test $p = .04$). More female patients were at the extremes of age, with 39% of female patients younger than 15 versus 9% of males ($p < .01$ in a 2×2 chi-squared model with age dichotomized as <15 vs. ≥ 15 years) and 16% of female patients older than age 60 versus 7% of males ($p < .01$ in a 2×2 chi-squared model with age dichotomized as ≤ 60 vs. >60 years) (Figure 1).

3.2. Mechanisms of injury

The majority of injuries were related to transportation ($n = 651$, 58%). The most common mechanisms of injury were RTIs ($n = 355$, 32%), railway injuries ($n = 296$, 27%), and falls ($n = 271$, 24%). Penetrating mechanisms

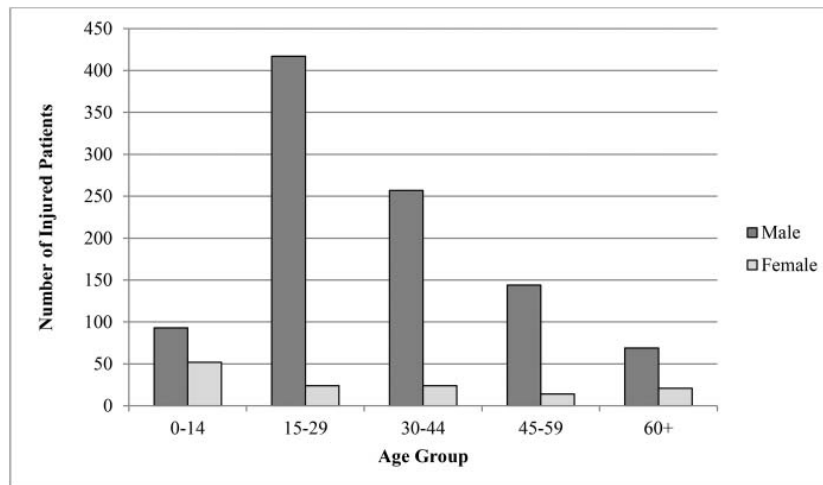


Figure 1. Distribution of trauma patients by age group and gender.

Table 1. Distribution of injury mechanisms by sex and age group.

Mechanism	Total N (column %)	Sex		p Value	Age Group			p Value
		Male, n (row %)	Female, n (row %)		0–14, n (row %)	15–59, n (row %)	60+, n (row %)	
RTI - pedestrian	184 (17)	160 (87)	24 (13)	0.67	23 (13)	140 (76)	21 (11)	0.14
RTI - 2-wheel	106 (10)	100 (94)	6 (6)	0.03	2 (2)	104 (98)	0 (0)	< 0.01 ^a
RTI - 4-wheel	65 (6)	60 (92)	5 (8)	0.26	8 (12)	53 (82)	4 (6)	0.94 ^a
Railway	296 (27)	272 (92)	24 (8)	0.01	10 (3)	267 (91)	18 (6)	< 0.01
Fall	271 (24)	211 (78)	60 (22)	< 0.01	94 (35)	144 (53)	32 (12)	< 0.01
Other blunt	71 (6)	59 (83)	12 (17)	0.20	7 (10)	57 (80)	7 (10)	0.60
Penetrating	78 (7)	74 (95)	4 (5)	0.05 [*]	1 (1)	74 (96)	2 (3)	< 0.01 ^a
Unknown	44 (4)	44 (100)	0 (0)	< 0.01 ^a	0 (0)	41 (93)	3 (7)	< 0.01 ^a
Total	1115	980 (88)	135 (12)		145 (13)	880 (79)	87 (8)	

RTI = road traffic injury.

^aFor each individual injury mechanism, mechanism was dichotomized (e.g., falls vs. not falls), and compared to sex in 2 × 2 models and to age group in 2 × 3 models using the chi-squared test or Fisher’s exact test.

accounted for 78 injuries (7%), of which 75 (96%) were due to stab wounds or lacerations and only three were due to gunshot wounds (4%). Other blunt mechanisms, including mostly blunt assault and workplace injuries, accounted for 71 injuries (6%). Victims of railway injuries and two-wheel vehicle RTIs were more likely to be male (Table 1). Injury mechanisms were not distributed equally across age, with more transportation injuries, and particularly railway injuries and motorcycle injuries, more common among patients age 15 to 59.

Among the 651 transportation injuries, 296 were railway injuries (45%), 184 were pedestrians struck by vehicles (28%), 106 were injured while riding motorcycles or bicycles (16%), and 65 were injured while driving or riding in four-wheeled motor vehicles (10%) (Figure 2).

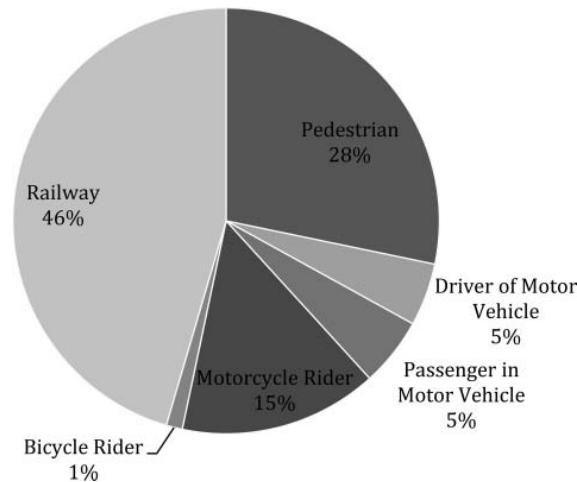


Figure 2. Types of transportation injuries (n = 651).

3.2. Injury severity

Sufficient data were available to calculate a GAP value for 1,024 patients (92%). Of these, 533 were mildly injured with a GAP value of 19 to 23 (52%), 414 were moderately injured with a GAP value of 11 to 18 (40%) and 77 were severely injured with a GAP value of 3 to 10 (8%). The distribution of injury severity differed by mechanism, with more moderate and severe injuries among victims with transportation injuries (54% vs. 40%, $p < .01$). In particular, moderate and severe injuries were significantly more common among pedestrians struck by motor vehicles (58%) and victims of railway injuries (57%) (Table 2).

3.3. Transfer status

LTMGH is a regional trauma center, and a total of 61% of the patients in the sample were transferred from another institution. There was no difference in rate of transfers by sex (61% of men vs. 59% of women, $p = .71$) or age (mean 30.2 among nontransfers vs. 31.2 among transfers, $p = .34$). Victims with transportation injuries were more likely to come directly to LTMGH without receiving medical care elsewhere first, compared with other victims of trauma (42% vs. 35%, $p = .02$). The mean injury severity quantified by GAP score was the same for transferred and non-transferred victims of trauma in general (17.9 vs. 17.6, $p = .31$), and for transferred and nontransferred victims with transportation injuries in particular (17.4 vs. 17.2, $p = .71$).

3.4. In-hospital mortality

Three hundred fifty-seven patients died prior to discharge, with an in-hospital mortality rate of 32%. An additional 44 patients survived to discharge but were believed to be likely to die soon after leaving the hospital (4%). In-hospital mortality was highest among victims with railway injuries (42%, $p < .01$) and pedestrians

Table 2. Distribution of injury mechanism by injury severity.

Injury Mechanism	Total, <i>n</i> (column %)	Mild, <i>n</i> (row %)	Moderate, <i>n</i> (row %)	Severe, <i>n</i> (row %)	<i>p</i> Value
RTI - pedestrian	175 (17)	74 (42)	92 (53)	9 (5)	0.02
RTI - 2-wheel	102 (10)	54 (53)	41 (40)	7 (7)	0.96
RTI - 4-wheel	60 (6)	37 (62)	19 (32)	4 (7)	0.07
Railway	273 (27)	118 (43)	126 (46)	29 (11)	< 0.01
Fall	236 (23)	124 (53)	94 (40)	18 (8)	0.98
Other blunt	67 (7)	45 (67)	17 (25)	5 (7)	0.03
Penetrating	72 (7)	70 (97)	2 (3)	0 (0)	< 0.01
Unknown	39 (4)	11 (28)	23 (59)	5 (13)	< 0.01
Total	1024	533 (52)	414 (40)	77 (8)	

RTI = road traffic injury.

For each individual injury mechanism, mechanism was dichotomized (e.g., falls vs. not falls), and compared to injury severity categories in 2×4 models using the chi-squared test.

Table 3. In-hospital mortality rates by injury mechanism.

Injury Mechanism	Total, <i>n</i> (column %)	Nonfatal, <i>n</i> (row %)	Fatal, <i>n</i> (row %)	<i>p</i> Value
RTI - pedestrian	184 (17)	115 (63)	69 (38)	0.08
RTI - 2-wheel	106 (10)	79 (75)	27 (25)	0.13
RTI - 4-wheel	65 (6)	46 (71)	19 (29)	0.62
Railway	296 (27)	172 (58)	124 (42)	< 0.01
Fall	271 (24)	189 (70)	82 (30)	0.48
Other blunt	71 (6)	61 (86)	10 (14)	< 0.01
Penetrating	78 (7)	75 (96)	3 (4)	< 0.01 ^a
Unknown	44 (4)	21 (48)	23 (52)	< 0.01
Total	1,115	758 (68)	357 (32)	

RTI = road traffic injury.

^aFor each individual injury mechanism, mechanism was dichotomized (e.g., falls vs. not falls), and compared to in-hospital mortality in 2 × 2 models using the chi-squared test or Fisher’s exact test.

struck by motor vehicles (38%, *p* = .08), and lowest among victims with penetrating injuries (4%, *p* < .01) (Table 3).

Odds of in-hospital mortality statistically significantly increased with injury severity as measured by GAP score, with in-hospital mortality rates of 8%, 48%, and 88% among patients with mildly, moderately, and severe injuries, respectively (Table 4). When controlling for injury severity in a logistic regression model,

Table 4. Logistic regression models of predictors of in-hospital mortality.

Variable	Unadjusted			Adjusting for Injury Severity		
	OR	<i>p</i> Value	95% CI	OR	<i>p</i> Value	95% CI
Injury Severity (bivariate model)						
GAP score	0.71	< 0.01	[0.68, 0.74]			
Age group						
0–14	0.93	0.75	[0.59, 1.46]	0.69	0.26	[0.36, 1.31]
15–29	1			1		
30–44	1.65	< 0.01	[1.18, 2.30]	1.54	0.05	[1.00, 2.36]
45–59	3.37	< 0.01	[2.30, 4.93]	3.93	< 0.01	[2.37, 6.52]
60+	3.75	< 0.01	[2.35, 6.00]	2.21	< 0.01	[1.21, 4.02]
GAP score				0.71	< 0.01	[0.68, 0.74]
Gender						
Female	0.92	0.66	[0.62, 1.35]	0.89	0.67	[0.53, 1.49]
GAP score				0.71	< 0.01	[0.68, 0.74]
Injury mechanism						
Fall	1			1		
RTI - pedestrian	1.38	0.11	[0.93, 2.05]	1.38	0.22	[0.83, 2.29]
RTI - 2-wheel	0.79	0.36	[0.47, 1.31]	0.94	0.86	[0.49, 1.80]
RTI - 4-wheel	0.95	0.87	[0.53, 1.72]	1.21	0.64	[0.55, 2.69]
Railway	1.66	< 0.01	[1.17, 2.35]	1.59	0.05	[1.01, 2.50]
Other blunt	0.38	< 0.01	[0.18, 0.77]	0.41	0.06	[0.16, 1.05]
Penetrating	0.09	< 0.01	[0.03, 0.30]	0.41	0.23	[0.09, 1.79]
Unknown	2.52	< 0.01	[1.32, 4.82]	2.27	0.05	[0.99, 5.20]
GAP score				0.72	< 0.01	[0.69, 0.75]
Transfer status						
Transferred	0.89	0.37	[0.69, 1.15]	1.03	0.85	[0.74, 1.45]
GAP score				0.71	< 0.01	[0.68, 0.74]

OR = Odds ratio; CI = 95% confidence interval; RTI = road traffic injury; GAP = Glasgow Coma Scale, Age, and Systolic Blood Pressure score.

increasing age group was associated with increasing in-hospital mortality rates. The increased likelihood of mortality among pedestrians struck by motor vehicles and victims of railway injuries persisted even after controlling for injury severity. Neither gender nor transfer status was associated with in-hospital mortality.

4. Discussion

Reliable information about the patterns of injury and hospital courses of patients who were severely injured are essential to guide injury prevention strategies in low- and middle-income countries. Documenting and reporting the volume and severity of injury is also essential in advocating for resources in development of systems of care. The data presented here adds to a small body of literature about the clinical realities of trauma care in urban India.

In this patient population, transportation injuries account for more than one half of all injuries and disproportionately affect young men, who are often breadwinners for their families. Despite receiving care in a tertiary trauma center, the in-hospital mortality rate in this severely injured cohort was 32%. Mortality rates were particularly high among victims of railway injuries and pedestrians struck by motor vehicles.

Railway injuries are a unique injury mechanism that is common in Mumbai and accounts for 7% of all unintentional injury deaths nationwide (National Crime Records Bureau, 2013). They often result from passengers falling from overcrowded cars of moving trains. These patients commonly have complex patterns of injuries from falling and striking blunt objects at high speeds. Because the injuries commonly occur in remote areas, these patients have especially prolonged pre-hospital delays in care.

Our findings are similar to those of several single-site, hospital-based cross-sectional studies reporting on patterns of injuries and clinical outcomes in India (Deshmukh et al., 2012; Farooqui et al., 2013; Goel, Kumar, & Bagga, 2004; Radjou et al., 2012; Rastogi, Meena, Sharma, & Singh, 2014; Uthkarsh et al., 2012). These studies all report predominantly young adult male victims of trauma. RTIs are the most common injury mechanism in most reports, followed by falls, with varying proportions of assault and burn injuries. In many cases, two-wheeled vehicles account for the majority of RTIs, suggesting regional variation in road traffic users (Deshmukh et al., 2012; Rastogi et al., 2014; Uthkarsh et al., 2012). Finally, several other studies from academic trauma referral centers noted mortality rates of 31% to 33%, which were much higher than predicted when adjusting for injury severity (Deshmukh et al., 2012; Goel et al., 2004). These rates reflect the severely injured cohort of patients being treated and the system-wide challenges in providing effective trauma care in this context.

This study is unique in that it reports on data from a trauma registry, which continuously collects data on patients who are injured. Data from this trauma registry was also reported 11 years ago (Murlidhar & Roy, 2004). Similar age and

gender distributions were then, and RTIs (39%), falls (27%), and railway injuries (23%) were the most common mechanisms of injury at that time. The mortality rate at that time was 21% with a predicted mortality rate of 11% based on injury severity, suggesting that the burden of trauma treated at this hospital may be increasing over time. A recent analysis shows that after controlling for injury severity, the early hospital mortality rate at LTMGH has significantly decreased since 1998 (Gerdin et al., 2014).

There are several important limitations to this study. We did not have access to data about prehospital mortality or patients who were severely injured who never presented for medical care, which introduces a selection bias that is nearly always inherent to hospital-based data. For example, several Indian studies have suggested that only one third of patients who died from road traffic injuries survived en route to the hospital (Farooqui et al., 2013; Hsiao et al., 2013). In addition, with the available data we are unable to comment on long-term functional outcomes of victims of trauma who survived to discharge. Because there are several trauma centers in Mumbai, the patient makeup at this center does not necessarily reflect the patterns of all injuries treated in the city. Finally, as a retrospective analysis of trauma registry data, this analysis did not include details about how injuries occurred or how they could have been prevented. For example, it would also be helpful to understand whether most railway injuries affected passengers or railway workers to better target prevention strategies. Answering those questions will require focused, prospective data collection using other data sources such as patient interviews and police reports.

Other sources of data about trauma epidemiology in India include regionally aggregated data from police reports that are reported by the National Crime Records Bureau (2013) and reports from community-based surveys and verbal autopsies (Hsiao et al., 2013; Jagnoor et al., 2011; Jagnoor et al., 2012). These sources also highlighted the burden RTIs among young men and the importance of pedestrian safety (Hsiao et al., 2013; National Crime Records Bureau, 2013).

The findings of this study help to identify potential areas of focus when considering strategies to reduce the burden of injury in Mumbai, India. Transportation injuries account for the majority of patients with trauma treated at tertiary trauma center in Mumbai. Most road traffic injuries in this population were due to pedestrians being struck by motor vehicles, as opposed to collisions between two motor vehicles, and these pedestrian injuries were more likely to be fatal. This suggests the importance of public safety initiatives that target road traffic safety for pedestrians, who are the most vulnerable road users. Moving forward, prevention strategies that focus on mixed-usage roadways, traffic law enforcement, and improving sidewalk safety should be explored.

These targets fit into the United Nations Road Safety Collaboration's Global Plan for the Decade of Action for Road Safety (2011–2020), which calls for building road safety management capacity, improving the safety of road infrastructure, and enhancing the behavior of road users (United Nations Road Safety

Collaboration, 2011–2020). A precedent for multidisciplinary efforts to coordinate risk factor reduction has been set at the international level by the Global Road Safety Partnership (2014), which uses capacity building, program coordination, and advocacy to facilitate the sustainable reduction of road traffic casualties in low- and middle-income countries through partnerships between business, civil society and government.

Railway injuries also require special emphasis. A focus on developing safe, affordable public transportation is crucial for reducing the prevalence of pedestrian and railway injuries. Railway safety infrastructure development merits further attention. Shifting financial responsibility for railway injuries to the train companies may encourage the train companies to ensure safe conditions for passengers.

Improved hospital data collection and combining data from multiple hospitals in the city would provide more comprehensive information on the distribution and severity of injuries, which would more optimally guide population-based prevention and treatment strategies. Efforts to establish a multicenter regional trauma registry are underway, which will provide a more comprehensive picture of trauma patients in Mumbai and generate longitudinal data to evaluate the impact of hospital-based and systems-based quality improvement measures. Regional trauma registries have been shown to decrease mortality in other settings (Bouzat et al., 2015; Hemmila et al., 2015; Mock et al., 2005).

5. Conclusions

As India continues to develop, urbanize, and industrialize, the burden of trauma will continue to grow unless appropriate prevention efforts are set in motion simultaneously. Transportation injuries account for the majority of patients seen at tertiary trauma center in Mumbai, and railway users and pedestrians struck by automobiles are especially common and have very high in-hospital mortality rates. It is important to work with local government and law enforcement to use this surveillance data to inform policy, and to collectively look for specific injury prevention strategies based on the current railway safety infrastructure, road usage, and built environments.

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