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Temporal trends in patient characteristics, injury mechanisms and outcomes in pediatric trauma admissions between 2010 and 2017

Fahad Mansuri [a, *], Tara Loux [b], Sandra E. Brooks [b], Nicole Slye [a], Yuanyuan Lu [a], Briana Lewis [b], Henian Chen [a], Kevin E. Kip [a]

[a] Study Design and Data Analysis Center, College of Public Health, University of South Florida, Tampa, FL, 33612, United States
[b] St. Joseph's Children's Hospital, 3001 W. Dr. Martin Luther King Jr. Dr, Tampa, FL, 33607, United States

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ABSTRACT

Introduction: Injuries are a leading cause of preventable morbidity and mortality in children. Mechanisms of injuries and presentations are diverse in pediatric injuries and require special attention. Dedicated pediatric trauma care centers are ideal for management of children with injuries simultaneously serving as sources of research data. The objective of the current study was to identify changes in injury mechanisms, modifiable risk factors, and outcomes independently associated with admissions at a large pediatric trauma center in Tampa, Florida.

Methods: We conducted retrospective analysis of 8-years (2010-2017) of pediatric trauma admissions to a large trauma center. Demographic factors and injury characteristics were examined for temporal trends over two year increments. Temporal changes in admissions with major trauma, admission to ICU, and length of stay were examined using logistic regression analysis, and factors associated with independent temporal trends were identified using ordinal logistic regression modeling.

Results: During the study period, there were 4,934 trauma admissions with a predominance of falls (45.1%) and traffic injuries (20.5%). Trends were observed with less frequent head injuries (2010-2011: 35.7% vs 2016-2017: 28.3%, $p < .01$) and abdominal injuries (2010-2011:10.3% vs 2016-2017: 8.2%, $p = .03$), and more frequent chest injuries (2010-2011: 9.0% vs 2016-2017: 11.4%, $p < .01$). Over the study period, evaluated in 2-year increments, higher use of private insurance (Adjusted Odds Ratio (AOR)=1.44, 95% Confidence Interval (CI) 95% CI: 1.29-1.61) and helicopter transport (AOR=1.91, 95% CI: 1.58 -2.30) was observed. Admissions for drownings (AOR=1.50, 95% CI: 1.10 -2.02) and animal bites (AOR=1.99, 95% CI: 1.46 -2.71) increased during the study period. Improvement in patient outcomes (adjusted for injury severity) were observed with shorter, ≤1 day length of stay (LOS) (AOR=1.19, 95% CI: 1.06 -1.33), reduction in complications (AOR=0.47, 95% CI: 0.33 -0.66), and more admissions without an intensive care unit (ICU) stay (AOR=1.6 95% CI = 1.36 -1.88).

Conclusions: Significant reductions in LOS, ICU stay, and complications were temporally observed despite an increase in admissions with higher use of helicopter transport. These results can most likely be attributed to dedicated pediatric trauma experts and resources available at an integrated pediatric trauma center.

Introduction

Pediatric injury represents one of the most immediate public health threats, resulting in the mortality of nearly 875,000 children ≤18 years of age annually around the world.[1] In the United States, injury is the leading cause of death among children aged 0–19, and remains a leading cause of hospitalization and long-term disability among children.[2] Beyond the initial burden of the physical injuries sustained, an injured child may experience ongoing limitations pertaining to their physical abilities, develop chronic pain, and manifest psychological disorders, such as post-traumatic stress disorder.[3]

Large-scale pediatric trauma registries are progressively

* Corresponding author. Study Design and Data Analysis Center, College of Public Health, University of South Florida, 13201 Bruce B. Downs Blvd, MDC 56, Tampa, FL, 33612, United States.
E-mail address: fahadmansuri@usf.edu (F. Mansuri).

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becoming the standard to inform decision making and to assess priorities for the prevention, control, minimization, and/or elimination of injury in children.[4] These clinical databases capture information on large patient cohorts, and can contribute to the understanding of how applied knowledge can be adapted to recognize important injury-related dynamics within a population.[5] A well-designed trauma registry with accurate, risk-adjusted data can help medical providers, community health agencies, and legislators in implementing a coordinated approach to trauma care and prevention strategies.[4]

A major challenge in addressing pediatric trauma is the need to understand the full spectrum of injury and their outcomes to better identify risk groups. The use of a pediatric trauma registry highlights the role that trauma registries can perform in agenda setting, identifying injury burden, determining resource planning, determining healthcare cost, identifying temporal changes in injury trends, evaluating the impact of injury, and determining success of efforts directed towards injury prevention.[6] In this realm, the present study examined temporal trends in patient characteristics and injuries to better characterize current trauma admissions, and to identify potentially modifiable risk factors in children admitted to the trauma center for future education and prevention efforts.

Methods

Data source and population

This study was an 8-year retrospective pediatric trauma registry review of all traumatic admissions at the state-approved St. Joseph's Children's Hospital– Steinbrenner Emergency/Trauma Center in Tampa, FL. The study period included January 1, 2010, through December 31, 2017, and was approved by Institutional Review Boards at Bay Care Health System and University of South Florida.

Each case was abstracted by a pediatric trauma registrar from the 24-h Emergency Department report. All declared trauma alert admissions, all operative, and non-operative admissions with traumatic injury were included in the registry. We included all patients aged 0–21 years, the age range that is served by the hospital. The pediatric trauma registry database includes sociodemographic factors, type of transport, nature and severity of injury, presence or absence of interventions prior to transport to the hospital, procedures performed while in the hospital, complications, and discharge status. Data for socioeconomic indicators was derived from the American Community Survey (ACS, 2012–2016 5 year data profile) which were available at the zip code level and merged into the primary trauma registry database.[7]

Mechanism of injury (primary cause of admission)

Mechanism of injury was defined as the primary cause at the time of presentation to the trauma center. The primary cause of admission was divided into 9 mutually exclusive categories: animal bite, assault (including rape or stabbing), traffic injuries (including automobile injury, bicycle or ATV injury, pedestrian injury and motorcycle injury), drowning, falls (from any cause), gun-shot wounds, sporting activity injury, suicide/hanging, and other causes (includes injuries that could not be categorized to any injury mechanism categories listed above – example penetrating injury other than by gun, burn injuries, crush injuries, marine injuries etc.).

Table 1
Demographic factors by year of admission to the pediatric trauma center.

Factor	Year of Admission				
	2010–2011 (n = 1092, 22.1%)	2012–2013 (n = 1135, 23.0%)	2014–2015 (n = 1291, 26.2%)	2016–2017 (n = 1416, 28.7%)	*p*-value
Age in years, mean (SD)[a]	8.7 (6.0)	9.1 (5.9)	8.7 (5.9)	8.8 (5.6)	0.41
Gender, *n (%)*					0.73
Male	673 (61.6)	734 (64.7)	833 (64.5)	887 (62.6)	
Female	419 (38.4)	401 (35.3)	458 (35.5)	529 (37.4)	
Race, *n (%)*[a]					<0.01
White	639 (58.6)	643 (56.7)	825 (64)	1005 (71.2)	
Black	190 (17.4)	222 (19.6)	249 (19.3)	293 (20.8)	
Asian	11 (1.0)	12 (1.1)	11 (0.9)	21 (1.5)	
Hispanic	217 (19.9)	204 (18)	136 (10.6)	23 (1.6)	
Other	33 (3.0)	54 (4.8)	68 (5.3)	69 (4.9)	
City of Residence, *n (%)*[a]					0.01
Tampa	414 (37.9)	478 (42.2)	486 (37.8)	491 (34.8)	
Other	678 (62.1)	655 (57.8)	801 (62.2)	920 (65.2)	
County of Residence, *n (%)*					<0.01
Hillsborough	569 (52.1)	609 (53.7)	590 (45.7)	608 (42.9)	
Pasco	226 (20.7)	191 (16.8)	224 (17.4)	255 (18.0)	
Pinellas	81 (7.4)	110 (9.7)	115 (8.9)	111 (7.8)	
Polk	42 (3.9)	46 (4.1)	124 (9.6)	129 (9.1)	
Hernando	80 (7.3)	70 (6.2)	68 (5.3)	61 (4.3)	
Other or not reported	94 (8.6)	109 (9.6)	170 (13.2)	252 (17.8)	
Health Insurance, *n (%)*					<0.01
Government insurance	678 (62.1)	749 (66)	757 (58.6)	667 (47.1)	
Private insurance	344 (31.5)	342 (30.1)	453 (35.1)	640 (45.2)	
Self-pay or other insurance	70 (6.4)	44 (3.9)	81 (6.3)	109 (7.7)	
Zip Code level Socio-economic Indicators[a]					
Median Household Income (Past 12 Mo.), mean (SD)	50652 (17669)	49442 (17867)	48695 (17322)	49851 (18079)	0.06
Percentage with Income to Poverty ratio <1, mean (SD)	12.8 (7.6)	13.2 (7.9)	13.3 (7.6)	13.0 (7.7)	0.34
Unemployment Rate (Age ≥ 16), mean (SD)	8.8 (3.2)	8.9 (3.3)	9.0 (3.4)	8.9 (3.4)	0.80

Notes.
p-values are for test of trend across admission years.
[a] Missing values < 0.01%.

Outcomes

Injury Severity Score (ISS) was calculated using Abbreviated Injury Scales (AIS) values at the time of admission.[8,9] ISS was divided into 5 categories: minor (ISS: 1–3), moderate (ISS: 4–8), serious (ISS: 9–15), severe (ISS: 16–24), and critical (ISS: 25–75).[10] Major trauma was defined as any admission with an ISS of more than 15.[11] Length of stay (LOS) was defined as the number of days from admission to discharge from the trauma center. Intensive Care Unit (ICU) stay was defined as admission to the ICU for one or more days due to any indication. The study period was divided into four discrete 2-year periods to facilitate comparison and to ensure adequate sample size for identification of distinct trends over a longer period. The aim of the study was identification of trends in potentially modifiable factors associated with admissions for future prevention of morbid and fatal outcomes. Thus, we aimed to identify temporal trends in patient demographic factors, injury characteristics, and injury mechanisms during the study period. We also sought to identify factors associated with independent temporal trends in admissions to the trauma center over the study period, as well temporal trends in ISS, ICU stay, and LOS by injury mechanisms.

Statistical methods

Descriptive statistics for demographics, socioeconomic variables, indicators of clinical severity, and patient outcomes are presented as mean (SD) for continuous variables, and count

Table 2
Trauma characteristics and clinical factors by year of admission to the pediatric trauma center.

Factor	Year of Admission				
	2010–2011 n = 1092 (22.1%)	2012–2013 n = 1135 (23.0%)	2014–2015 n = 1291 (26.2%)	2016–2017 n = 1416 (28.7%)	*p*-value
Mode of Transport to Hospital, *n (%)*[a]					<0.01
Ambulance	771 (70.6)	807 (71.2)	874 (67.7)	908 (64.1)	
Privately owned vehicle	233 (21.3)	245 (21.6)	252 (19.5)	312 (22.0)	
Helicopter	88 (8.1)	81 (7.1)	162 (12.6)	192 (13.6)	
Police	0 (0.0)	1 (0.1)	3 (0.2)	4 (0.3)	
Service patient admitted to, *n (%)*a					0.01
Pediatric	436 (48.1)	518 (48.5)	622 (48.3)	751 (53)	
Pediatric intensivist	137 (15.1)	135 (12.6)	71 (5.5)	44 (3.1)	
Pediatric trauma	68 (7.5)	79 (7.4)	228 (17.7)	259 (18.3)	
Trauma surgeon	81 (8.9)	91 (8.5)	96 (7.5)	86 (6.1)	
Emergency room	0 (0.0)	88 (8.2)	179 (13.9)	204 (14.4)	
Ortho surgery	157 (17.3)	112 (10.5)	42 (3.3)	25 (1.8)	
Other	28 (3.1)	45 (4.2)	49 (3.8)	47 (3.3)	
Admission Source, *n (%)*					0.36
Direct Admission	579 (53)	638 (56.2)	723 (56)	784 (55.4)	
Transferred from other Hospital	513 (47)	497 (43.8)	568 (44)	632 (44.6)	
Trauma Type, *n (%)*					0.02
Blunt-diffuse force	993 (90.9)	1023 (90.1)	1162 (90)	1236 (87.3)	
Penetrating-point force	85 (7.8)	101 (8.9)	115 (8.9)	169 (11.9)	
Burn (e.g. thermal, chemical)	14 (1.3)	11 (1)	14 (1.1)	11 (0.8)	
Trauma Severity (Injury Severity Score), *n (%)*					0.60
Minor (ISS 1–3)	248 (22.7)	269 (23.9)	330 (25.7)	333 (23.6)	
Moderate (ISS 4–8)	509 (46.7)	528 (46.8)	587 (45.7)	703 (49.8)	
Serious (ISS 9–15)	280 (25.7)	271 (24.0)	271 (21.1)	291 (20.6)	
Severe (ISS 16–24)	37 (3.4)	44 (3.9)	52 (4.1)	42 (3.0)	
Critical (ISS 25–75)	17 (1.6)	16 (1.4)	44 (3.4)	42 (3.0)	
Region Injured, *n (%)*[a]					
Head	383 (35.7)	400 (36.0)	449 (34.9)	398 (28.3)	<0.01
Arm	362 (33.7)	398 (35.9)	453 (35.3)	523 (37.1)	0.11
Leg	272 (25.4)	288 (26.0)	290 (22.6)	323 (22.9)	0.05
Chest	97 (9.0)	96 (8.7)	177 (13.8)	161 (11.4)	<0.01
Abdomen	110 (10.3)	112 (10.1)	108 (8.4)	116 (8.2)	0.03
Spine	19 (1.8)	23 (2.1)	37 (2.9)	31 (2.2)	0.31
Multi-site (>1 region injured), *n (%)*[a]					0.14
No	825 (76.9)	818 (73.7)	955 (74.3)	1112 (78.9)	
Yes	248 (23.1)	292 (26.3)	330 (25.7)	297 (21.1)	
Days in ICU, *n (%)*					<0.01
One or more	194 (17.8)	194 (17.1)	183 (14.2)	140 (9.9)	
None	898 (82.2)	941 (82.9)	1108 (85.8)	1276 (90.1)	
Ventilator use (≥1 day), *n (%)*[a]					<0.01
Yes	33 (3.0)	36 (3.2)	52 (4.0)	69 (4.9)	
No	1052 (97.0)	1099 (96.8)	1239 (96.0)	1347 (95.1)	
Documented Complication, *n (%)*					<0.01
Yes	65 (6.0)	32 (2.8)	20 (1.6)	22 (1.6)	
No	1027 (94.1)	1103 (97.2)	1271 (98.5)	1394 (98.5)	
Death, *n (%)*					0.74
Yes	17 (1.6)	21 (1.9)	31 (2.4)	23 (1.6)	
No	1075 (98.4)	1114 (98.2)	1260 (97.6)	1393 (98.4)	
Length of Stay (LOS), *n (%)*					<0.01
One day or less	650 (59.6)	682 (60.2)	804 (63.1)	905 (64.3)	
Two to Seven Days	378 (34.7)	412 (36.4)	420 (32.9)	450 (32.0)	
More than a week	62 (5.7)	39 (3.4)	51 (4.0)	53 (3.8)	

Notes: a Missing <0.1%; *p*-values are test for trend across admission years.

(percent) for categorical variables. The temporal trends over the study period for demographic, injury characteristics, and clinical characteristics were examined using a one degree of freedom Cochran-Armitage test of trend or Cochran-Mantel-Haenszel statistic, as appropriate. Trends in ISS, ICU stay, and LOS by injury mechanism were examined using logistic regression models. Forward stepwise ordinal logistic regression modeling was used to identify factors (demographic, socioeconomic, clinical severity and patient outcomes) associated with independent temporal trends in admission over the study period. Results are presented as adjusted odds ratios (AOR) and corresponding 95% confidence intervals (CI). Statistical significance was defined as a p-value less than 0.05. All analyses were conducted using the SAS (Version 9.4, SAS Institute Inc., Cary, NC).

Results

Demographic factors and trauma admissions

During the years 2010–2017, there were 4,934 hospital admissions related to traumatic injury, of which, nearly half (48.2%) originated from Hillsborough County (the location of the trauma center in Tampa). Patients admitted to the trauma center were an average age of 8.8 years, with higher prevalence of male sex (63.4%), and white race (63.2%). Small, yet significant increases were seen in admissions originating from; outside Hillsborough County (2010–2011: 47.9% vs. 2016–2017: 57.1%, $p < .01$) and outside Tampa (2010–2011: 62.1% vs. 2016–2017: 65.2%, $p = .01$) over the 8 years. An upward trend was observed in the use of private health insurance (2010–2011: 31.5% vs. 2016–2017: 45.2%, $p < .01$) as primary payment source (Table 1).

Clinical characteristics of admissions to trauma center

During the study period, 89.5% of the admissions presented with blunt trauma and more than half of the admissions were directly presented to the trauma center. The most common mode of transport to the trauma center was ambulance (68.1%) and most patients were admitted to pediatric service (49.7%). Most admissions resulted in a length of stay of one day or less (62%). Less than 3% of patients suffered a complication [139 (2.8%)], and ninety-two patients (1.9%) died.

Time trends were observed during the study period (Table 2) with higher use of helicopter transportation to the trauma center (2010–2011: 8.1% vs. 2016–2017: 13.6%, $p < .01$), increase in admissions to pediatric trauma unit (2010–2011:7.5% vs. 2016–2017:18.3%, $p = .012$), and increase in admissions due to penetrating mechanism (2010–2011: 7.8% vs. 2016–2017: 11.9%, $p = .02$). Additionally, significant downward trends were seen in admissions with head injuries (2010–2011: 35.7% vs. 2016–2017: 28.3%, $p < .01$) and abdominal injuries (2010–2011:10.3% vs. 2016–2017: 8.2%, $p = .03$), whereas an upward trend was seen in admissions with chest injuries (2010–2011: 9.0% vs. 2016–2017: 11.4%, $p < .01$). The increase in chest injury admissions was attributable mainly to an increase in drowning admissions over the study period. Improvements were observed in clinical outcomes with more patients staying for one day or less (2010–2011: 59.6% vs. 2016–2017: 64.3%, $p < .01$), fewer ICU admissions for one or more days (2010–2011:17.8% vs. 2016–2017: 9.9%, $p < .01$), and fewer complications (2010–2011: 6.0% vs. 2016–2017: 1.6%, $p < .01$) (Table 2).

Injury mechanisms of admission to trauma center

Falls and traffic injuries were the most common causes of admission, responsible for almost 65% of all admissions to the trauma center. Suicide/hanging was the least common cause of admission to the trauma center, accounting for less than one percent of all admissions (Table 3). The trauma center saw a non-significant increase in admissions (number of cases) due to falls (2010–2011: 502 vs. 2016–2017: 630, $p = .063$), drownings (2010–2011: 18 vs. 2016–2017: 51, $p = .068$), and gun-shot wounds (2010–2011: 14 vs. 2016–2017: 36, $p = .079$). The increase in animal bites was statistically significant (2010–2011: 22 vs. 2016–2017: 63, $p = .026$) (Fig. 1). Males were significantly more likely to be injured by most injury mechanisms except for suicide/hanging ($p = .07$) and animal bite ($p = .08$), where the rates were similar by gender. (Fig. 2).

Although not common, both drownings and gun-shot wounds had a higher complication rate and case-fatality rate as compared to other injury mechanisms, findings consistent with National Trauma Data Bank statistics (Fig. 3). The injury severity, LOS, and ICU admissions differed by injury mechanism (Table 3). The LOS adjusted for ISS showed that admissions due to traffic injuries (AOR = 1.13, 95% CI:1.01,1.26) and other causes (AOR = 1.26, 95% CI: 1.08, 1.46) were significantly more likely to have a shorter hospital stay (LOS ≤1 day) in 2016–2017 as compared to 2010–2011 (Table 3). Similarly, ICU stay adjusted for ISS showed that admissions due to falls (OR = 1.50, 95% CI: 1.29–1.74), traffic injuries (OR = 1.37, 95% CI: 1.16, 1.61), other causes (OR = 1.32, 95% CI: 1.01,

Table 3
Association between year of admission and ISS, LOS, and ICU admission by injury mechanisms.

Injury Mechanism	N = 4934	Major Trauma (ISS>15)		LOS (≤1day)[a]		No ICU Stay (0 day)[a]	
		%[c]	OR (95% CI)	%[c]	OR (95% CI)	%[c]	OR (95% CI)
Fall	2223	2.1	1.04 (0.80, 1.34)	27.9	1.02 (0.94, 1.11)	9.0	1.50 (1.29, 1.74)
Traffic injuries	1010	12.8	1.08 (0.92, 1.27)	53.6	1.13 (1.01, 1.26)	24.2	1.37 (1.16, 1.61)
Automobile injury	*462*	*14.3*	*0.95 (0.75, 1.2)*	*51.3*	*1.29 (1.09, 1.53)*	*26.0*	*1.35 (1.09, 1.67)*
Bicycle or ATV injury	*244*	*6.6*	*0.89 (0.57, 1.38)*	*51.2*	*0.93 (0.74, 1.16)*	*19.3*	*1.92 (1.35, 2.71)*
Pedestrian injury	*190*	*18.4*	*1.41 (0.99, 2.02)*	*60.0*	*1.21 (0.92, 1.59)*	*30.0*	*1.47 (1.07, 2.03)*
Motorcycle injury	*114*	*11.4*	*1.88 (1.02, 3.44)*	*57.5*	*0.92 (0.66, 1.28)*	*18.4*	*0.76 (0.47, 1.22)*
Other causes	626	5.1	0.99 (0.72, 1.36)	37.9	1.26 (1.08, 1.46)	12.4	1.32 (1.01, 1.71)
Sporting activity injury	391	1.7	1.15 (0.55, 2.37)	40.1	1.16 (0.94, 1.42)	8.4	1.00 (0.68, 1.48)
Assault	219	11.4	1.41 (0.96, 2.06)	55.5	0.97 (0.75, 1.23)	23.2	1.07 (0.74, 1.53)
Animal bite	156	2.5	1.90 (0.53, 6.76)	49.6	0.82 (0.60, 1.11)	7.0	1.23 (0.64, 2.36)
Drowning	153	15.0	0.84 (0.54, 1.31)	29.4	1.24 (0.85, 1.80)	40.5	1.16 (0.79, 1.70)
Gun shot	114	20.1	0.96 (0.61, 1.51)	48.1	1.14 (0.78, 1.66)	20.1	1.23 (0.68, 2.21)
Suicide/hanging	39	7.6	1.41 (0.41, 4.85)	51.2	0.77 (0.42, 1.42)	20.5	13.56 (1.38, 132.5)

Notes.
[b]Odds ratio for 1 unit (2 year) change in the year of admission.
[a] LOS and ICU stay adjusted for ISS.
[c] The percentage presented are row percent.

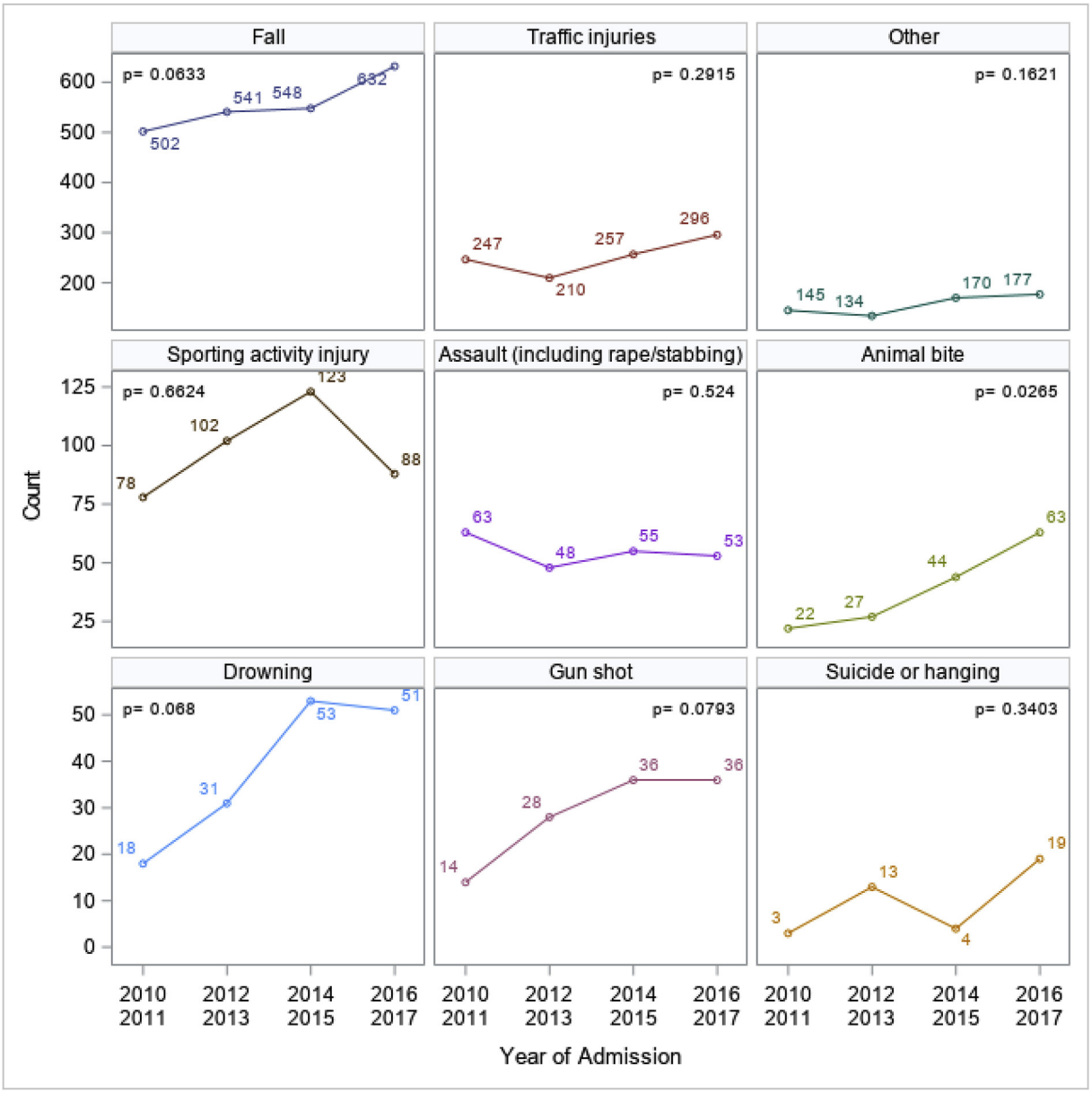

Fig. 1. Admissions to Pediatric Trauma Center between 2010 and 2017 by Injury Mechanism. The figure shows the count of admissions for each injury mechanism between 2010 and 2017. The p-value shown are for linear trend.

1.71) and suicide/hanging (OR = 13.56, 95% CI: 1.38, 132.5) were more likely to have no ICU stay in 2016–2017 as compared to 2010–2011.

Ordinal logistic regression analysis for factors independently associated with the year of admission

Table 4 shows that over the 8-year admission period, demographic profiles changed with higher representation from beyond Hillsborough county (AOR = 1.10, 95% CI: 0.98, 1.23), apparently lower Hispanic ethnicity (AOR = 0.34, 95% CI: 0.29, 0.41), and higher use of private insurance (AOR = 1.44, 95% CI: 1.29, 1.61). The odds of drowning admissions (AOR = 1.50, 95% CI: 1.10, 2.02) and admissions for animal bites (AOR = 1.99, 95% CI: 1.46, 2.71) increased from 2010 to 2017. More severe admissions from farther distance occurred over time, as indicated by higher use of helicopter transport (AOR = 1.91, 95% CI: 1.58, 2.30). The odds of length of stay for just a single day (generally favorable outcome) increased (AOR = 1.19, 95% CI: 1.06, 1.33), as did the odds of no days in the ICU (AOR = 1.60, 95% CI = 1.36,1.88). The odds of in-hospital complications decreased significantly (AOR = 0.47, 95% CI: 0.33, 0.66) from 2010 to 2017.

Discussion

We observed that males were more likely than females to be injured by most injury mechanisms in our cohort which is similar to findings of national reports and other studies.[2,12,13] We also observed an increase in admissions from outside the Hillsborough County and use of helicopter for transportation. A possible explanation for the rise in admissions from counties outside Hillsborough County could be the increase in awareness of the services provided by the trauma center and its expertise. More admissions from a farther distance appeared to account for the higher use of helicopter for transport to trauma center in later years, and independent of injury severity. Although we did not examine the impact

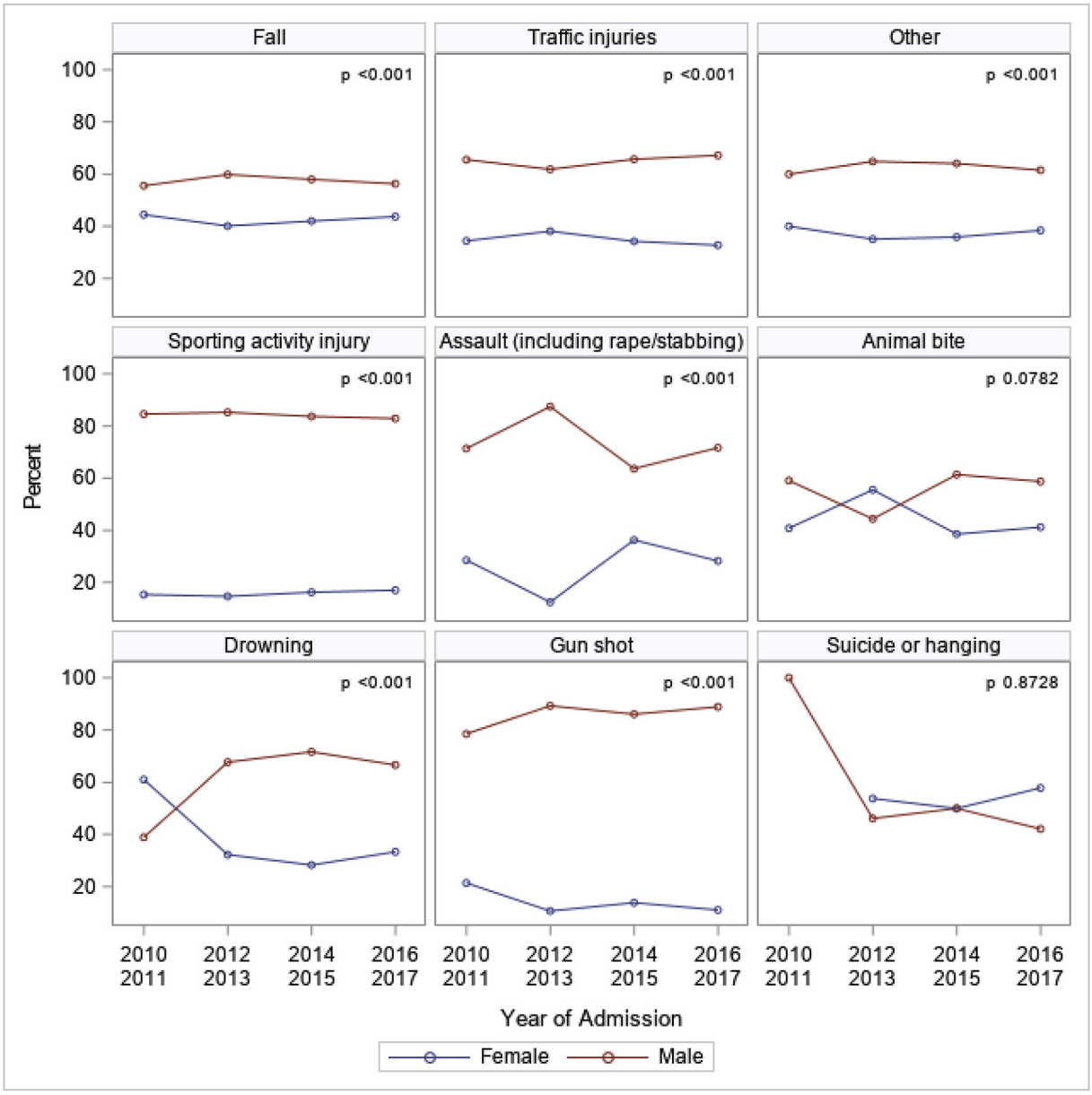

Fig. 2. Gender Differences in Admissions between 2010 and 2017 by Injury Mechanism. The red line represents males and blue line represents females. The inset shows p-values for difference admission for injury mechanism by gender. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

of helicopter transport on patient outcomes in this study, earlier studies have shown that helicopter transport is associated with better outcomes in patients with critical injuries as compared to ambulance when significant time is saved by helicopter use.[14,15] However, in the present analysis, we believe that the higher use of helicopter could be a result of over triage which needs to be explored further in future studies.

The most common injury mechanisms in our cohort were falls and traffic injuries, a finding consistent with national reports on injuries in this age group.[2,12,16] A disturbing finding was the number of ATV and motorcycle injuries, In addition we identified a trend in our trauma center of an apparent increase in admissions due to drowning, gun-shot wounds, and animal bites over the study period. The rise in drowning and gun-shot wound admissions is especially concerning due to high case fatality rates as well as higher rate of complications as expected and seen in our study. The gravity of the rise in gun-shot wound admissions should not be routinely dismissed simply on the basis of not being statistically significant after adjusting for other factors. Multiple studies have observed high mortality and morbidity after drowning and gun-shot wounds making them prime targets for prevention in the pediatric age group.[2,12,16–18] The occurrence of ATV and motorcycle injuries are also of concern and could potentially be the target for prevention initiatives. In addition, falls and traffic injuries represented about two-thirds of admissions to the trauma center during the study period and are marked as high burden injuries under national action plan for prevention of childhood injuries.[19]

Over the 8-year study period, we observed an independent downward trend in overall LOS and ICU stay for admissions to the trauma center. A shorter LOS for traffic injuries and injuries from other causes, and a reduction in ICU stay for falls, traffic injuries and injuries due to other causes independent of injury severity. Thus, observed improvements over time in our trauma center in clinical outcomes for patients with these injuries appear to be favorable. A shorter LOS and lower admission to ICU for these specific injury mechanisms could also explain the overall reduction in LOS and ICU

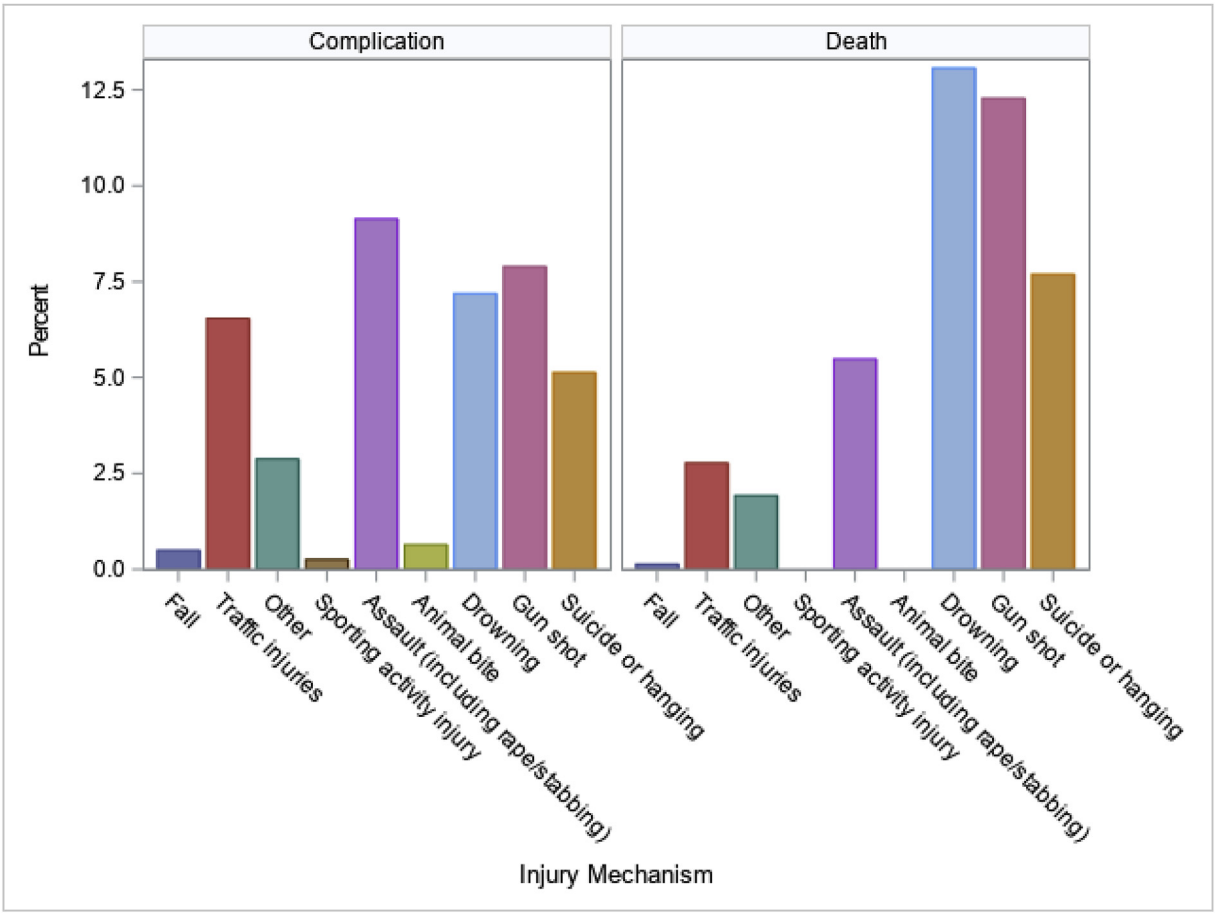

Fig. 3. Percentage of Complications and Deaths in Admissions to Pediatric Trauma Center between 2010 and 2017 by Injury Mechanism. Left panel represents the rate of complication for the injury mechanisms. Right panel represents the rate of death for the injury mechanisms.

Table 4
Ordinal Logistic Regression Model for Factors associated with Year of Admission to the Pediatric Trauma Center.

Factor	Odds Ratio (95% CI)[a]	P-value
Cause of Admission - Animal bite	1.99 (1.46, 2.71)	<0.001
Helicopter transport	1.91 (1.58, 2.3)	<0.001
Zero days in ICU	1.6 (1.36, 1.88)	<0.001
Cause of Admission – Drowning	1.5 (1.1, 2.02)	0.009
Private insurance	1.44 (1.29, 1.61)	<0.001
Length of stay ≤ 1 day	1.19 (1.06, 1.33)	0.002
County outside of Hillsborough	1.1 (0.98, 1.23)	0.0997
Patient had complication documented	0.47 (0.33, 0.66)	<0.001
Hispanic ethnicity	0.34 (0.29, 0.41)	<0.001

admissions observed in the study. We did not explore specific factors (e.g. triage approaches and surgical procedures) associated with patient outcomes in this study. Nevertheless, results observed by other studies could help explain the findings observed in our study. Studies have shown that pediatric trauma patients treated at dedicated pediatric trauma centers have better outcomes as compared to those treated at adult trauma centers.[20,21] Possible explanations for improved patient outcomes among pediatric admissions are standardized protocols, expertise in treating pediatric trauma patients who present with different injury mechanisms as compared to their adult counterparts, and possibly better resource utilization.[22–26] Our pediatric trauma center has ongoing quality improvement programs with clearly defined measures that are tracked over time. Well-established quality improvement projects have been shown to be effective in improving patient outcomes over time.[27,28]

Strengths of this study include analysis of a relatively large sample of trauma admissions, consistent data definitions used in the electronic medical record system over 8 years, inclusion of individual level (patient) data, and ability to examine trends in patient outcomes by injury mechanisms. Limitations of this study include its retrospective nature, and the relatively low incidence of certain injury mechanisms which precluded the ability to perform detailed subset analyses. In addition, the study cohort represents admissions to the trauma center and does not account for patients who were not admitted after initial consult. Thus, we are not able to differentiate if the trends are due to increase in the injuries from an injury mechanism, or just change in admission practices at the trauma center over the study period. The apparent reduction in Hispanic admissions to the trauma center does not appear to be consistent with population growth in the catchment area, and thus potentially reflects a reporting or ascertainment bias that requires further examination. In addition, the data from this single trauma center limits the generalizability of the study. Still, these findings may be valuable to guide better resource allocation and utilization at the trauma center and for planning local campaigns for injury prevention. Analytically, residual confounding due to unmeasured factors cannot be ruled out for multivariable estimates of factors associated with trends observed in the study. Despite the above noted study limitations, the significantly reduced LOS and ICU stay observed after adjusting for injury severity represent important findings and are unlikely to be biased as these outcomes are reliably

measured.

Finally, at the broadest level, all the major pediatric injury mechanisms described in this report are potentially preventable. Having said this, they represent multi-factorial etiology and clearly no single strategy can adequately address prevention at large. For example, some injuries include a strong behavioral and mental health component (e.g. suicide, assault, gun shots), others may be favorably affected by technological improvements in safety equipment (e.g. sports injuries, motor vehicle injuries), others prevented by more rigorous supervision and educational messages (e.g. drowning, ATV injuries), and some by policy and infrastructure changes (e.g. pedestrian walkways and appropriate signage, licensure requirements). This complexity provides a basis for careful collection and examination of comprehensive, standardized hospital registry data, such as the large pediatric trauma registry examined in this report for the years 2010–2017.

Conclusions

Pediatric trauma is a leading cause of preventable morbidity and mortality, and multi-faceted efforts are needed to reduce their burden at every level. This 8-year cohort study identified temporal increases in drownings and gun-shot wound injuries in the cohort, with additional studies and examination needed to better understand the underlying cause(s) of the apparent rise in these severe injury mechanisms. Still, the simple recognition and acknowledgement of an increase in drowning and gun-shot wounds can help plan for targeted local education campaigns to ensure awareness on prevention of these highly fatal injury mechanisms. Furthermore, improved patient outcomes observed over time also indicate that a dedicated pediatric trauma care center is presumably an ideal setup for management of pediatric trauma patients. Nonetheless, despite the improvements in outcomes observed in our study, pediatric injuries are still a significant burden in our community and at large. This compelling circumstance provides a rationale and opportunity for trauma centers like the present one to lead research efforts aimed at improving outcomes in pediatric trauma patients, including identification of evidence based interventions for prevention of pediatric injuries in the community. The trends identified in our study will guide future research and practice at our trauma center and perhaps abroad, with the long-term goal of continued decline in morbidity and mortality due to pediatric injuries.

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