Association for Academic Surgery

Pediatric Injury Transfer Patterns During the COVID-19 Pandemic: An Interrupted time Series Analysis

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ABSTRACT

Introduction: With the expected surge of adult patients with COVID-19, the Children's Hospital Association recommended a tiered approach to divert children to pediatric centers. Our objective was understanding changes in interfacility transfer to Pediatric Trauma Centers (PTCs) during the first 6 mo of the pandemic.

Methods: Children aged < 18 y injured between January 1, 2016 and September 30, 2020, who met National Trauma Databank inclusion criteria from 9 PTCs were included. An interrupted time-series analysis was used to estimate an expected number of transferred patients compared to observed volume. The "COVID" cohort was compared to a historical cohort (historical average [HA]), using an average across 2016-2019. Site-based differences in transfer volume, demographics, injury characteristics, and hospital-based outcomes were compared between cohorts.

Results: Twenty seven thousand thirty one/47,382 injured patients (57.05%) were transferred to a participating PTC during the study period. Of the COVID cohort, 65.4% (4620/7067) were transferred, compared to 55.7% (3281/5888) of the HA ($P < 0.001$). There was a decrease in 15-y-old to 17-y-old patients (10.43% COVID *versus* 12.64% HA, $P = 0.003$). More patients in the COVID cohort had injury severity scores ≤ 15 (93.25% COVID *versus* 87.63% HA, $P < 0.001$). More patients were discharged home after transfer (31.80% COVID *versus* 21.83% HA, $P < 0.001$).

Conclusions: Transferred trauma patients to Level I PTC increased during the COVID-19 pandemic. The proportion of transferred patients discharged from emergency departments increased. Pediatric trauma transfers may be a surrogate for referring emergency department capacity and resources and a measure of pediatric trauma triage capability.

Introduction

The COVID-19 pandemic increased the demand on hospital systems nationwide. Surge estimation efforts were required to provide adequate care for hospitalized patients, including those with and without SARS-CoV-2 viral infection. In March 2020, at the beginning of the pandemic, hospital systems delayed elective surgeries and healthcare providers had to quickly pivot to accommodate the needs of the United States healthcare system as a whole.[1-3] On April 3, 2020, the Children's Hospital Association (CHA) released a report calling for efforts to increasingly coordinate care for children to accommodate capacity needs for the expected surge in adult COVID-19 patients.[4] A tiered system based on local resources was recommended, prioritizing first the transfer or diversion of neonatal and pediatric patients aged < 18 y to dedicated children's hospitals (Tier 1), followed by young adults (Tier 2) and finally adults (Tier 3) as needed. Based on this system, Pediatric Trauma Centers (PTCs) would possibly receive patients who may otherwise have been cared for at an adult hospital.

Simultaneously, pediatric injury trends appeared to be changing nationwide, with reports of initial decline in both emergency department (ED) visits and hospital admissions for pediatric injury, followed by reports of subsequent increases.[5-11] The types of pediatric injuries were shifting, with an increase in violent injuries, penetrating injuries, and burns.[6,9] How the CHA recommendation and the COVID-19 pandemic were associated with pediatric injury and interfacility transfer to pediatric hospitals is unknown.

Our objective was to understand how the COVID-19 pandemic and the CHA recommendation were associated with changes in interfacility transfer of injured patients to Level I PTCs during the first 6 mo of the pandemic. We looked at whether characteristics of the patient population transferred to PTCs changed during this time period. We hypothesized that children with lower injury severity and injured adolescents would be transferred to a greater extent during the COVID-19 pandemic compared with prior years.

Methods

Institutional trauma registry data were merged from 9 American College of Surgeons verified Level I PTCs participating in the Midwest Pediatric Surgery Consortium (MWPSC; http://www.mwpsc.org) from January 1, 2016 to September 30, 2020. All children aged < 18 y who met National Trauma Data Bank criteria were included.[12] These children sustained a traumatic injury as defined by International Classification of Disease, Tenth Revision (ICD-10) diagnosis codes S00-S99, T07, T14, T20-T28, T30-T32, and T79.A1-T79. Transferred patients were identified by a binary variable provided by each site, concordant with the National Trauma Data Standard, which defines "interfacility transfer" as transfer from another acute care facility (ED or inpatient setting).[12] Five patients missing data in the transfer variable were excluded. The study was approved by each institution's Institutional Review Board with a waiver of informed consent.

The number of transferred patients and the proportion of transferred patients relative to overall volume of injured patients were explored. Monthly averages were graphed over time for all patients and by site with locally estimated scatterplot smoothing (LOESS) techniques. An interrupted time-series analysis with autoregressive integrated moving average modeling was used to estimate the expected number of transferred pediatric trauma patients based on the transfer patterns from January 1, 2016 through April 3, 2020. This was graphed against the observed transfer volume to evaluate whether the CHA recommendation was associated with a change in transfer volume of injured children to PTCs above what would be expected when accounting for prior years' triage patterns. A two-sample Kolmogorov–Smirnov test was used to test for significant differences.

Injured children transferred to one of the participating PTCs during the first 6 mo of the COVID-19 pandemic were compared with children transferred in prior years during the same time period. To account for the possibility of outlying data from a single year, a historical cohort was generated from an average across years 2016-2019 (denoted as HA for "Historical Average"). A sensitivity analysis was completed comparing the COVID cohort to a 2019 cohort alone to evaluate the change between the COVID cohort and the nearest year prior, thus minimizing the effect of changes in triage patterns and maturation of trauma systems over time. Demographics, injury characteristics, and hospital-based outcomes were compared between cohorts.

Among demographic variables, we included median household income by resident zip code and weight-adjusted Area Deprivation Index (ADI) by resident zip code.[13] The ADI is a multidimensional measure of community-level material deprivation based on the American Community Survey 5-y estimates and has been linked to individual health outcomes.[14,15] ADI percentile rankings range from 0 indicating the least disadvantaged to 1, the most disadvantaged and are stratified by decile. Mechanism of injury, type of injury, and intent of injury were defined by ICD-10 External Cause of Injury codes concordant with the Trauma Quality Improvement Program matrix, and diagnosis groups were created by the authors based on ICD-10 diagnosis codes to better understand differences in the transferred population (Supplement Table 1).

To understand if changes in the transferred population were reflective of changes in pediatric trauma characteristics during the pandemic as whole, nontransferred patient cohorts were also compared. Based on preliminary findings, a post hoc analysis evaluating patients discharged home from the ED after transfer was completed. In addition, transfer patterns by site relative to regional COVID case volumes were compared.

Descriptive statistics are presented for each cohort. Missing data for key variables are presented due to concerns data were not missing at random. Pearson's Chi-squared test was used to compare categorical variables, and when significant differences were identified among more than two groups, a comparison of binomial proportions was used. Student's *t*-test and Wilcoxon rank-sum were used to compare mean values for normally distributed continuous variables and median values for nonparametric continuous variables,

respectively. To assess the likelihood of transfer status compared to nontransfer status based on a cohort, a multivariable generalized linear model with binominal log-link distribution was used, controlling for age, injury severity and mechanism of injury, and controlling for clustering. Two-tailed significance was set at $P \leq 0.05$. All analyses were performed using R statistical software (RStudio, version April 1, 1717 2009-2021).

Results

Overall, 47,382 injured patients met inclusion criteria and were treated at one of the 9 participating PTCs. Among those, 27,031 (57.05%) were transferred from an outlying institution. Of the COVID cohort, 65.4% (4620/7067) were transferred, compared with 55.7% (3281/5888) of the HA cohort ($P < 0.001$). The number of transferred pediatric patients demonstrated monthly variation (Fig. 1A); however, both the total number of transferred patients and the proportion of transferred patients relative to all pediatric trauma volume increased in 2020 (Fig. 1A and B). The observed volume of pediatric transfers to PTCs was above and beyond the volume expected based on transfer patterns from the preceding years (P value < 0.001, Fig. 2). All sites saw an increase in transferred patients but there was a site-specific variation in magnitude of the transfer volume changes, with six of the nine sites having significant increases in transferred patients (Table 1). There was no association with COVID cases (Supplement Table 3 and Figs. 1-3). When adjusted for age, injury severity, and mechanism of injury, while controlling for clustering by site, there is an increased adjusted likelihood (i.e., association) of transfer status of 1.49 (95% confidence interval 1.41-1.58) during COVID compared to HA.

While the overall trauma volume increased in all age groups, there was a relative increase in 10-y-old to 14-y-old patients transferred in the COVID cohort (26.89% *versus* 24.68% HA, $P = 0.031$) and a decrease in infants (8.25% COVID *versus* 10.82% HA, $P < 0.001$) and 15-y-old to 17-y-old patients (10.43% COVID *versus* 12.64% HA, $P = 0.003$) (Table 2). There were no differences in gender or race by cohort. The proportion of transferred patients with private insurance increased in the COVID cohort (50.00% *versus* 46.59% HA, $P = 0.003$), as did the proportion of patients who reside in zip codes associated with the highest median income quintile (23.85% COVID *versus* 21.08% HA, $P = 0.004$). Similarly, there was an increase in the proportion of patients transferred with resident zip codes associated with ADI deciles 1-2, indicating less resource deprivation (5.91% COVID *versus* 4.69% HA, $P = 0.016$).

Patients transferred for burn-related injuries and penetrating injuries increased (burn: 6.43% COVID *versus* 4.82% HA, $P = 0.003$; and penetrating: 10.63% COVID *versus* 7.68% HA, $P < 0.001$) (Table 2). By specific mechanism of injury, there was a significant increase in patients transferred with bites/stings (5.50% COVID *versus* 3.54% HA, $P < 0.001$) and fire/flame injuries (6.43% COVID *versus* 4.79% HA, $P = 0.002$) and a decrease in patients transferred after falls (40.50% COVID *versus* 43.96% HA, $P = 0.002$) and injuries related to being struck (7.75% COVID *versus* 9.63% HA, $P = 0.004$). While fewer patients in motor vehicle collisions were transferred in the COVID cohort,
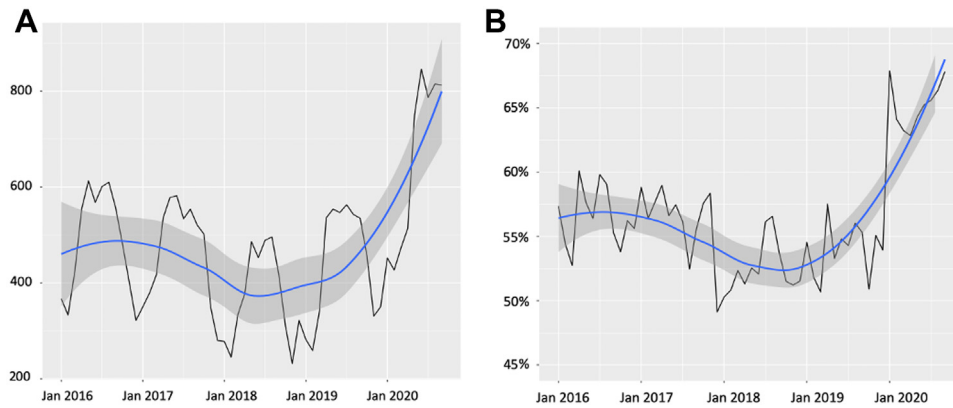
Fig. 1 — (A) Number of patients transferred and (B) proportion of patients transferred (compared to all trauma patients) to a level I pediatric trauma center over time. Raw values in black. LOESS curve in blue with 95% confidence interval.

there were more patients with bicycle (8.14% COVID *versus* 5.86% HA, P < 0.001) and all-terrain vehicle-related (ATV)-related injuries (8.25% COVID *versus* 5.73% HA, P < 0.001).

Among patients transferred for care, there was an increase in unintentional injury (94.07% COVID *versus* 91.80% HA,

P = 0.002) and a decrease in intentional assault-related injuries (4.72% COVID *versus* 5.64% HA, P < 0.0001) and no change in the volume of patients transferred after self-harm. Fewer patients were transferred with head and neck injuries (36.69% COVID *versus* 39.56% HA, P = 0.010) and intra-
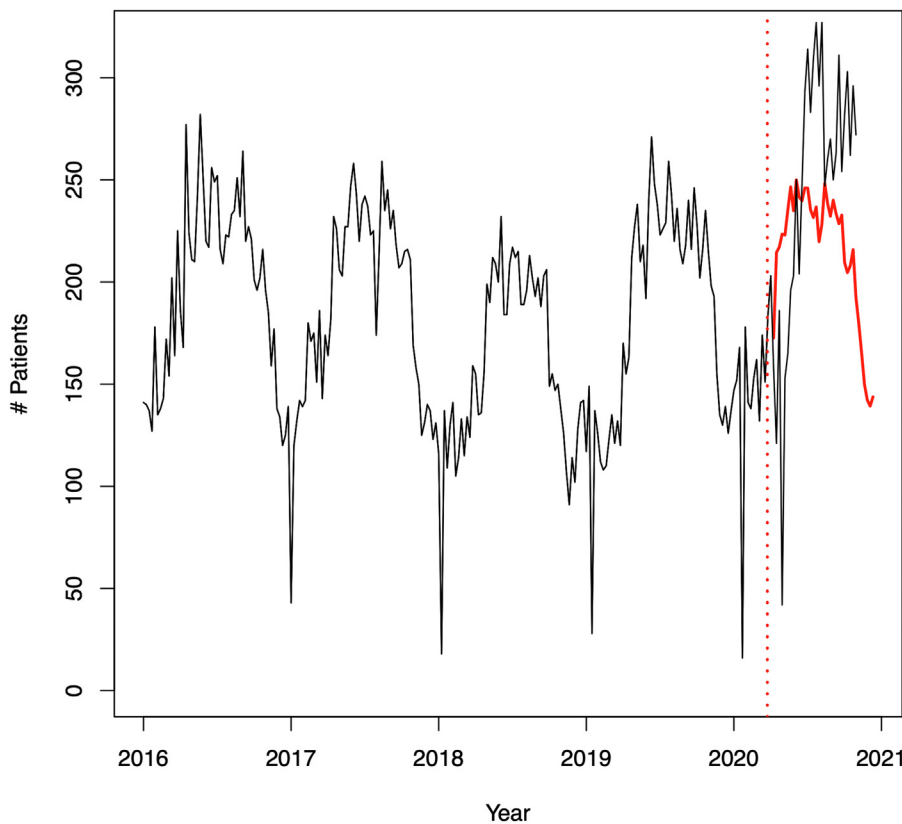
Fig. 2 — Interrupted time-series analysis with autoregressive integrated moving average modeling to predict the expected number of transfer patients (solid red), compared to the observed number of transferred patients (black) over time; two-sample Kolmogorov-Smirnov test P < 0.001. Red dashed line represents date of the published Children's Hospital Association's recommendation to transfer pediatric and young adult patients to pediatric centers.

Table 1 − Proportion of patients transferred relative to all trauma patients, by site.					
Site	HA (March-September, average)		COVID (March-September, 2020)		P value COVID *versus* HA
	Transferred/Total	%	Transferred/Total	%	
A	392/744	52.7%	603/933	64.6%	<0.001
B	484/768	63.0%	778/1028	75.7%	<0.001
C	152/296	51.2%	212/356	59.6%	0.039
D	593/918	64.8%	838/1222	68.6%	0.057
E	281/543	51.7%	344/555	62.0%	0.001
F	74/117	63.6%	57/88	64.8%	0.979
G	582/1157	50.3%	848/1328	63.9%	<0.001
H	176/498	35.3%	181/493	36.7%	0.685
I	549/848	64.7%	759/1064	71.3%	0.002
ALL	3281/5888	55.7%	4620/7067	65.4%	<0.001

abdominal injuries (including solid organ injury, hollow viscus injury, and injuries of the genitourinary tract; 3.68% COVID *versus* 4.91% HA, $P = 0.009$), while more patients were transferred with upper extremity fractures in the COVID cohort, compared to prior years (44.85% COVID *versus* 39.90% HA, $P < 0.001$). Detailed injury patterns are presented in Table 3, demonstrating a decrease in virtually all types and severities of head and neck injuries, a decrease in solid organ injuries, and a decrease in hip and femur fractures. Among upper extremity injuries, injuries with and without fracture and/or neurovascular injury increased for both forearm and elbow regions.

A higher proportion of children transferred in the COVID cohort had lower injury severity as reflected by an injury severity score (ISS) of 0-15 (93.25% COVID *versus* 87.63% HA, $P < 0.001$). As a corollary, a greater proportion of patients were discharged home after transfer (31.80% COVID *versus* 21.83% HA, $P < 0.001$) in the COVID cohort compared with prior years. Overall, the sensitivity analysis comparing the COVID cohort to 2019 demonstrated few meaningful differences in findings and is thus presented in the Supplemental material only (Supplement Tables 2, 4-6).

Discharged home from the emergency department after transfer

More patients were discharged home from the ED after transfer during the COVID period compared with the HA (Fig. 3, $P < 0.001$). There were no significant differences in the age, gender, or race of patients transferred and ultimately discharged home from the ED (Table 4). Reflective of the transferred patient population as a whole, more patients with private insurance in the fifth quintile for median household income and in the lower ADI deciles (i.e., less deprivation) were discharged home from the ED after transfer in the COVID cohort compared to the prior years (Table 4). For the most part, type, mechanism, and intent of injury of the population discharged home after transfer in the COVID cohort were reflective of the population transferred overall, with the exception of burn injuries, which changed in a similar manner but did not reach statistical significance. There were minimal changes in injury patterns in patients treated and released between the two cohorts, apart from upper extremity injuries which increased in the COVID cohort (46.36% COVID *versus* 41.06% HA, $P = 0.022$). More specifically, there was an increase
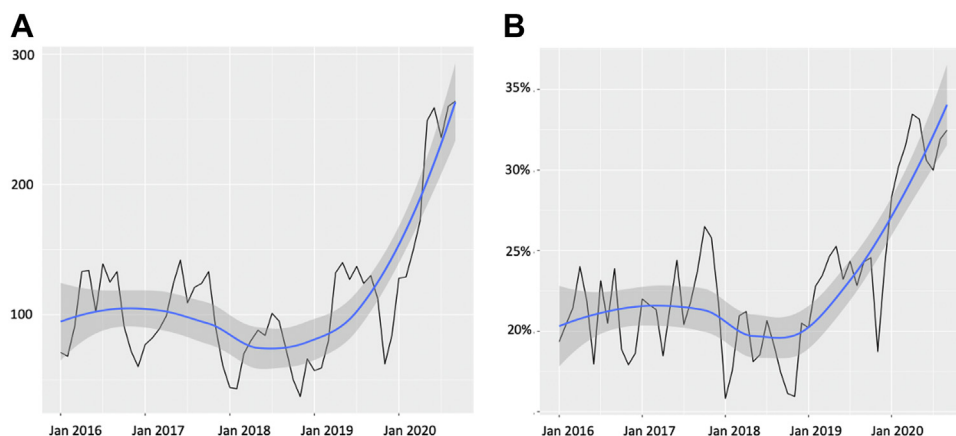

Fig. 3 − Patients discharged home after transfer over time. (A) Number of patients and (B) proportion of transferred patients. Raw values in black. LOESS curve in blue with 95% confidence interval.

Demographic and injury characteristics	HA	COVID	P value
	N (%)	N (%)	
	N = 3281	N = 4620	
Age (y)			<0.001
< 1	355 (10.82%)	381 (8.25%)	
1-4	676 (20.6%)	1012 (21.9%)	
5-9	1026 (31.26%)	1504 (32.55%)	
10-14	810 (24.68%)	1241 (26.86%)	
15-17	415 (12.64%)	482 (10.43%)	
Gender			0.099
Male	2060 (62.79%)	2815 (60.93%)	
Female	1221 (37.21%)	1805 (39.07%)	
Race			0.215
White	2670 (81.4%)	3708 (80.26%)	
Black	356 (10.85%)	522 (11.30%)	
Asian/Pacific Islander	38 (1.16%)	57 (1.23%)	
Other	118 (3.6%)	148 (3.20%)	
Unknown/Missing	98 (2.99%)	185 (4.00%)	
Ethnicity			<0.001
Hispanic	176 (5.37%)	270 (5.84%)	
Non-Hispanic	2590 (78.96%)	4205 (91.02%)	
Unknown/Missing	514 (15.67%)	145 (3.14%)	<0.001
Insurance			0.011
Private	1529 (46.59%)	2310 (50.00%)	
Public	1440 (43.88%)	1935 (41.88%)	
No insurance	200 (6.09%)	248 (5.37%)	
Unknown/Missing	113 (3.44%)	127 (2.75%)	
Median household income			0.010
Quintile 1	545 (16.61%)	709 (15.35%)	
Quintile 2	712 (21.69%)	901 (19.50%)	
Quintile 3	658 (20.05%)	948 (20.52%)	
Quintile 4	662 (20.17%)	945 (20.45%)	
Quintile 5	692 (21.08%)	1102 (23.85%)	
Missing	13 (0.40%)	15 (0.32%)	
Area deprivation index decile			0.026
1st-2nd, least deprivation	154 (4.69%)	273 (5.91%)	
3rd	865 (26.36%)	1298 (28.10%)	
4th	1425 (43.43%)	1979 (42.84%)	
5th	662 (20.18%)	829 (17.94%)	
6th	122 (3.72%)	177 (3.83%)	
7th-10th, most deprivation	40 (1.22%)	53 (1.15%)	
Missing	11 (0.40%)	13 (0.24%)	
Type			<0.001
Blunt	2666 (81.26%)	3677 (79.59%)	
Burn	158 (4.82%)	297 (6.43%)	
Penetrating	252 (7.68%)	491 (10.63%)	
Unspecified	66 (2.01%)	81 (1.75%)	
Not applicable	96 (2.93%)	70 (1.52%)	
Missing	43 (1.31%)	4 (0.09%)	

Table 2 — Demographic and injury characteristics of pediatric patients transferred to level I pediatric trauma centers.

(continued)

Table 2 − (continued)

Demographic and injury characteristics	HA	COVID	P value
	N (%)	N (%)	
	N = 3281	N = 4620	
Mechanism of injury			<0.001
Bites/Stings	116 (3.54%)	254 (5.50%)	
Child abuse	125 (3.81%)	144 (3.12%)	
Cut/Pierce	101 (3.08%)	168 (3.64%)	
Drown/Submerge	10 (0.3%)	14 (0.30%)	
Fall	1442 (43.96%)	1871 (40.50%)	
Fire/Flame	157 (4.79%)	297 (6.43%)	
Firearm	36 (1.10%)	76 (1.65%)	
MVC	214 (6.53%)	234 (5.06%)	
MVC, other	89 (2.71%)	71 (1.54%)	
Bicycle	192 (5.86%)	376 (8.14%)	
Pedestrian	50 (1.52%)	52 (1.13%)	
ATV and other land transport	188 (5.73%)	381 (8.25%)	
Transport, other	8 (0.24%)	16 (0.35%)	
Natural	48 (1.46%)	48 (1.04%)	
Other	144 (4.39%)	256 (5.54%)	
Struck by or against	316 (9.63%)	358 (7.75%)	
Missing	43 (1.31%)	4 (0.09%)	
Intent			<0.001
Unintentional	3012 (91.8%)	4346 (94.07%)	
Assault	185 (5.64%)	218 (4.72%)	
Self-harm	22 (0.67%)	21 (0.45%)	
Other	18 (0.55%)	32 (0.69%)	
Missing	43 (1.31%)	3 (0.06%)	
Injuries sustained[*]			
Head/Neck	1298 (39.56%)	1695 (36.69%)	0.010
Thoracic	270 (8.23%)	337 (7.29%)	0.135
Abdomen/pelvis, other	273 (8.32%)	352 (7.62%)	0.273
Intra-abdominal injury	161 (4.91%)	170 (3.68%)	0.009
Upper extremity	1309 (39.9%)	2072 (44.85%)	<0.001
Lower extremity	779 (23.74%)	1079 (23.35%)	0.714
Burn	192 (5.85%)	363 (7.86%)	0.001
Other	256 (7.8%)	299 (6.47%)	0.026
Injury severity score (ISS)			<0.001
0-15	2875 (87.63%)	4308 (93.25%)	
16-24	144 (4.39%)	183 (3.96%)	
25+	80 (2.44%)	112 (2.42%)	
Missing	182 (5.55%)	17 (0.37%)	
Emergency department disposition			<0.001
Dead	1 (0.03%)	4 (0.09%)	
Floor/Observation	1616 (49.27%)	1816 (39.31%)	
Home	716 (21.83%)	1469 (31.80%)	
Intensive care unit	220 (6.71%)	216 (4.68%)	
Operating room	325 (9.91%)	309 (6.69%)	
Other	3 (0.09%)	7 (0.15%)	
Transfer out	3 (0.09%)	7 (0.15%)	
Unknown/Missing	396 (12.07%)	792 (17.14%)	

Table 2 — (continued)

Demographic and injury characteristics	HA	COVID	P value
	N (%)	N (%)	
	N = 3281	N = 4620	
Mortality	26 (0.79%)	29 (0.63%)	0.465
Location of death			0.417
Emergency department	1 (3.85%)	4 (13.79%)	
Inpatient	25 (96.15%)	25 (86.21%)	

MVC other includes Unspecified, 'other', and nontraffic MVCs.

Bicycle includes collisions between of motor vehicle and a bicycle and bicycle collisions.

Pedestrian includes collisions between of motor vehicle and pedestrian and pedestrian collisions.

Transport other includes various mechanisms related to watercraft.

MVC = motor vehicle collisions, includes occupant motor vehicle collisions and motorcycle collisions; ATV = all-terrain vehicle-related.

[*]Patients may have more than one anatomic location of injury, and thus "Injuries sustained" column totals are more than the number of patients in each cohort; however, if they have more than one injury per anatomic category, here they are counted only once per that category.

in elbow injuries (8.10% COVID *versus* 5.44% HA, P 0.030) and forearm injuries (8.65% COVID *versus* 6.15% HA, P = 0.05) without fracture or neurovascular injury (Supplement Table 7). Fewer patients with concussion were transferred and discharged home (4.63% COVID *versus* 9.21% HA, P < 0.001) (Supplement Table 7).

Nontransferred patients

The characteristics of the nontransferred population are provided (Supplement Table 8). While most of the changes in transferred patients are also appreciated in the non-transferred patients, there were some differences. There was a decrease in 5-y-old to 9-y-old children in nontransferred patients but no changes in the other age groups and there was a decrease in patients with private insurance, while there was no change in median household income or ADI. Injury patterns by cohort in the nontransferred population differed from that in the transferred population with increases in thoracic injury, intra-abdominal injury (including solid organ injury, hollow viscus injury, and injuries of the genitourinary tract), and lower extremity fractures. While there was still an increase in proportion of patients with mild injury (i.e., ISS 0-15), there was a statistically significant increase in children with an ISS 16-24 during the COVID cohort in the nontransferred population. Finally, compared to the transferred population, there was a more prominent increase in penetrating injury and there was an increase in assault-related injuries in the nontransferred population.

Discussion

In this multi-institutional study, we identified an increase in the interfacility transfer of injured pediatric patients after the COVID-19 pandemic began, with 65% transferred, compared with 55% during the same months in years prior. Contrary to our hypothesis, older adolescents did not account for this increase in volume. There was an increase in the proportion of transferred patients with lower injury severity (ISS 0-15). A significantly higher proportion of patients were discharged

home: one of three patients was discharged home after transfer during the COVID time period, compared with one of five patients in years prior. Predominant mechanisms of injury that increased in the transferred population between cohorts included bites/stings, burns, and bicycle and ATV-related injuries. This may be the first study to assess how regional transfer patterns of the injured child to Level I PTCs changed during the COVID-19 pandemic.

As some regional protocols recommend adolescents, at or above the age of 15 y, be triaged to the local adult trauma center, we hypothesized that surge need for adult beds at adult hospitals would translate to an increase in transfers of this older adolescent population to PTCs. However, in our study, the relative proportion of patients aged 15-17 y who were transferred decreased during the first 6 mo of the COVID pandemic, from 12.64% to 10.43%, while the proportion of children aged 10-14 y increased. The increase in transfers was primarily associated with an increase of the 5-9-y-old age group, which accounted for 35.7% of the increase in transfer volume, followed by the 10-14-y-old and 1-4-y-old age groups (32.2% and 25.1% of the increase in transfer volume, respectively). While the factors driving these changes are likely multifactorial, the primary increase in the 5-14-y-old range may have been due to changes in structured and supervised time, including a decrease in afterschool activities.

The proportion of patients transferred with private insurance, higher median household income, and less resource deprivation increased during the pandemic. As the majority of sites in our study are nonprofit inner city or suburban children's hospitals, it is possible the regular point of care for the more economically advantaged children are privately owned hospitals and during the pandemic these children were transferred at a higher rate than normal.

Notably, while all sites saw an increase in the proportion of patients transferred, 3 of the 9 sites did not reach statistical significance. For one site, there are low trauma numbers overall, low transfer volume, and overall low power. For two sites, it is likely that before the pandemic they already had triage patterns in place that maximized/saturated the transfer volume. For example, one of these sites is the only PTC in that region of the state (and by land mass, also for proximal areas

Table 3 – Injury types among transferred patients.

Injury types	HA	COVID	P value
	N (%)	N (%)	
	N = 3281	N = 4620	
Head injury			
Intracranial injury	369 (11.25%)	362 (7.84%)	<0.001
Concussion	255 (7.77%)	259 (5.61%)	<0.001
Facial fracture	576 (17.56%)	705 (15.26%)	0.007
Head, other	854 (26.02%)	1247 (26.99%)	0.349
Neck injury			
BCVI	59 (1.8%)	66 (1.43%)	0.228
Neck, other	94 (2.86%)	80 (1.73%)	0.001
Thoracic injury			
T-spine fracture	58 (1.77%)	88 (1.9%)	0.718
Rib fracture	62 (1.89%)	87 (1.88%)	1.000
Thoracic, other	217 (6.61%)	266 (5.76%)	0.130
Abdominal injury			
L-spine fracture	87 (2.65%)	111 (2.4%)	0.532
Solid organ injury	144 (4.39%)	151 (3.27%)	0.011
Hollow viscus injury	29 (0.88%)	37 (0.8%)	0.784
Abdomen, other	206 (6.28%)	267 (5.78%)	0.532
Upper extremity			
Shoulder/arm FxNV	572 (17.43%)	681 (14.74%)	0.001
Shoulder/arm, other	166 (5.06%)	206 (4.46%)	0.235
Elbow FxNV	437 (13.32%)	872 (18.87%)	<0.001
Elbow, other	246 (7.5%)	435 (9.42%)	<0.001
Forearm/wrist FxNV	84 (2.56%)	171 (3.7%)	0.006
Forearm/wrist, other	148 (4.51%)	308 (6.67%)	<0.001
Lower extremity			
Hip/leg FxNV	223 (6.8%)	218 (4.72%)	<0.001
Hip/leg, other	156 (4.75%)	216 (4.68%)	0.915
Knee FxNV	204 (6.22%)	295 (6.39%)	0.796
Knee, other	264 (8.05%)	439 (9.5%)	0.028
Lower leg/ankle FxNV	50 (1.52%)	76 (1.65%)	0.740
Lower leg/ankle, other	82 (2.50%)	147 (3.18%)	0.087
Other			
Multisystem	5 (0.15%)	6 (0.13%)	1.000
Unspecified	170 (5.18%)	225 (4.87%)	0.569
Foreign body	3 (0.09%)	1 (0.02%)	0.395
Burn	192 (5.85%)	363 (7.86%)	0.001
Poison	6 (0.18%)	7 (0.15%)	0.955
External	65 (1.98%)	55 (1.19%)	0.006
NAT	50 (1.52%)	41 (0.89%)	0.012
Complication	16 (0.49%)	22 (0.48%)	1.000

BCVI = blunt cerebrovascular injury; T-spine = thoracic spine; L-spine = lumbar spine; FxNV = fracture and/or neurovascular injury; NAT = nonaccidental trauma.

of surrounding states) and already accepts children aged up to and including 18 y. Furthermore, the region in which this site is located also does not have many hospitals in the region which accept/admit children. Hence, existing triage patterns, existing protocols for treating children locally and regionally,

and surrounding trauma centers (adult, pediatric, and combined), among other factors likely worked together to drive the regional changes seen during COVID.

One of the most salient findings of our study is the high proportion of children discharged home after transfer. This

Table 4 – Demographic and injury characteristics of pediatric patients transferred to level I pediatric trauma centers and then discharged home without admission.

Demographic and injury characteristics	HA	COVID	P value
	N (%)	N (%)	
	N = 716	N = 1469	
Age (y)			0.071
< 1	75 (10.47%)	120 (8.17%)	
1-4	134 (18.72%)	318 (21.65%)	
5-9	229 (31.98%)	501 (34.1%)	
10-14	194 (27.09%)	395 (26.89%)	
15-17	84 (11.73%)	135 (9.19%)	
Gender			0.054
Male	456 (63.69%)	871 (59.29%)	
Female	260 (36.31%)	598 (40.71%)	
Race			0.384
White	566 (78.94%)	1154 (78.56%)	
Black	88 (12.27%)	162 (11.03%)	
Asian/Pacific Islander	7 (0.98%)	17 (1.16%)	
Other	34 (4.74%)	66 (4.49%)	
Unknown/Missing	22 (3.07%)	70 (4.77%)	
Ethnicity			<0.001
Hispanic	33 (4.61%)	82 (5.58%)	
Non-Hispanic	517 (72.21%)	1331 (90.61%)	
Unknown/Missing	166 (23.18%)	56 (3.81%)	
Insurance			0.024
Private	314 (43.92%)	705 (47.99%)	
Public	331 (46.29%)	661 (45%)	
No insurance	60 (8.39%)	96 (6.54%)	
Unknown/Missing	10 (1.4%)	7 (0.48%)	
Median household income			0.012
Quintile 1	137 (19.24%)	252 (17.2%)	
Quintile 2	172 (24.16%)	297 (20.27%)	
Quintile 3	116 (16.29%)	250 (17.06%)	
Quintile 4	131 (18.4%)	250 (17.06%)	
Quintile 5	156 (21.91%)	416 (28.4%)	
Unknown/Missing	4 (0.56%)	4 (0.27%)	
Area deprivation index decile			0.033
1st-2nd, least deprivation	37 (5.17%)	94 (6.40%)	
3rd	180 (25.14%)	445 (30.29%)	
4th	298 (41.62%)	569 (38.73%)	
5th	157 (21.93%)	263 (17.90%)	
6th	32 (4.47%)	69 (4.70%)	
7th -10th, most deprivation	8 (1.12%)	26 (1.77%)	
Missing	3 (0.56%)	4 (0.20%)	
Type			<0.001
Blunt	588 (82.24%)	1136 (77.33%)	
Burn	34 (4.76%)	94 (6.4%)	
Penetrating	60 (8.39%)	182 (12.39%)	
Unspecified	11 (1.54%)	29 (1.97%)	
NA	10 (1.4%)	28 (1.91%)	
Missing	12 (1.68%)	0 (0%)	

Table 4 − (continued)			
Demographic and injury characteristics	HA	COVID	P value
	N (%)	N (%)	
	N = 716	N = 1469	
Mechanism of injury			<0.001
Bites/Stings	32 (4.47%)	113 (7.69%)	
Child abuse	10 (1.4%)	22 (1.5%)	
Cut/Pierce	23 (3.21%)	58 (3.95%)	
Drown/Submersion	0 (0%)	3 (0.2%)	
Fall	333 (46.51%)	609 (41.46%)	
Fire/Flame	34 (4.75%)	94 (6.4%)	
Firearm	5 (0.7%)	12 (0.82%)	
MVC	30 (4.19%)	42 (2.86%)	
MVC, other	16 (2.23%)	8 (0.54%)	
Bicycle	37 (5.17%)	109 (7.42%)	
Pedestrian	7 (0.98%)	6 (0.41%)	
ATV and other land transport	34 (4.75%)	108 (7.35%)	
Transportation, other	1 (0.14%)	2 (0.14%)	
Natural	10 (1.4%)	12 (0.82%)	
Other	46 (6.42%)	129 (8.78%)	
Struck by or against	86 (12.01%)	142 (9.67%)	
Missing	12 (1.68%)	0 (0%)	
Intent			<0.001
Unintentional	676 (94.55%)	1421 (96.73%)	
Assault	22 (3.08%)	42 (2.86%)	
Self-harm	0 (0%)	2 (0.14%)	
Other	5 (0.7%)	4 (0.27%)	
Missing	12 (1.68%)	0 (0%)	
Injuries sustained[*]			
Head/Neck	285 (39.75%)	521 (35.47%)	0.057
Thoracic	21 (2.93%)	40 (2.72%)	0.892
Intra-abdominal injury	2 (0.28%)	2 (0.14%)	0.840
Abdomen/pelvis, other	30 (4.18%)	56 (3.81%)	0.762
Upper extremity	294 (41.06%)	681 (46.36%)	0.022
Lower extremity	110 (15.36%)	258 (17.56%)	0.219
Burn	42 (5.87%)	114 (7.76%)	0.127
Other	36 (5.03%)	48 (3.27%)	0.059
Injury severity score			<0.001
0-15	684 (95.53%)	1452 (98.84%)	
16-24	2 (0.28%)	5 (0.34%)	
25+	0 (0.00%)	0 (0.00%)	
Missing	30 (4.19%)	12 (0.82%)	

MVC includes occupant motor vehicle collisions and motorcycle collisions.

MVC other includes Unspecified, 'other', and nontraffic MVCs.

Bicycle includes collisions between of motor vehicle and a bicycle and bicycle collisions.

Pedestrian includes collisions between of motor vehicle and pedestrian and pedestrian collisions.

Transport other includes various mechanisms related to watercraft.

MVC = motor vehicle collisions; ATV = all-terrain vehicle-related.

[*] Patients may have more than one anatomic location of injury, and thus "Injuries sustained" column totals are more than the number of patients in each cohort; however, if they have more than one injury per anatomic category, here they are counted only once per that category.

likely reflects lower injury severity but the threshold to admit patients was conceivably higher to mitigate the risk of exposure to the SARS-CoV-2 virus and to optimize inpatient bed availability for potential surge response needs. This population can correctly be defined by the term, "secondary over triage," referring to the transfer of minimally injured trauma patients to higher level centers. Each definition varies slightly, but this population is generally thought to require few resources and be a population that may not need to be transferred at all.

A single-center retrospective review of trauma activations from 2015 to 2017 defined secondary over triage as transferred patients with ISS ≤ 9 and a hospital length of stay ≤ 24 h who required neither intensive care unit admission nor an operation. Among 1789 trauma activations, 766 (42.8%) were transfers, and of those, 335 (43.7%) met criteria for over triage.[16] The Pennsylvania Trauma Outcome Study database was retrospectively queried from 2003 to 2017 for pediatric trauma patients aged ≤ 18 y transferred to 1 of 6 PTCs in the state. Overtriage was defined as discharge within 24 h and almost 50% of patients met criteria. Accounting for demographic and injury severity covariates, concussion, closed skull vault fractures, supracondylar humeral fractures, and consults to neurosurgery were associated with increased odds of overtriage.[17] This is similar to a 2019 single-center study, in which secondary overtriage was defined as having a "minor" injury, not requiring an invasive procedure or intensive care unit monitoring and discharge within 48 h. Factors independently associated with a higher risk of overtriage were self-pay insurance status and diagnosis of isolated skull fracture, concussion, or traumatic brain injury not otherwise specified. There was a nonsignificant trend (P = 0.07) toward a higher risk of avoidable transfer among patients aged 5 to 9 y.[18] All together, these studies reported higher levels of overtriage than the estimated 32% and 22% of patients discharged home from the ED after transfer during the COVID time period and HA time period, respectively, identified in our study. This may be explained by a more stringent definition, as our population for this estimate did not include admissions. We expected an increase in transfer of minor injuries like concussions but saw a decrease in proportion of concussions in this population during COVID, relative to prior years.

Among all transfers, we identified an increase in upper extremity injuries, including those with and without fracture, during the pandemic. Most other injuries by anatomic region decreased, including head injury and femur fractures. This injury pattern corresponds to the overall decrease in severity of injury among transferred patients, which is concordant with fewer motor vehicle collisions and more injuries from bicycle and ATV collisions. Nontransferred patients had increases in thoracoabdominal and lower extremity fractures, and compared to the transferred population, had overall high injury severity. These patterns may reflect the field triage of more severely injured patients directly to PTCs to a greater extent during the COVID time period than in prior years. Among transferred patients, injuries related to bites and stings (mostly dog bites) and burns also increased. This may reflect limited resources at referring emergency departments for the provision of sedation, time, and staff for suture repairs and/or wound debridement in children compared with expected pediatric-specific resources at the PTCs.

Pre-COVID studies have looked at the associations with likelihood of transfer from adult trauma centers to PTCs and from lower-level to higher-level centers.[19-21] A 2020 Pediatric Trauma Society systematic review found that in general, young age, intracranial injury, and more severely injured patients are most consistently transferred.[21] Hamilton *et al.* analyzed the National Trauma Databank from 2007 to 2012 and also identified female gender and lack of insurance as independent predictors of transfer. Injuries sustained were not reported in this study.[20] A study from the Pennsylvania Trauma Outcomes Study (2008-2012), after controlling for ISS, mechanism, and type of injury, also identified age, non-White race, female gender, and lack of insurance to independently predict interfacility transfer of injured children aged < 15 y from adult to PTCs.[19] These studies differ from ours in that the comparison population is the nontransferred population at the lower-level trauma center and/or adult trauma center and not the patients seen directly at the PTC. This is important because the nontransferred patients in our study likely represent 2 populations worthy of comment: (1) the field triage patients sent directly to the closest PTC due to a prehospital identified need for the higher level of pediatric expertise available at Level I PTCs and (2) an urban/suburban population as the majority of included PTCs are located in highly populated cities.

This study has several limitations. This is a retrospective study of registry data. It is not an epidemiologic study and has limited generalizability. It does not capture the patients who remained at adult hospitals and were not transferred, limiting comparative analyses. Reasons for transfer and trauma level designation of the referring hospital are not available. During our analysis, we found that we could not isolate the effect of the CHA recommendation from hospital system-based or local or regional shifts that may have been in response to the pandemic and not the published recommendation.

Conclusions

The number of transferred pediatric trauma patients to designated regional Level I PTCs increased during the COVID-19 pandemic. The proportion of transferred patients who were ultimately discharged home from the PTCs also increased. Pediatric trauma transfers may be a surrogate for referring ED capacity and resource utilization and a measure of pediatric trauma triage capability during surges in adult diseases, including pandemics.

Supplementary Materials

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jss.2022.08.029.

Author Contributions

Katherine T. Flynn-O'Brien: Conceptualization, methodology, validation, formal analysis, investigation, data curation, writing–original draft, writing–review/editing, visualization,

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